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Effect of Packing and Some Irradiation Doses on Quality and Composition of Gondaila Date Fruits (*Phoenix dactylifera L.*) During Storage

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THIS investigation was done to evaluate the quality of Gondaila dates during storage at room temperature for periods 0, 4, 8, and 12 months using packing normal and under vacuum only, and with irradiation treatment at doses of 1 and 2 KGy. Results indicated that the packed under vacuum sample is more effective for preventing insect infestation (15.00±1.00%) than the packed normal sample (29.41±1.00%), while the packed under vacuum sample with irradiation by dose 2 KGy, recorded the lowest rate of infestation (10.52±1.00%) at the end of the storage duration.On the contrary, the moisture, protein, fiber, and fat in all samples declined during storage; the greatest reduction was recorded for moisture during the first four months of storage, and the maximum decreases in moisture, protein, and fiber contents were found after 12 months of storage in the two control samples (PN and PUV). Besides that, the total and reducing sugars in all samples increased gradually, and the non-reducing sugar content decreased as storage duration increased.The data disclosed that total bacterial counts, molds, and yeasts immediately declined after irradiation and remained at a low count in irradiated treated samples until the end of storage duration; irradiated samples by a dose of 2 KGy had the lowest microbial counts. The organoleptic evaluations showed that the doses used had no detectable negative effect on preference for irradiated date fruit samples; a dose of 1 KGy occupied the first rank in overall acceptability.

Keywords: Packing normal, Packing under vacuum, Gamma irradiation.

Introduction

The date's fruits are a high-nutritive value food with a huge amount of easily available energy (70–80% carbohydrates); they are in the form of simple sugars easy to digest and absorb, like fructose and glucose, besides sucrose. Furthermore, its high content of dietary fiber qualifies it for many forms of food (Mahomoodally et al., 2023). Date also contains many kinds of important minerals (K, P, Ca, Mg, Fe, and Zn) (Echegaray et al., 2021), phenolic compounds, and antioxidant activity (Assirey, 2021). Dates hold immense cultural and religious significance in all Arab and Islamic countries, featuring prominently in Ramadan celebrations and hospitality customs. Egypt is one of the global leaders in date production. According to the Food and Agriculture Organization (FAO), in 2023, Egypt ranked the highest in the production of dates, with 1,733,432.48 tons, followed by Saudi Arabia, Algeria, and Iran. The global date market was valued at 29.48 billion USD in 2023 and is projected to grow from 31.03 billion USD in 2024 to 49.14 billion USD in 2032, exhibiting a

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CAGR of 5.91% during the forecast period. While the market value of the Middle East and Africa stood at USD 25.12 billion in 2023, equivalent to 85.21% of the global market for dates (FAO, 2023).

Dates that are stored at high temperatures and high humidity are vulnerable to microbiological harm and insect infestation, which can result in significant losses from storage (Gadalla et al., 2022). Huge economic losses are also caused by insect infestations of stored dates. These losses can be direct due to bug eating or indirect due to the insects' presence in the dates or any portions of them, like the exuviae, wings, or antennae (Burks et al., 2015). On the other hand, the primary fumigant used to treat stored dates is methyl bromide, which the Montreal Protocol has designated as an ozone-depleting chemical due to its adverse effect on human health and the environment (Chipperfield et al., 2020). Its restricted use and anticipated phasing out highlight the need for an alternate method of treatment immediately (Abdelmegiud, 2016). Several alternative methods exist for preserving dates, but they are costly and require careful consideration (Sarraf et al., 2021). Other methods also have some disadvantages, such as: enzymatic reactions may not be wiped out, microbial and insect activities (Zamir et al., 2018) discoloration; separation of the fruit's skin from the flesh (Lobo et al., 2013) and some negative impacts on the chemical composition and sensory qualities (Assirey, 2021).

Vacuum packaging provides a means of prolonging the shelf life during long durations of shipment and storage (Rovira et al., 2023). Reducing weight loss and preserving fruit quality are further advantages of vacuum-packed storage. This is because vacuum-packed fruit may reduce weight loss by up to 50%, preserve colour, enhance date visual appeal, lessen stickiness, and increase hygienic control (Yu et al., 2024). Increased research efforts aimed at enhancing packaging solutions have yielded some of these benefits. However, some negative impacts are focused primarily on texture and appearance. The most effective way to preserve natural dates from drying and the growth of mold and yeast is to pack them under vacuum (Elsharawy et al., 2019).

On the other hand, irradiation is considered one of the most economical and safe methods of preserving foods. International bodies such as FAO, IAEA, and WHO approved gamma radiation treatment in 1981, and most foods were irradiated by gamma at doses ranging from 1-10 KGy. As irradiation is not raising the food's temperature—it is less than canning, drying, pasteurisation, or sterilization—nutritional value losses are slight (Joshua Ajibola, 2020). It was investigated if radiation treatment, which has been proven to be a safe method of food preservation, might be utilised for microbial decontamination of both fresh and dried food without affecting the food's inherent physico-chemical characteristics (Bhatnagar et al., 2022). Furthermore, irradiation is a good alternative to controlling insects on dates; several studies have been conducted on the use of radiation to control insects on dates (Ramadan et al., 2016; Ramadan et al., 2017). When determining the conditions for irradiation stored food disinfestation, selecting an appropriate radiation dose is of great importance (Mshelia et al., 2023). On the other hand, it is necessary to know how radiation affects the chemical composition of dates, including its effect on colour and nutritional properties. This knowledge is crucial for anyone using dates, especially packers, processors, and traders, since it affects the possibilities and stipulations for the intended end use. Therefore, in order to determine quality, measurements of moisture, protein, sugar, and fat content will need to be made, along with a detection of any microbial infestation. Therefore, the main objective of this research is to investigate the effects of packing normal and under vacuum only and with irradiation by doses of 1 and 2 KGy on the chemical composition, quality properties, and shelf life of Gondaila date fruits during storage for a duration of 12 months at room temperature.

Materials and Methods

Materials

The Gondaila date (*Phoenix dactylifera L.*) was obtained from the local market in Aswan governorate, Egypt, during the 2022 season.

Methods

Technological treatments

Packing normal (PN)

Date fruit was packaged in the polyethylene bags (½ kg) and sealed using the packing plastic bag sealing machine model PFS-100.

Packing under vacuum (PUV)

Date fruit was packaged in the polyethylene bags (½ kg) and scaled using under vacuum packing machine model M2 Pack 603.

Gamma irradiation

The irradiation process of date fruits were carried out in the National Center for Radiation

Research and Technology (NCRRT), Cairo, Egypt, using the Co_{60} facility ''Indian Gamma Cell'' type Ge-4000A. The applied doses were 1 and 2 KGy delivered at a dose rate of 2.08 KGy per hour at time of experiment.

Physical analysis

Gondaila date fruits characteristics

The Gondaila date fruits were evaluated for fruit number per kg, mean weights of fruit (gm), flesh (gm), pit (gm), and calyx (gm), flesh/pit ratio, percent of flesh and pits, and percent of fruit insect infestation.

Total soluble solids (TSS)

TSS was estimated by the method described by Abdel-Hafiz et al. (1980).

pH value

pH value was measured using a Systronic 324-combination glass electrode pH meter at 25 °C.

Colour

The colour was determined as the optical density (OD) of the diluted and centrifuged extract of fruit flesh (5% TSS), and the absorbance was measured at 400 nm using a Perkin Elmer Lambda UV/VIS spectrophotometer (Abd-Ellah, 2009).

Chemical analysis

Gross chemical composition

The gross chemical composition of the raw Gondaila date fruits (before treatments), after treatments directly (zero time), and during storage durations (4, 8, and 12 months) were evaluated. The moisture content was determined by drying the samples at 70°C; sugars (reducing and total), protein, crude fat, ash, and crude fiber contents (on a dry weight basis (dwb)) were determined according to official methods (AOAC, 2019). The caloric value was calculated using 2 cal/g for fiber, 4 cal/g for protein and carbohydrates, and 9 cal/g for fat (FAO/WHO, 2003). Acidity was determined as malic acid by titration, according to Dalaly and Al-Hakiem (1987).

Total phenolic compound (TPC) concentration was determined using Folin-Ciocalteu reagent according to Velioglu et al. (1998) and is expressed as gallic acid equivalents (mg/100 g) relative to dwb (Asami et al., 2003). The samples were extracted, and the free radical scavenging activity of the date fruit extract was determined using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) according to the method described by Ao et al. (2008).

DPPH radical scavenging (AA %) =
OD control – OD sample×100

Mineral composition

The mineral composition of Gondaila date flesh through extraction via the dry ashing method was determined according to the Jackosn (1973) methods. Potassium (K) and sodium (Na) were determined using flame photometry (410). Calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), zinc (Zn), and manganese (Mn) were determined using the Perkin-Elmer Atomic Absorption Spectrophotometer 2380 (Chapman et al., 1962), and phosphorus (P) was measured by the ammonium molybdate method using a Philips PV 8650 spectrophotometer (AOAC, 2019).

Microbial evaluation

Total bacterial counts were determined using the plate counts technique on a nutrient agar medium according to APHA(1976) and Difco-Manual (1984) procedures. The plates were incubated at 37°C for 48 hr. Yeast and mold counts were determined using the plate counts technique on potato dextrose agar (PDA) according to APHA (1976) and Difco-Manual (1984) methods. The plates were kept between 3 and 5 days, depending on the type of fungi, at 25–28 ºC.

Sensory evaluation

Raw Gondaila date fruits (before treatments), after treatments directly (zero time), and during storage durations (4, 8, and 12 months) were sensory evaluated. Trained panelists of twelve arbitrators evaluated the quality attributes, including colour, texture, taste, appearance, and overall acceptability, according to Molander (1960).

Statistical analysis

Data obtained from three replicates were analyzed by analysis of variance (ANOVA) using the SPSS 20.0 software statistical package program, and differences among the means were compared using the Duncan's multiple range test (SPSS, 2011). A significance level of 0.05 was chosen,and continuous variables were described by the mean and standard deviation (mean, SD).

Results and Discussion

Physical characteristics of Gondaila date fruits

The mean values of physical characteristics of Gondaila date fruits at the Tamr stage are shown in Table 1.The Gondaila date fruits at Tamr stage were evaluated for their fruit number (69±2.00/

kg), average weight of fruit (14.49±0.35g) and pit (1.09±0.03g), percentage of flesh (91.98±0.23%) and pit (7.56±0.32%), insect infestation percentage (4.34±0.11%), total soluble solids (86.90±0.13%), and pH value (5.81±0.04) (Table 1). Data on physical measurements are in the same ranges reported by other researchers (Selim et al., 2012; Ramadan et al., 2016). Numerous factors, including soil, fertilisation, and other environmental circumstances, could be the causes responsible for variations in the physical characteristics of the same date variety cultivated in different areas (Ramadan et al., 2017).

Gross chemical composition of Gondaila date fruits

The mean values of gross chemical composition and caloric value of Gondaila date fruits are given in Table 2 at the Tamr stage. The moisture, total sugars (reducing and non-reducing), crude protein, crude fiber, ash, crude fat, and total acidity (as malic acid) contents were 14.51±0.09, 80.97±0.13 (35.15±0.11 and 45.82±0.24), 4.11±0.09, 2.47±0.02, 2.13±0.06, 2.15±0.08, and 0.37±0.03%, respectively. Abdelmegiud (2016) found that the total, reducing, and non-reducing sugars contents in three date's types rangedfrom75.17–84.14%, 30.84–82.37%, and 1.77–44.33%, respectively. These results are in line with the trend recorded by Hasnaoui et al. (2010), and Borchani et al. (2010).

Results in Table 2 illustrate that the calorific value of Gondaila date fruits was 359.67±0.15 Cal/100g. A concept that sugars make up the majority of a date's ingredients means that the calorific value and sugar content are tied together. It is noteworthy that this makes dates a key food staple that the mob prefers, especially for those who are working hard and during the holy month of Ramadan, to break the fast (Ramadan, 1995). Data in Table 2 recorded that Gondaila date flesh contained a TPC of 815.54±16.90 mg as gallic acid/100 g on a dwb. This result is consistent with what Benmeddour et al. (2006) reported. They found that in ten Algerian dates from Tolga (Biskra), the TPC values ranged from 226 to 955 mg GAE/100 g dwb. Results also have shown that the antioxidant activity (AA) of Gondaila date fruits was 48.84±2.03% (on a fresh weight basis).

Minerals composition of Gondaila date fruits

Minerals like calcium, magnesium, and iron are inadequate in foods and diets. Dates, which are high in these and other essential minerals, can help to alleviate this shortage. Due to its high mineral content, date fruit is practically a mine unto itself. It has phosphorus content comparable to apricots, pears, and grapes together. Saharas areas dates consumers are known to have the lowest rate of cancer diseases, a fact attributed to the high amount of minerals found in the dates they consume (Abdelmegiud, 2016). These elements are valuable and useful for the human body and the metabolic operation of human cells.

TABLE 1. Physical characteristics of Gondaila date fruits.

Gondaila date fruits	Physical characteristics
Fruits number/kg	69±2.00
Fruits weight	14.49±0.35g
Flesh weight	13.32±0.09g
Pit weight	1.09±0.03g
Calyx weight	0.08±0g
Flesh/pits ratio	12.22±0.05
Flesh	91.98±0.23%
Pit	7.56±0.32%
Calyx	0.46±0%
Insect infestation	4.34±0.11%
TSS	86.90±0.13%
pH value	5.81±0.04
Colour (at 400nm as OD)	1.33±0.01

- Values are the mean of triplicate determinations with standard division.

TABLE 2. Gross chemical composition of Gondaila date fruits.

Components	(%)*
Moisture	14.51±0.09
Total solids	85.49±0.09
Total sugars	80.97±0.13
Reducing sugars	35.15±0.11
Non-reducing sugars	45.82±0.24
Crude protein	4.11±0.09
Crude fiber	2.47±0.02
Ash	2.13±0.06
Crude fat	2.15±0.08
Acidity (% malic acid)	0.37±0.03
Calorific value (Cal/100g)	359.67±0.15
TPC (mg/100g)	815.54±16.90
AA	48.84±2.03

*On dry weight basis;TPC: Total phenolic compounds; AA: Antioxidant activity

- Values are the mean of triplicate determinations with standard division.

Results of the average values of the potassium, calcium, phosphorus, magnesium, sodium, iron, copper, zinc, and manganeseof Gondaila date fruits are shown at the Tamr stage in Table 3. The potassium was the predominant element present in Gondaila date fruits (477.30±2.27 mg), followed by calcium (75.56±0.48 mg) and phosphorus (83.16±1.22 mg/100 g dwb). The same data revealed that Gondaila date flesh contained 53.49±1.17 mg magnesium and 33.97±1.07 mg sodium/100 g dry matter. On the other hand, among the microelements (Table 3), iron was the predominant element present in Gondaila date fruits (24.34±0.16 mg/100 g dwb). The levels of copper, zinc, and manganese were 1.71±0.04, 1.09±0.03, and 0.59±0.02 mg/100 g dwb of Gondaila flesh, respectively. These data are in the same vein with those reported by Sahari et al. (2007) and El-Sohaimy and Hafez (2010).

Effect of packing normal and under vacuum, and with gamma irradiation treatment at dose of 1 and 2 KGy on the physical characteristics of Gondaila date fruits during storage

During the storage duration (12 months), the pH value decreased from 5.81±0.04 to 5.05±0.05 and from 5.81±0.04 to 4.84±0.04 for the two control samples packed normal (PN) and under vacuum (PUV), respectively. While decreasing from 5.77±0.07 to 4.92±0.02, from 5.80±0.05 to 5.13±0.03, from 5.79±0.04 to 5.07±0.07, and from 5.80±0.03 to 5.14±0.04 for PNR 1, PNR 2, PUVR 1, and PUVR 2samples, respectively (Table 4). According toHasnaoui et al. (2011), there is a relationship between the pH value, colour, and enzyme activity of date fruits.

From the data in Table 4, it is clear that the insect infestation percentage in Gondaila fruits before storage was 4.34±0.16% and decreased to zero (at zero time) after irradiation treatment by dose 2 KGy for samples packaged normal and under vacuum. In addition to that, the results also showed that the packed under vacuum sample with irradiation treated by dose 2 KGy (PUVR 2) was more effective for controlling the insect infestation at 10.52±1.00% after 12 months in storage, followed by the PUVR 1 sample at 14.28±2.00%, and followed by the PNR 2 sample at 15.00±1.00%, respectively. While the PN sample had the insect infestation ratio highest recorded was 29.41±1.00% at the same storage duration (12 months). These results are in the same trend as those recorded by Ramadan et al. (2016); Ramadan et al. (2017) and Adam et al. (2018).

Results in Table 4 also indicate that there is an increase in the colour intensity (OD) of the studied date samples during storage durations. However, the irradiated samples recorded a good negative effect against fruit colour darkening during storage durations, especially the irradiated samples with a dose of 1 KGy, followed by the irradiated samples with a dose of 2 KGy compared with two control samples. For all of the samples under study, the OD values gradually increased during storage in varying percentages. According to the Zhou et al. (2022) study, tannin oxidation is most likely the cause of the rise in fruit colour intensity during storage. The pigment degradation associated with postharvest physiological reactions also influences colour stability (Ramadan et al., 2017).

TABLE 3. Minerals composition of the Gondaila date fruits.

Element	(mg/100g; on dwb)
K	477.30±2.27
Ca	75.56±0.48
P	83.16±1.22
Mg	53.49±1.17
Na	33.97±1.07
Fe	24.34±0.16
Cu	1.71±0.04
Zn	1.09±0.03
Mn	0.59±0.02

TABLE 4. Effect of different treatments on physical characteristics of Gondaila date fruits during storage duration at room temperature.

Treatment	Storage time (month)	Physical characteristics		
		pH value	Insect infestation (%)	Colour (OD)
PN (Control 1)	**0**	5.81±0.04^{a}	4.34±0.16^{jkl}	1.33±0.03^{jk}
	4	5.56±0.06^{c}	22.22±2.00^{c}	1.57±0.05^{f}
	8	5.19±0.09^{de}	26.32±3.00^{b}	1.94±0.04^{b}
	12	5.05±0.05^{gh}	29.41±1.00^{a}	2.15±0.05^{a}
PUV (Control 2)	**0**	5.81±0.04^{a}	4.34±0.16^{jkl}	1.33±0.03^{jk}
	4	5.48±0.08^{c}	5.56±0.06^{j}	1.49±0.04^{gh}
	8	4.97±0.03^{ij}	11.77±0.07^{g}	1.87±0.03^{cd}
	12	4.84±0.04^{k}	15.00±1.00^{ef}	1.94±0.04^{b}
PNR1	**0**	5.77±0.07^{a}	3.26±0.06^{kl}	1.30±0.02^{kl}
	4	5.54±0.04^{c}	7.50±0.50^{i}	1.38±0.03^{ij}
	8	5.12±0.02^{efg}	11.95±0.05^{g}	1.53±0.03^{fg}
	12	4.92±0.02^{j}	17.51±1.00^{d}	1.70±0.04^{e}
PNR2	**0**	5.80±0.05^{a}	2.76±0.03^{l}	1.22±0.02^{m}
	4	5.64±0.04^{b}	5.42±0.20^{j}	1.34±0.04^{jk}
	8	5.22±0.02^{d}	11.12±0.12^{g}	1.48±0.03^{gh}
	12	5.13±0.03^{efg}	16.67±2.00^{de}	1.89±0.04^{bc}
PUVR1	**0**	5.79±0.04^{a}	0±0.00^{m}	1.26±0.06^{lm}
	4	5.52±0.02^{c}	5.26±0.20^{j}	1.43±0.03^{hi}
	8	5.16±0.06^{de}	9.18±0.18^{hi}	1.58±0.03^{f}
	12	5.07±0.07^{fgh}	14.28±2.00^{f}	1.69±0.04e
PUVR2	**0**	5.80±0.03^{a}	0±0.00^{m}	1.28±0.02^{klm}
	4	5.56±0.03^{c}	5.00±0.50^{jk}	1.44±0.04^{hi}
	8	5.01±0.01^{hi}	5.56±0.20^{j}	1.73±0.03^{e}
	12	5.14±0.04^{def}	10.52±1.00^{gh}	1.82±0.02^{d}

- OD: optical density, PN: packing in normal atmosphere, PUV: packing under vacuum atmosphere, PNR 1: packing in normal atmosphere followed by irradiation treatment by dose 1 KGy, PNR 2: packing in normal atmosphere followed by irradiation treatment by dose 2 KGy, PUVR 1: packing under vacuum atmosphere followed by irradiation treatment by dose 1 KGy, and PUVR 2: packing under vacuum atmosphere followed by irradiation treatment by dose 2 KGy. - Values are the means of triplicate determinations with standard division. -- The different letters in the column mean significant differences at $p \leq 0.05$, and the same letters mean no significant differences.

Effect of packing normal and under vacuum, and with gamma irradiation treatment at doseof 1 and 2 KGy on the chemical composition of Gondaila date fruits during storage

The product's nutritional characteristics are the focus of the consumer's attention. To draw up a date quality evaluation during storage, therefore, an evaluation of chemical composition, TPC and AA were determined (Tables 5, 6, 7, and 8). Results showed that all samples' moisture contents dropped over the duration of storage, with the first four months of storage showing the greatest drop. The decreased moisture content and increase in dry matter content of all samples could be the direct result of evaporation following months of storage at room temperature (Zarbakhsh and Rastegar, 2019).

The total and reducing sugars in all samples increased gradually with increasing storage time, and the highest levels of total and reducing sugars were obtained at the end of the storage duration in the two control samples (Tables 5, 6, 7, and 8). Ramadan et al. (2017) have reported that when food is exposed to ionising radiation, radiolytic products of carbohydrates, such as glucuronic, gluconic, and saccharic acid, glyoxal, arabinose, erythrose, formaldehyde, and dihydroxyacetone, might be produced. Radiation at levels ranging from 0.3 to 0.9 KGy was found to dramatically lower the fructose, glucose, and total sugar content of dates (Khalas variety) immediately following irradiation. The hydrolysis of sucrose was related to the increasing rise in the content of reducing sugars during storage (Ghnimi et al., 2018). In contrast, the invertase action on sucrose caused the non-reducing sugar content to decrease in all treatments during storage periods up to the end of the storage duration; this is in agreement with what he said, El-Beltagi et al. (2023).

On the other hand, the protein contents decreased from 4.11±0.10 to 3.38±0.13% and from 4.11±0.10 to 2.95±0.13% for the two control samples, PN and PUV, respectively. The protein contents decreased from 4.04±0.14 to 3.41±0.13, from 4.06±0.14 to 3.49±0.05, from 4.07±0.12 to 3.64±0.11, and from 4.12±0.09 to 3.58±0.06 for samples PNR 1, PNR 2, PUVR 1, and PUVR 2, respectively. The maximum decreases in protein contents at the end of the storage duration were found in the two control samples (PN and PUV), while there was no significant difference between the all other samples. According to Ihsanullah et al. (2005), the protein content of the irradiated date samples was unaffected significantly by radiation up to 300 Krads. Irradiation at 0.7–2.7 KGy had no effect on the protein content of three Iraqi date varieties (Ramadan et al., 2016). These results are in close agreement with those reported by Kenawi et al. (2011) and Selim et al. (2012).

Results in Tables 5, 6, 7, and 8 also show that the fiber content of the studied date samples was reduced during storage for up to 12 months at room temperature. The research conducted by Mohammadzai et al. (2010), who studied the effects of gamma irradiation up to 300 Krads on date fruit, all samples showed a gradual decrease in fiber levels as time passed in an uneven pattern. The impact of analytic enzymes on cellulose and hemicellulose is the primary reason for the date fruits' decreased crude fibre content, according to Selim et al. (2012). During the duration of twelve months of storage, the date samples' ash content decreased slightly, but all the treatments had no discernible impact and no significant difference between them (Tables 5, 6, 7, and 8). According to Stewart (2001), radiation has no effect on the minerals that make up food.

In the end storage duration (after 12 months), the crude fat content decreased by ratio 20.93, 20.00, 15.10, 16.49, 17.95, and 18.55% for the PN, PUV, PNR 1, PNR 2, PUVR 1, and PUVR 2 samples, respectively. A number of factors, including heat, moisture, light, and oxygen, have an effect on the quality of lipids both during and after processing (Wang et al., 2023). After storing Pakistani dates for five months, Ihsanullah et al. (2005) studied the effect of different radiation doses on their fat content and found that all treatments led to decreased levels of fat. On the other hand, during the storage duration (4, 8, and 12 months), the acidity (as % malic acid) increased in all samples.

The all-stored samples showed a gradual decrease in their TPC during storage duration of 12 months. At the end of storage, the lowest TPC content was recorded in the PN sample (521.73± 13.19 mg/100g dwb), while the packing under vacuum sample (PUV, control 2) had the highest phenolic content was recorded (624.66±11.66 mg/100g, dwb) compared with the other samples. Phenolic compounds attachment to other organic materials like proteins or carbohydrates causes the loss of TPC content (Shahidi and Hossain, 2023). It is possible for the enzyme polyphenol oxidase to become active, which would lead to the degradation and eventual loss of polyphenols

TABLE 5. Effect of the different treatments on chemical composition of Gondaila date fruits in zero time (after treatments directly) at room temperature.

Samples Component (%)*	PN (Control 1)	PUV (Control 2)	PNR 1	PNR 2	PUVR 1	PUVR 2
Moisture	14.51±0.10^{a}	14.51±0.10^{a}	14.40±0.02^{ab}	14.24±0.13^{bc}	14.30±0.02^{ab}	14.04±0.13^{c}
Total solids	85.49±0.10^{m}	85.49±0.10^{m}	85.60±0.02^{lm}	85.76±0.13^{kl}	85.70±0.02^{lm}	85.96±0.13^{k}
Total sugars	80.97±0.13^{h-k}	80.97±0.13^{h-k}	80.91±0.06^{jk}	80.79±0.04^{k}	80.84±0.08^{k}	80.95±0.06^{i-k}
Reducing sugars	35.15±0.12^{l}	35.15±0.12^{l}	35.19±0.09^{kl}	34.89±0.03^{m}	34.96±0.06^{lm}	35.11±0.07^{lm}
Non-reducing sugars	45.82±0.25^{ab}	45.82±0.25^{ab}	45.72±0.15^{a-c}	45.90±0.07^{a}	45.88±0.02^{a}	45.84±0.01^{ab}
Crude protein	4.11±0.10^{ab}	4.11±0.10^{ab}	4.04±0.14^{abc}	4.06±0.14^{ab}	4.07±0.12^{ab}	4.12±0.09^{a}
Crude fiber	2.47±0.02^{ab}	2.47±0.02^{ab}	2.41±0.23^{a-d}	2.38±0.03^{a-e}	2.44±0.12^{a-c}	2.49±0.18^{a}
Ash	2.13±0.62^{a-f}	2.13±0.62^{a-f}	2.21±0.20^{a-c}	2.18±0.16^{a-d}	2.25±0.14^{a}	2.16±0.06^{a-e}
Crude fat	2.15±0.09^{a}	2.15±0.9^{a}	1.92±0.16^{bc}	1.94±0.13^{b}	1.95±0.19^{b}	1.94±0.07^{b}
Acidity (% malic acid)	0.37±0.05^{f}	0.37±0.05^{f}	0.38±0.03^{ef}	0.38±0.05^{ef}	0.37±0.02^{f}	0.37±0.03^{f}
TPC (mg/100)	815.54±16.90^{b-d}	815.54±16.90^{b-d}	817.46±27.87^{b-d}	844.55±14.08^{ab}	854.90±31.87^{a}	829.29±30.78^{a-c}
AA	50.53±0.10^{b-f}	50.96±1.22^{a-e}	53.44±0.46^{a}	51.81±1.26^{a-d}	52.62±0.93^{ab}	50.35± 0.06^{b-g}

*On dry weight basis. - Abbreviations for symbols PN, PUV, PNR 1, PNR 2, PUVR 1, PUVR 2, TPC and AA see footnote of Tables 2 and 4. - Values are the mean of triplicate determinations with standard division.
- The different letters at the one row during different storage durations (0, 4, 8 and 12 months) mean significant differences at ($p \leq 0.05$), and the same letters mean no significant differences.

TABLE 6. Effect of the different treatments on chemical composition of Gondaila date fruits after 4 months storage at room temperature.

Samples Component (%)*	PN (Control 1)	PUV (Control 2)	PNR 1	PNR 2	PUVR 1	PUVR 2
Moisture	11.08±0.16^{i}	11.98±0.21^{d}	11.45±0.05^{g}	11.90±0.02^{ef}	11.36±0.05^{gh}	11.68±0.14^{f}
Total solids	88.92±0.16^{f}	88.02±0.21^{j}	88.55±0.05^{h}	88.10±0.02^{ij}	88.64±0.05^{gh}	88.32±0.14^{i}
Total sugars	81.29±0.11^{d-g}	81.22±0.07^{e-h}	81.18±0.08^{g-i}	80.91±0.13^{jk}	80.97±0.06^{h-k}	81.15±0.10^{g-j}
Reducing sugars	35.67±0.16^{g-i}	35.54±0.11^{h-j}	35.50±0.11^{h-j}	35.39±0.17^{jk}	35.48±0.14^{ij}	35.43±0.11^{ij}
Non-reducing sugars	45.62±0.05^{cd}	45.68±0.04^{b-d}	45.68±0.03^{b-d}	45.52±0.11^{de}	45.49±0.08^{d-f}	45.72±0.01^{a-c}
Crude protein	3.91±0.04^{b-e}	3.78±0.14^{d-g}	3.81±0.14^{d-g}	3.75±0.07^{d-g}	3.86±0.10^{c-f}	3.95±0.03^{a-d}
Crude fiber	2.28±0.06^{c-j}	2.36±0.03^{a-f}	2.26±0.05^{d-k}	2.34±0.05^{a-g}	2.32±0.08^{a-h}	2.44±0.12^{a-c}
Ash	2.01±0.12^{c-g}	2.07±0.04^{a-g}	2.19±0.08^{a-c}	2.14±0.05^{a-e}	2.21± 0.08^{a-c}	2.03±0.12^{c-g}
Crude fat	1.80±0.01^{b-d}	1.81±0.07^{b-d}	1.74±0.08^{de}	1.71±0.17^{de}	1.73±0.09^{de}	1.69±0.08^{de}
Acidity (% malic acid)	0.48±0.06^{cd}	0.50±0.05^{cd}	0.41±0.01^{d-f}	0.48±0.08^{c-e}	0.43±0.03^{d-f}	0.47±0.05^{c-e}
TPC (mg/100)	774.98±20.17^{de}	788.57±29.86^{de}	812.65±26.46^{b-d}	801.03±36.20^{c-e}	808.66±16.38^{b-d}	799.30±48.78^{c-e}
AA	49.55±1.76^{c-h}	49.33±1.20^{d-h}	53.09±0.50^{ab}	50.61±0.84^{b-f}	52.36±0.50^{ab}	47.47±1.23^{hi}

*On dry weight basis. - Abbreviations for symbols PN, PUV, PNR 1, PNR 2, PUVR 1, PUVR 2, TPC and AA see footnote of Tables 2 and 4. - Values are the mean of triplicate determinations with standard division.
- The different letters at the one row during different storage durations (0, 4, 8 and 12 months) mean significant differences at ($p \leq 0.05$), and the same letters mean no significant differences.

TABLE 7. Effect of the different treatments on chemical composition of Gondaila date fruits after 8 months storage at room temperature.

Samples Component (%)*	PN (Control 1)	PUV (Control 2)	PNR 1	PNR 2	PUVR 1	PUVR 2
Moisture	10.40 ± 0.07^{k}	11.17 ± 0.38^{hi}	$11.25\pm0.07^{g-i}$	10.82 ± 0.11^{j}	$11.23\pm0.26^{g-i}$	10.71 ± 0.09^{j}
Total solids	89.60 ± 0.07^{d}	88.83 ± 0.38^{fg}	$88.75\pm0.07^{f-h}$	89.18 ± 0.11^{e}	$88.77\pm0.27^{f-h}$	89.29 ± 0.09^{e}
Total sugars	$81.47\pm0.04^{b-f}$	$81.32\pm0.11^{d-g}$	$81.41\pm0.11^{c-g}$	$81.28\pm0.13^{d-g}$	$81.36\pm0.11^{d-g}$	$81.21\pm0.11^{f-h}$
Reducing sugars	36.12 ± 0.07^{cd}	$36.00\pm0.08^{c-e}$	$35.85\pm0.20^{e-g}$	$35.73\pm0.21^{f-h}$	$35.79\pm0.14^{e-g}$	$35.92\pm0.07^{d-f}$
Non-reducing sugars	$45.35\pm0.03^{e-g}$	45.32 ± 0.19^{fg}	45.56 ± 0.09^{cd}	45.55 ± 0.08^{cd}	45.57 ± 0.03^{cd}	45.29 ± 0.04^{fg}
Crude protein	$3.63\pm0.16^{f-k}$	3.23 ± 0.12^{lm}	$3.52\pm0.13^{h-l}$	$3.58\pm0.09^{g-k}$	$3.71\pm0.06^{e-k}$	$3.69\pm0.09^{f-k}$
Crude fiber	$2.14\pm0.05^{i-k}$	$2.31\pm0.08^{b-i}$	$2.17\pm0.05^{g-k}$	$2.21\pm0.11^{e-k}$	$2.18\pm0.07^{g-k}$	$2.23\pm0.06^{e-k}$
Ash	1.89 ± 0.05^{g}	$1.97\pm 0.04^{e-g}$	2.25 ± 0.10^{a}	$2.11\pm0.03^{a-f}$	$2.19\pm0.14^{a-c}$	$1.98\pm0.02^{d-g}$
Crude fat	1.73 ± 0.03^{de}	$1.75\pm0.02^{c-e}$	1.72 ± 0.07^{de}	1.65 ± 0.13^{de}	1.69 ± 0.09^{de}	1.63 ± 0.02^{de}
Acidity (% malic acid)	0.50 ± 0.07^{cd}	0.54 ± 0.04^{bc}	$0.45\pm0.05^{c-f}$	0.48 ± 0.04^{cd}	0.47 ± 0.07^{cd}	0.49 ± 0.09^{cd}
TPC (mg/100)	710.13 ± 20.14^{f}	767.71 ± 10.97^{e}	$807.98\pm19.26^{b-d}$	$795.87\pm8.75^{c-e}$	$796.17\pm30.84^{c-e}$	761.75 ± 10.21^{e}
AA	$48.84\pm2.03^{e-h}$	$48.84\pm2.03^{e-h}$	52.37 ± 1.93^{ab}	$49.19\pm1.02^{d-h}$	$52.23\pm1.21^{a-c}$	46.03 ± 1.85^{ij}

*On dry weight basis. - Abbreviations for symbols PN, PUV, PNR 1, PNR 2, PUVR 1, PUVR 2, TPC and AA see footnote of Tables 2 and 4. - Values are the mean of triplicate determinations with standard division.
- The different letters at the one row during different storage durations (0, 4, 8 and 12 months) mean significant differences at ($p\leq0.05$), and the same letters mean no significant differences.

TABLE 8. Effect of the different treatments on chemical composition of Gondaila date fruits after 12 months storage at room temperature.

Samples Component (%)*	PN (Control 1)	PUV (Control 2)	PNR 1	PNR 2	PUVR 1	PUVR 2
Moisture	8.18 ± 0.06^{n}	9.72 ± 0.17^{m}	9.78 ± 0.02^{m}	10.12 ± 0.04^{l}	9.79 ± 0.12^{m}	10.27 ± 0.09^{kl}
Total solids	91.82 ± 0.06^{a}	90.22 ± 0.17^{b}	90.28 ± 0.02^{b}	89.88 ± 0.04^{c}	90.21 ± 0.12^{b}	89.73 ± 0.09^{cd}
Total sugars	81.85 ± 0.28^{a}	81.67 ± 0.22^{ab}	$81.65\pm0.21^{a-c}$	$81.51\pm0.13^{b-d}$	$81.48\pm0.24^{b-e}$	$81.39\pm0.21^{d-g}$
Reducing sugars	36.61 ± 0.23^{a}	36.38 ± 0.14^{b}	$36.15\pm0.14^{b-d}$	$36.02\pm0.08^{c-e}$	$35.93\pm0.18^{d-f}$	36.21 ± 0.14^{bc}
Non-reducing sugars	45.24 ± 0.05^{fg}	45.29 ± 0.08^{fg}	$45.50\pm0.07^{d-f}$	$45.49\pm0.05^{d-f}$	45.55 ± 0.06^{cd}	45.18 ± 0.07^{fg}
Crude protein	3.38 ± 0.13^{kl}	2.95 ± 0.13^{m}	$3.41\pm0.13^{j-l}$	$3.49\pm0.05^{i-l}$	$3.64\pm0.11^{f-k}$	$3.58\pm0.06^{g-k}$
Crude fiber	2.10 ± 0.01^{k}	$2.19\pm0.10^{f-k}$	$2.14\pm0.10^{i-k}$	$2.19\pm0.10^{f-k}$	$2.16\pm0.06^{h-k}$	2.12 ± 0.02^{jk}
Ash	1.93 ± 0.09^{fg}	$2.06\pm0.13^{a-g}$	2.24 ± 0.15^{ab}	$2.08\pm0.05^{a-g}$	$2.17\pm0.19^{a-e}$	$2.04\pm0.03^{b-g}$
Crude fat	1.70 ± 0.08^{de}	1.72 ± 0.07^{de}	1.63 ± 0.08^{de}	1.62 ± 0.08^{de}	1.60 ± 0.08^{e}	1.58 ± 0.14^{e}
Acidity (% malic acid)	0.64 ± 0.06^{a}	0.63 ± 0.03^{ab}	0.60 ± 0.05^{ab}	0.63 ± 0.03^{ab}	0.62 ± 0.02^{ab}	0.63 ± 0.03^{ab}
TPC (mg/100)	521.73 ± 13.19^{j}	624.66 ± 11.66^{gh}	605.70 ± 6.73^{hi}	584.89 ± 8.61^{hi}	596.17 ± 30.84^{hi}	573.57 ± 14.97^{i}
AA	$48.13\pm2.30^{f-i}$	$48.16\pm1.22^{f-i}$	$48.23\pm 0.83^{f-I}$	$47.78\pm1.20^{g-i}$	$52.10\pm1.90^{a-c}$	44.59 ± 2.46^{j}

*On dry weight basis. - Abbreviations for symbols PN, PUV, PNR 1, PNR 2, PUVR 1, PUVR 2, TPC and AA see footnote of Tables 2 and 4. - Values are the mean of triplicate determinations with standard division. - The different letters at the one row during different storage durations (0, 4, 8 and 12 months) mean significant differences at ($p\leq0.05$), and the same letters mean no significant differences.

(Saxena et al., 2003; Selim et al., 2012). On the other hand, the data proved that there was a powerful relationship between the TPC and AA. This relationship indicated that TPC are the main micro-constituents contributing to the AA of dates, as reported by Kchaou et al. (2013).

Effect of packing normal and under vacuum, and with gamma irradiation treatmentat dose of 1 and 2 KGy on the total microbial counts of Gondaila date fruits during storage

The dates often come into contact with soil, insects, animals, or people; they can get contaminated with pathogenic microbes at any stage, from the farm to the table (Obajuluwa et al., 2023). In the same context, the dates can become contaminated and/or cross-contaminated by a variety of means, including human handling, harvesting equipment, processing, transportation, distribution, and displaying. They can also become contaminated from exposure to unsanitary surfaces and water at the point of sale (Hamad et al., 2012; Abass, 2013). There are numerous studies of dates being contaminated by microorganisms, particularly fungi and bacteria (Al Hazzani et al., 2014; Jdaini et al., 2022). The results shown in Table 9 demonstrated that, in comparison to the decrease in molds and yeasts, the total bacterial counts were lowered more significantly right after irradiation. Since bacteria are generally less radiation-sensitive (Danyo et al., 2024).

Regarding the results presented in Figure 1, it was observed that the microbial counts in all samples remained low until the end of the storage duration (12 months). The irradiated samples at doses of 2 KGy had the lowest microbial counts, followed by the irradiated samples at 1 KGy. Moreover, it was clear that after 8 months of storage, the fungus and yeasts were not detected in the irradiated samples at doses of 2 KGy. The low moisture content and high sugar contents have contributed to the resistance to microbial deterioration, due to the unfavorable growing circumstances for microorganisms(Alp & Bulantekin, 2021). This result indicates that the microbiological quality of can be dates substantially improved by irradiation by doses of 1 and 2 KGy.Additionally, Figure 1 showed that the microbial counts decreased more with the increasing irradiation dose of date samples from 1 to 2 KGy, as well as with the advancement of storage duration, attributable to the low moisture content and high sugar contents. This agreement is with that reported by Al-Kahtani et al. (1998).

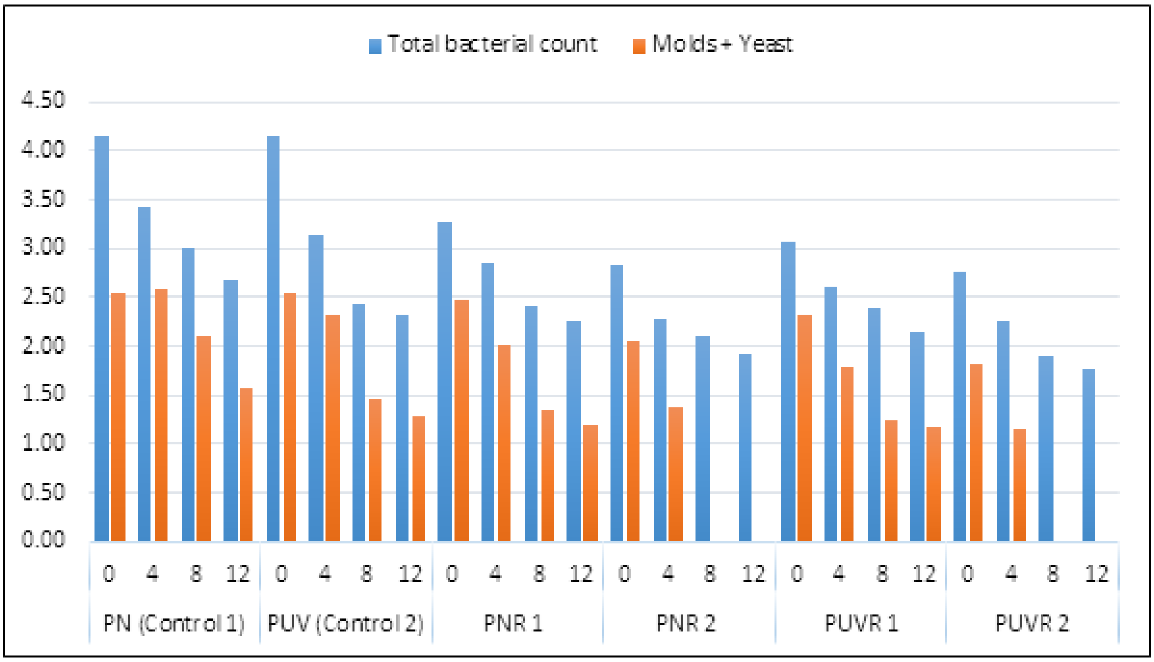

Fig. 1. Effect of different treatments on the total microbial count (total bacterial and molds + yeast; log cfu/gm) of Gondaila fruits during storage at room temperature.

Effect of packing normal and under vacuum, and with gamma irradiation treatment at dose of 1 and 2 KGy on the sensory evaluation of Gondaila date fruits during storage

The use of sensory evaluation is considered important for evaluating the quality of a product. Dates show a big variation in their quality and final appearance because of growth conditions, variables, and genetic differences. Regarding consumers, important quality criteria of the product and its appearance include colour, taste, texture, flavor, etc. (Ray, 2021). The results of the organoleptic evaluation in Fig. 2 show that the panelists could not discriminate between the irradiated and non-irradiated date fruits during storage durations. A taste panel's preference evaluation of the date fruits indicates virtually no negative impact from any of the treatments.

The results are shown in Fig. 2 that all samples were consistent in their texture and appearance values up to 4 months of storage. The best texture in the end of the storage duration for the normal packing sample with irradiation by dose 2 KGy (PNR 2), followed by those irradiated by dose 1 KGy (PNR 1). While the texture and appearance values of the packaged under vacuum samples (PUV, PUVR1, and PUVR2) gradually decreased during storage until the end of the storage duration and recorded the lowest values, there were no significant differences between all treatments at the zero storage time.The color value of all samples recorded a gradual decrease during the storage duration; the PN sample (control 1) had the lowest colour value at the end of the storage duration. The taste value of the PN (control 1) sample decreased to the lowest value, followed by the PUVR 2, and PNR 2 samples. Finally, the irradiated with dose 1 KGy samples occupied the first rank in overall acceptability, followed by the irradiated with 2 KGy samples. These results follow the same trend as those recorded by Ismail et al. (2008), and Abd El Bar et al. (2014).

Conclusion

The storage quality of Gondaila date fruits can be improved and the shelf life extended by packing under vacuum with irradiation treatment at doses of 1 and 2 KGy. On the other hand, the irradiation-treated Gondaila samples excelled and were far better in quality and acceptability than the untreated samples. In addition, the packing under vacuum with irradiation treatment at dose 2 KGy was very potent in reducing insect infestation with fewer losses in chemical composition and sensory characteristics compared to the rest of the other treatments throughout a storage duration of twelve months. In this way, we can contribute to the economy's growth and increase the nation's revenue and foreign exchange earnings.

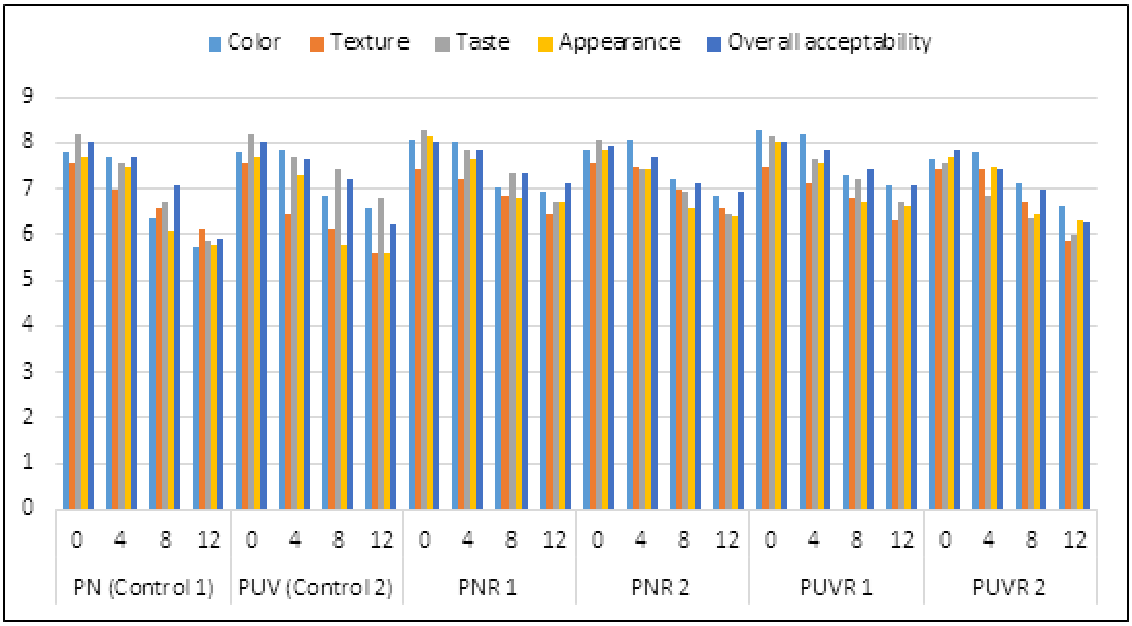

Fig. 2. Effect of different treatments on sensory evaluation of Gondaila date fruits during storage at room temperature

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, writing and/ or publishing of this paper.

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