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Pre and Post-Harvest Studies on Barhi Date

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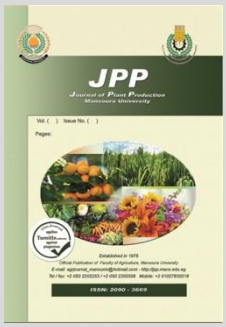

ABSTRACT

The necessity of this study stems from the increasing importance of enhancing the post-harvest quality and storability of Barhi dates (*Phoenix dactylifera* L. CV "Barhi") in Egypt, a vital crop for the agricultural economy. The study aimed to investigate the effects of palm age (5 and 10 years) and bunch thinning (5 or 10 bunches per palm) on both the physical and chemical characteristics of the fruit at harvest and during cold storage. The experiment was conducted over two consecutive seasons (2021 and 2022) at a farm in Abu Suwayr, Egypt. Measurements at harvest included fruit set, fruit drop, bunch weight, fruit weight, firmness, soluble solid content (SSC), total sugars, carotenoids, flavonoids, tannins, and total phenols. Post-harvest quality was evaluated over storage periods of 0, 10, 20, and 30 days. The results showed that older palms (10 years) with fewer bunches (5 per palm) produced higher-quality fruits. During storage, fruits from the palm at 10 years also exhibited lower decay rates and better preservation of quality parameters. Bunch thinning was found to improve fruit quality at both harvest and during storage, particularly in terms of reduced weight loss and better retention of phenolic compounds. In conclusion, managing palm age and bunch thinning practices can significantly enhance the quality and storability of Barhi dates. Future recommendations include optimizing these practices at a commercial scale to improve marketability and extend the storage life of this valuable crop.

Keywords: Barhi dates, storability, decay, Egypt

INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is one of the most economically important fruit crops in arid and semi-arid regions, particularly in Egypt (Ghazzawy *et al.* 2022; Ghanim *et al*. 2024). Among the various date varieties, Barhi dates are highly valued for their exceptional flavor, texture, and nutritional content. However, the quality and storability of dates can be significantly influenced by various pre-harvest and post-harvest factors (Ahmed *et al.* 2021; Fekry *et al.* 2021). Optimizing these factors is crucial to improving fruit quality and extending shelf life, thereby enhancing marketability (Abdelkarim *et al.* 2022; Younis *et al.* 2023).

Palm age and bunch thinning are key agronomic practices that can directly affect the development of date fruits. Palm age plays a crucial role in determining the growth, yield, and quality of date fruits. As palm trees mature, their ability to absorb and utilize water and nutrients improves due to more developed root systems. Older palms generally produce higher-quality fruits with better texture, size, and nutritional content (Alotaibi *et al.* 2023). This is because mature trees have more established energy reserves and a greater capacity to support fruit development. In contrast, younger palms, while capable of producing fruits, may not yet have fully developed these traits, leading to smaller or less mature fruits. The difference in fruit quality between younger and older palms is a significant factor to consider when optimizing the management of date palm orchards for both pre- and post-harvest outcomes. Understanding the influence of palm age helps in developing strategies to improve fruit yield, quality, and marketability (Khalid *et al.* 2012; Sudhersan *et al.* 2015).

Bunch thinning is an agricultural practice used to regulate the number of fruit bunches per palm to enhance fruit quality and optimize yield. In date palm cultivation, thinning is essential to balance the tree's energy distribution, ensuring that the remaining fruits receive adequate nutrients and resources for proper development. Reducing the number of bunches, the palm can concentrate its resources on fewer fruits, leading to improvements in size, weight, and overall quality (Ghazzawy *et al.* 2023). Thinning also helps in reducing fruit drop, improving the uniformity of fruit ripening, and lowering the risk of diseases and pests that can thrive in overly dense fruit clusters. This practice is particularly effective when managing high-yielding varieties, as it promotes healthier, more marketable fruits with longer shelf life. Moreover, thinning can positively impact post-harvest attributes such as firmness, sugar content, and storability. Therefore, bunch thinning is a key factor in improving both the pre- and post-harvest quality of date fruits, making it a valuable tool in commercial date palm cultivation (Moallemi *et al.* 2023; Najafiniya and Rahkhodaei, 2024).

Despite the importance of these practices, there is limited research on how the interaction between palm age and bunch thinning influences both the physical and chemical properties of Barhi dates at harvest and during storage. This study aims to fill this gap by evaluating the impact of palm age and different levels of bunch thinning on Barhi date fruit quality, both at harvest and throughout cold storage.

The primary objective of this study is to investigate how palm age and bunch thinning affect the post-harvest quality and storability of Barhi dates, with the ultimate goal of identifying optimal management practices that enhance fruit quality and prolong shelf life.

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MATERIALS AND METHODS

This study was carried out over two consecutive seasons (2021 and 2022) at a farm in the Abu Suwayr area along the Cairo-Ismailia desert road, Egypt, where Barhi date palms (*Phoenix dactylifera* L. CV "Barhi") were grown in sandy soil under a drip irrigation system, following standard agricultural practices.

Experimental Design and Treatments

The experiment followed a completely randomized design having two factor (palm age and bunch thinning) with the following treatments to evaluate the physical and chemical characteristics at harvest time:

- Palm trees aged 5 years, thinned to 5 bunches per palm.
- Palm trees aged 5 years, thinned to 10 bunches per palm.
- Palm trees aged 10 years, thinned to 5 bunches per palm.
- Palm trees aged 10 years, thinned to 10 bunches per palm.

The experimental design for the post-harvest experiment was expanded to include three studied factors: palm age, bunch thinning, and storage duration (0, 10, 20, and 30 days). This design aimed to evaluate the combined effects of these factors on the post-harvest quality of Barhi date palms during cold storage. Storage days were assessed at four time points: 0, 10, 20, and 30 days after harvest, with cold storage.

Experimental Setup

The selected palms were hand-pollinated using the same male strands and managed according to the common agricultural practices in the region. A total of 36 palms, showing uniform growth and free from insect damage or diseases, were chosen for the experiment. The date palms, spaced 8 × 8 meters apart, were maintained with the same horticultural treatments recommended by the Ministry of Agriculture and Soil Reclamation. Fruits were harvested at full maturity, characterized by a yellow skin color (with less than 10% yellowish-green areas) and a soluble solids content (SSC) exceeding 28%. Immediately after harvest, the fruits were transported to the post-harvest laboratory, where they were sorted based on similar shape, color, and development. The fruits were cleaned and stored at 5 °C for further analysis.

Measurements

Evaluation at harvest time

- **Fruit set (%):** The percentage of flowers that successfully developed into fruits was calculated.
- **Fruit drop (%):** The percentage of fruits that dropped prematurely before harvesting was recorded.
- **Bunch weight (kg):** The total weight of each bunch at harvest time was measured.
- **Fruit weight (kg):** The average weight of individual fruits within the bunch was determined.
- **Fruit firmness (kg/cm²):** The firmness of the fruit was measured using a penetrometer.
- **Soluble solid content (SSC,** %): Measured using a refractometer to determine the sugar concentration in the fruit as described in AOAC (2000).
- **Total sugars (g/100g FW):** The total sugar content of the fruit was analyzed using the phenol sulphuric acid method as described by Dubois *et al.* (1956).
- **Carotenoids (mg/100g FW):** Measured to assess the level of carotenoids, which contribute to the fruit's color and nutritional value. it was colorimetrically assayed at 440 nm using a spectrophotometer as described by Tudor-Radu *et al.* (2016).
- **Total flavonoids (mg/g FW):** Analyzed to determine the concentration of flavonoids, which are important antioxidants in the fruit. It was determined according the standard method reported by Zhishen *et al.* (1999),
- **Tannins (mg/g DW):** It was analyzed using the vanillin-hydrochloride assay method, as detailed by Burlingame (2000).
- **Total phenols (mg/g DW):** Phenolic content was analyzed to evaluate the antioxidant capacity of the fruit. It was determined according the standard method reported by Wolfe *et al*. (2003).

Evaluation during storage periods

A total of 180 fully mature fruits at full color (at the end of the Bisr stage) from each treatment were harvested and packed in three perforated transparent polyethylene bags, then placed in a carton box for cold storage under room conditions (5 ºC and approximately 90% relative humidity). The fruits were examined after 10, 20, and 30 days to assess the following characteristics:

- **Weight loss (%):** Calculated by measuring the difference between the initial fruit weight and the weight after each storage period (0, 10, 20, and 30 days).
- **Decay percentage (%):** The percentage of fruits showing signs of decay or spoilage during storage.
- **Rutab percentage (%):** Fruits are identified as rutab when they change color to dark brown and show softening of approximately 20% of their surface.**:** The rutab percentage is calculated using the following equation:

Rutab % =Weight of rutab fruits / Initial weight X 100.

Additionally, the following parameters were reassessed to evaluate fruit quality throughout the storage periods: Fruit firmness (kg/cm²), soluble solid content (SSC, %), total sugars (g/100g FW), carotenoids (mg/100g FW), total flavonoids (mg/g FW), tannins (mg/g DW) and total phenols (mg/g DW).

Statistical Analysis

The differences among the means of the tested treatments and the control were evaluated using a factorial randomized complete block design as outlined by Gomez and Gomez (1984). Data from both seasons were analyzed using analysis of variance (ANOVA) with the aid of the CoStat software. Duncan's multiple range tests were applied to compare treatment means, with a significance level of 0.05, as described by Duncan (1955). Additionally, correlation coefficients were computed to assess the relationships between the various studied parameters, following the methodology of Cohen (1988).

RESULTS AND DISCUSSION

Effect of Palm Age and Number of Bunches per Palm on Physical and Chemical Characteristics of Barhi Date Palm at Harvest Stage

Fruit set and dropping

Table 1 illustrates the impact of palm age and bunch thinning on fruit set and fruit drop percentages of Barhi date palm during seasons of 2021 and 2022.

Fruit set percentage

Older palms (10 years) consistently demonstrated higher fruit set percentages compared to younger palms (5

years) across all treatments. For instance, palm at 10 years with 5 bunches gave higher significant of fruit set compared to younger palms with the same bunch number. This suggests that older trees may have better-developed reproductive structures or enhanced physiological capabilities to support fruit set. Reducing the number of bunches per palm appears to positively influence fruit set. Specifically, thinning to 5 bunches per palm resulted in higher fruit set percentages compared to 10 bunches per palm, especially in older trees. This could be due to reduced competition for resources among the fruits, leading to better fruit development and retention (Younis *et al.* 2023; Ghanim *et al.* 2024).

Table 1. Effect of palm age and bunch thinning on fruit set and fruit drop percentages of Barhi date palm

Treatments		Fruit set,%		Fruit drop,%	
Palm age	No. of benches	Season of 2021	Season of 2022	Season of 2021	Season of 2022
5 years	5 Bunches	61.93 b	64.93 b	17.40 b	15.33 c
	10 Bunches	51.56 c	54.53 c	24.17 a	28.13 a
10 years	5 Bunches	68.75 a	70.50 a	5.24 c	5.50 d
	10 Bunches	52.43 c	56.50 c	25.62 a	22.53 b

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Fruit drop percentage

The percentage of fruit drop was significantly lower in older palms compared to younger ones. For example, palm at 10 years with 5 bunches a lower fruit drop percentage compared to palm at 5 years with the same bunch number. This indicates that older trees may have better resource allocation or more stable fruit retention mechanisms. Higher fruit drop percentages were observed when 10 bunches were maintained per palm, especially in younger trees. The increase in fruit drop with more bunches may be due to higher competition for nutrients and water among the fruits, leading to a higher rate of fruit abscission. Generally, the results suggest that both palm age and bunch thinning significantly impact fruit set and drop percentages in Barhi date palms. Older trees with fewer bunches per palm tend to exhibit better fruit set and lower fruit drop, which could be attributed to improved resource allocation and physiological maturity (Najafiniya and Rahkhodaei, 2024).

Bunch weight, fruit weight and fruit firmness

Table 2 shows the effect of palm age and bunch thinning on bunch weight (kg), fruit weight (g) and fruit firmness (Lb/inch^2) of Barhi date palm during seasons of 2021 and 2022.

Bunch weight (kg)

The data reveals that older palms (10 years) consistently produced heavier bunches compared to younger palms (5 years) across both seasons. In particular, palms with 5 bunches produced significantly heavier bunches than those with 10 bunches. This trend underscores the advantage of older trees in terms of their capacity to support larger and heavier bunches. As palms age, their root systems and overall physiological development enhance their ability to accumulate and allocate nutrients, contributing to increased bunch weight (Moallemi *et al.* 2023).

Table 2. Effect of palm age and bunch thinning on bunch weight (kg), fruit weight (kg) and fruit firmness of Barhi date palm

Treatments		Bunch weight, kg		Fruit weight, g		Fruit firmness, Lb/inch^2	
Palm age	No. of benches	Season of 2021	Season of 2022	Season of 2021	Season of 2022	Season of 2021	Season of 2022
5 years	5 Bunches	15.08 c	15.94 c	15.74 b	15.90 b	18.47 a	18.51 a
	10 Bunches	12.71 d	12.96 d	12.56 c	12.83 c	17.06 b	17.08 b
10 years	5 Bunches	18.11 a	18.31 a	16.67 a	16.75 a	18.95 a	19.00 a
	10 Bunches	16.74 b	16.89 b	12.72 c	13.06 c	17.49 b	17.56 b

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Thinning bunches to 5 per palm results in heavier bunches compared to having 10 bunches per palm. This result highlights the benefits of reduced competition among bunches for resources, allowing each bunch to receive more nutrients and water, thus increasing its weight. The increased bunch weight in the palm at 10 years with fewer bunches demonstrates the positive impact of both palm age and thinning practices on bunch development **(**Najafiniya and Rahkhodaei, 2024).

Fruit weight (g)

The fruit weight followed a similar pattern to bunch weight. Fruits from palm at 10 years were heavier than those from the palm at 5 years in both seasons. The greater fruit weight in older palms can be attributed to their more developed physiological systems, which enhance their ability to support and develop larger fruits. Older palms have better nutrient and water uptake capabilities, which are crucial for fruit growth and development.

Bunch thinning also improved fruit weight. Palms with 5 bunches produced fruits with higher weights compared to those with 10 bunches. This effect is consistent with the principle that thinning reduces intra-bunch competition, leading to better resource distribution per fruit. By reducing the number of bunches, each bunch can allocate more resources to its individual fruits, resulting in increased fruit weight.

Fruit firmness (Lb/inch^2)

The firmness of the fruits was higher in the older palms (10 years) compared to the younger palms (5 years) across both seasons. Increased fruit firmness in older palms is likely due to their advanced physiological state and more robust fruit tissues. Mature palms typically produce fruits with better structural integrity, which contributes to higher firmness (Ghazzawy *et al.* 2023).

The impact of bunch thinning on fruit firmness was also significant. Fruits from palms with 5 bunches were firmer compared to those with 10 bunches. Thinning appears to reduce the stress on individual fruits, allowing them to develop firmer tissues. Less competition among fruits results in better overall fruit development, including improved firmness (Ghazzawy *et al.* 2023; Moallemi *et al.* 2023)**.**

Overall, the results indicate that both palm age and bunch thinning practices play crucial roles in enhancing the physical characteristics of Barhi dates. Older palms with

fewer bunches tend to produce heavier, larger, and firmer fruits, highlighting the importance of these factors in optimizing fruit quality. Also, the results presented, the most impactful treatment combining both positive effects on fruit characteristics is the palm at 10 year with 5 bunches (**Sudhersan *et al.* 2015)**. This treatment consistently demonstrates superior outcomes across multiple parameters, including bunch weight, fruit weight, and fruit firmness. The enhanced performance of this treatment can be attributed to the physiological maturity of the 10-year-old palms, which are better equipped to allocate resources efficiently. Additionally, having only 5 bunches per palm reduces intra-palm competition, allowing for more substantial growth and development of each bunch. This results in heavier and firmer fruits with improved quality. The combination of an older palm age and a lower number of bunches per palm appears to offer an optimal balance, promoting both the quantity and quality of the fruit (Fekry *et al.* 2021; Alotaibi *et al.* 2023).

Fruit quality traits

The analysis of quality traits for Barhi dates reveals significant differences based on palm age and bunch thinning treatments. The data from Tables 3, 4 and 5 highlights the effects on various quality parameters including soluble solid content (SSC), total sugars, carotenoids, total flavonoids, tannins, and total phenols across two seasons.

Soluble solid content (SSC,%) and total sugars (g/100g FW)

According to the data in Table 3, the highest values of SSC (%) and total sugar (g/100g FW) content were observed in the fruits from palm at 10 years with 5 bunches. This superior performance indicates a higher concentration of soluble solids and sugars, which are crucial for the sweetness and overall flavor of the dates. The older palms with fewer bunches likely benefit from better resource allocation and physiological maturity, enhancing fruit quality (Alotaibi *et al.* 2023; Moallemi *et al.* 2023).

Table 3. Effect of palm age and bunch thinning on quality traits of Barhi date palm (SSC, total sugars)

Treatments		Soluble solid content SSC, %)		Total sugars (g/100g FW)	
Palm age	No. of benches	Season of 2021	Season of 2022	Season of 2021	Season of 2022
5 years	5 Bunches	25.00 a	28.67 a	25.42 b	25.30 b
	10 Bunches	24.67 a	24.06 c	21.06 d	21.09 d
10 years	5 Bunches	29.33 a	29.64 a	27.11 a	27.42 a
	10 Bunches	26.33 a	26.00 b	24.61 c	24.11 c

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Carotenoids(mg/100 g FW)and total flavonoids(mg/g FW)

According to the data in Table 4, the palm at 10 years with 5 bunches also demonstrated the highest carotenoid content and total flavonoids**.** Carotenoids are important for their antioxidant properties and contribute to the color quality of the fruit. Higher carotenoid levels suggest that these fruits have better nutritional and sensory qualities. Flavonoids are known for their health benefits and their role in enhancing fruit quality. The high flavonoid content in these fruits underscores the beneficial impact of this treatment on fruit health-promoting compound (Ghazzawy *et al.* 2023).

Table 4. Effect of palm age and bunch thinning on quality traits of Barhi date palm (carotenoids, total flavonoids)

Treatments		Carotenoids (mg/100 g FW)		Total flavonoid (mg/g FW)	
Palm age	No. of benches	Season of 2021	Season of 2022	Season of 2021	Season of 2022
5 years	5 Bunches	0.32 b	0.33 b	4.97 a	5.10 b
	10 Bunches	0.21 b	0.28 b	3.84 b	3.91 d
10 years	5 Bunches	0.56 a	0.56 a	5.00 a	5.27 a
	10 Bunches	0.25 b	0.29 b	4.53 a	4.68 c

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Tannins and total phenols (mg/g DW)

Although the tannins content was lower in the palm at 10 years with 5 bunches compared to other treatments (Table5), this level is still within a desirable range for quality dates. Total phenols, which are important for antioxidant activity, were highest in this treatment as well. The balanced tannin and high phenol content contribute to the overall health benefits and shelf life of the dates.

Table 5. Effect of palm age and bunch thinning on quality traits of Barhi date palm (tannins and total phenols)

Treatments		Tannins (mg/g DW)		Total phenols (mg/g DW)	
Palm age	No. of benches	Season of 2021	Season of 2022	Season of 2021	Season of 2022
5 years	5 Bunches	0.65 b	0.66 bc	60.24 a	61.30 b
	10 Bunches	0.99 a	1.0 a	50.18 b	51.44 d
10 years	5 Bunches	0.51b	0.52 c	62.49 a	64.01 a
	10 Bunches	0.76ab	0.77 ab	51.81 b	54.70 c

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Generally, the palm at 10 years with 5 bunches show the most positive effects on the quality traits of Barhi dates. This treatment enhances SSC, total sugars, carotenoids, total flavonoids, and total phenols, while maintaining a favorable level of tannins. The older palms with fewer bunches optimize fruit quality by maximizing the beneficial compounds and minimizing excess competition among bunches (Alotaibi *et al.* 2023; Moallemi *et al.* 2023).

Effect of Palm Age and Number of Bunches per Palm on Storage Life of Barhi Date Palm at Harvest Stage

Loss in weight and decay percentages

Tables 6 and 7 presents the impact of palm age and bunch thinning on the loss in weight and decay percentages of Barhi date palms during cold storage over two seasons. The data illustrates significant differences in storage performance based on these variables.

Loss in weight percentage

Concerning the treatments' effects on average a weight loss in Barhi date fruits, the data of Table 6 show that all treatments resulted non-significant differences in weight loss during the storage periods of 10, 20, and 30 days across both study seasons. This indicates that variations in palm age and bunch thinning did not significantly influence the amount of weight lost by the fruits under the given storage conditions. The lack of significant differences in weight loss across the treatments suggests that the factors tested (palm age and number of bunches) may not have a substantial impact on the rate of moisture loss or weight reduction in Barhi date fruits during storage. This could be due to

inherent physiological properties of the fruit or the storage conditions, which may be more influential in determining weight loss than the treatments applied. Factors such as fruit maturity, initial moisture content, and storage environment might play a more critical role in weight loss than the specific treatment combinations. As a result, all treatments show similar effectiveness in maintaining fruit weight during storage.

Table 6. Effect of palm age and bunch thinning on loss in weight percentages of Barhi date palm under cold storage

Treatments		Loss in weight %					
		Storage period (days)					
		Season of 2021			Season of 2022		
Palm age	No. of benches	10	20	30	10	20	30
5 years	5 Bunches	1.37 a	1.61 a	1.90 a	1.44 a	1.68 a	1.97 a
	10 Bunches	1.53 a	1.89 a	2.33 a	1.64 a	2.00 a	2.44 a
10 years	5 Bunches	0.51 a	0.73 a	0.96 a	0.59 a	0.82 a	1.06 a
	10 Bunches	1.74 a	2.01 a	2.31 a	1.78 a	2.07 a	2.38 a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Decay percentage

Regarding the impact of the treatments on fruit decay, the data of Table7 indicate that no decay was observed in fruits stored for 10 or 20 days under cold conditions. However, after 30 days of cold storage, the treatment of leaving 5 bunches on 10-year-old palms resulted in significantly lower fruit decay compared to the other treatments. Specifically, this treatment exhibited the least amount of decay compared to leaving 5 bunches on palm at 5 years or 10 bunches on palm at 10 years, which both showed lower decay values than leaving 10 bunches on palm at 5 years.

Table 7. Effect of palm age and bunch thinning on decay percentages of Barhi date palm under cold storage

Treatments		Decay%					
		Storage period (days)					
		Season of 2021			Season of 2022		
Palm age	No. of benches	10	20	30	10	20	30
5 years	5 Bunches	0.0 d	0.0 d	11.01 b	0.0 d	0.0 d	11.23 b
	10 Bunches	0.0 d	0.0 d	27.41 a	0.0 d	0.0 d	27.50 a
10 years	5 Bunches	0.0 d	0.0 d	5.03 c	0.0 d	0.0 d	5.11 c
	10 Bunches	0.0 d	0.0 d	12.34 b	0.0 d	0.0 d	12.36 b

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

From this study, it is evident that treating Barhi date palms by retaining 5 bunches on palm at 10 years significantly reduced the total loss in fruit weight and decay during storage at 5°C for 30 days. This treatment resulted in only 5-6% total loss after 30 days of cold storage, suggesting that it is more effective in minimizing fruit weight loss and decay. This effectiveness may be attributed to the physiological maturity of the older palms and the optimal bunch thinning strategy, which could enhance fruit quality and storage performance by reducing stress and improving resource allocation in the fruits.

The reduced fruit decay observed with the treatment of 5 bunches on palm at 10 years can be explained by several factors. Older palms may produce fruit with better inherent storage qualities due to their physiological maturity, which could contribute to enhanced resistance to decay. Additionally, retaining fewer bunches per palm could result in better resource allocation, leading to improved fruit quality and a more resilient fruit structure that is less prone to decay. In contrast, treatments involving more bunches or younger palms showed higher decay rates, possibly due to increased stress on the fruit or less optimal conditions for fruit development and preservation. These findings highlight the importance of both palm age and bunch thinning in managing post-harvest fruit quality and storage life.

Rotability and firmness

Table 5 presents the impact of palm age and bunch thinning on the rotability (%) of Barhi date palm during cold storage over two seasons, while Table 6 shows the impact of the studied treatments on and firmness (Lb/inch^2).

Rotability percentage

The data on fruit rotability (Table 8) show significant differences based on palm age and bunch thinning treatments. Data show that rotability % increase as the storage period advanced. For both study seasons, fruits from 10-year-old palms with 5 bunches exhibited the lowest rotability percentages compared to other treatments. Specifically, this treatment resulted in the lowest rotability values across all storage periods, with only 7.01% to 16.20% rotability over 10, 20, and 30 days. In contrast, fruits from palm at 5 years with 10 bunches had the highest rotability percentages, ranging from 16.33% to 43.00% over the same periods. This suggests that older palms with fewer bunches tend to produce fruit with better resistance to rot during cold storage (Abdelkarim *et al.* 2022; Zein *et al.* 2022).

Table 8. Effect of palm age and bunch thinning on rotability (%) and firmness (Lb/inch^2) of Barhi date palm under cold storage

Treatments		Rotability, %					
		Storage period (days)					
		Season of 2021			Season of 2022		
Palm age	No. of benches	10	20	30	10	20	30
5 years	5 Bunches	8.33 c	15.00 c	22.40 c	8.50 c	15.34 c	22.61 c
	10 Bunches	16.33 a	24.70 a	42.20 a	17.01 a	25.61 a	43.00 a
10 years	5 Bunches	7.01 d	10.54 d	16.20 d	7.23 d	11.00 d	17.03 d
	10 Bunches	11.32 b	18.73 b	27.02 b	12.00 b	19.33 b	27.81 b

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Firmness (Lb/inch^2)

In terms of firmness (Table 9), fruits from palm at 10 years with 5 bunches consistently showed the highest firmness values throughout the storage periods. This contrasts with fruits from 5-year-old palms with 10 bunches, which displayed lower firmness values, particularly after 30 days of storage. The increased firmness in fruits from older palms with fewer bunches indicates that these fruits maintain their texture better over time, potentially due to reduced stress on the palm and improved fruit quality.

Table 9. Effect of palm age and bunch thinning on rotability (%) and firmness (Lb/inch^2) of Barhi date palm under cold storage

Treatments		Firmness, Lb/inch^2							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	18.47 a	17.08 a	15.41 ab	13.22 bc	18.51 a	17.01 a	15.35 ab	13.11 ab
	10 Bunches	17.06 b	15.69 ab	11.41 c	7.01 d	17.08 b	15.66 ab	11.33 bc	6.73 c
10 years	5 Bunches	18.95 a	18.00 a	17.63 a	17.00 ab	19.00 a	17.91 a	17.60 a	16.82 a
	10 Bunches	17.49 b	17.00 ab	14.31 abc	11.22 c	17.56 b	17.01 a	14.22 ab	11.21 bc

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Based on the data in Tables 8 and 9, it can be noticed that leaving 10 bunches on palm at 5 years resulted in the highest fruit rotability and the lowest fruit firmness by the end of the study. The improved rotability and firmness observed in fruits from 10-year-old palms with 5 bunches can be attributed to several factors. Older palms typically have more developed physiological processes and better resource allocation, which may enhance fruit quality and resistance to decay. Fewer bunches per palm also mean less competition for resources among the fruits, resulting in better-developed, firmer, and more rot-resistant fruits. Conversely, younger palms or those with more bunches may produce fruits that are less well-developed and more prone to rot, as the palms might be under greater stress and resource competition. Additionally, the higher firmness values in the older palms' fruits suggest that these fruits are better able to withstand mechanical stress and maintain their structural integrity over the storage period **(**Abd El-Rauof, 2022).

Soluble solid content(SSC,%)and total sugars(g/100g FW)

Table 10 illustrates the impact of palm age and bunch thinning on the soluble solid content (SSC,%) of Barhi date palm during cold storage across two seasons. Whilst, Table 11 the impact of palm age and bunch thinning on the total sugars of Barhi date palm during cold storage across two seasons.

It is evident that both SSC and total sugars increased with the duration of cold storage. However, the data reveal that Barhi dates from palm at 10 years with 5 bunches showed significantly lower SSC and total sugar levels after 30 days of storage compared to other treatments.

Table 10. Effect of palm age and bunch thinning on the soluble solid content (SSC,%) of Barhi date palm under cold storage

Treatments		Soluble solid content (SSC,%)							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	25.00 a	29.01 e	33.16 cd	34.00 c	28.67 a	29.05 e	33.21 cde	34.10 cd
	10 Bunches	24.67 a	29.56 de	35.66 bc	41.86 a	24.06 c	29.91 de	36.01 bc	42.28 a
10 years	5 Bunches	29.33 a	29.40 de	30.11 de	33.04 cd	29.64 a	29.75 de	30.64 de	33.29 cde
	10 Bunches	26.33 a	29.34 de	34.09 c	39.00 ab	26.00 b	29.91 de	34.62 cd	39.52 ab

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 11. Effect of palm age and bunch thinning on the total sugars (g 100g FW) of Barhi date palm under cold storage

Treatments		Total sugars, g /100g FW							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	25.42 b	26.02 d	30.17 bc	31.01 bc	25.30 b	25.69 f	29.85 cdef	30.74 cde
	10 Bunches	21.06 d	25.96 d	32.06 b	38.26 a	21.09 d	26.34 ef	32.44 bc	38.71 a
10 years	5 Bunches	27.11 a	27.18 cd	27.89 cd	30.82 bc	27.42 a	27.51 def	28.40 cdef	2.65 cde
	10 Bunches	24.61 c	27.62 cd	32.37 b	37.28 a	24.11 c	27.36 def	32.07 cd	36.97 ab

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

The soluble solid content (SSC) and total sugars increased as the cold storage duration progressed. This can be attributed to the physiological processes that continue in the fruit even after harvest, such as the conversion of starches into sugars, leading to an increase in SSC and sugar levels during storage. The significantly lower SSC and total sugar levels in the dates from palm at 10 years with 5 bunches after 30 days of cold storage, compared to other treatments, could be due to less stress on the palm, resulting in slower metabolic activity. Having fewer bunches on the palm may reduce the overall demand for nutrients and energy, leading to a more gradual maturation process and slower accumulation of sugars. In contrast, treatments with 10 bunches or younger palms may experience a higher metabolic rate, leading to a quicker increase in SSC and total sugars. Additionally, environmental factors and the palm's capacity to photosynthesize may have contributed to the observed differences in sugar accumulation (Fekry *et al.* 2021). The results indicated that an increase in Soluble Solid Content (SSC) was significantly correlated with a higher total sugars content in Barhi dates at harvest and throughout the storage periods. Fruits from older palms (10 years) and those with reduced bunches (5 bunches per palm) showed higher levels of SSC, which directly translated to an increase in total sugar content.This relationship highlights that fruits with higher SSC were sweeter and of better quality, making SSC a reliable indicator of fruit quality. Furthermore, the ability to maintain higher levels of SSC and total sugars during storage reflects the enhanced capacity of these fruits to retain their quality over time, contributing to improved

marketability and extended shelf life (Ghazzawy *et al.* 2023; Moallemi *et al.* 2023).

Total flavonoid (mg/g FW) and carotenoids (mg/100g FW)

The results in Tables 12 and 13 show the impact of palm age and bunch thinning on the total flavonoid and carotenoid content of Barhi date palm during cold storage over two seasons. It is evident that total flavonoids tended to decrease as storage period increased, with some variations depending on the treatment. On the contrary, carotenoid content tended to increase as storage time increased.

For total flavonoids (Table 12), it was observed that palm at 10 years with 5 bunches maintained significantly higher flavonoid levels throughout the storage period compared to the other treatments. This may be due to the lower stress on these palms, allowing them to retain more secondary metabolites like flavonoids, which are known for their antioxidant properties. Conversely, the flavonoid content in palms with 10 bunches, particularly younger palms (5 years), showed a sharper decline, possibly due to increased metabolic activity, which could have accelerated the degradation of these compounds **(Younis *et al.* 2023).**

Table 12. Effect of palm age and bunch thinning on the total flavonoid (mg/g FW) of Barhi date palm under cold storage

Treatments		Total flavonoid, mg/g FW							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	4.97 a	4.64 a	4.08 ab	3.34 ab	5.10 b	4.77 a	4.21 ab	3.47 ab
	10 Bunches	3.84 b	1.96 ab	1.00 ab	0.45 c	3.91 d	2.03 ab	1.03 ab	0.48 c
10 years	5 Bunches	5.00 a	4.81 a	4.59 a	4.29 ab	5.27 a	5.08 a	4.86 a	4.56 ab
	10 Bunches	4.53 a	3.88 ab	3.07 ab	1.27 ab	4.68 c	4.03 ab	3.22 ab	1.42 ab

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 13. Effect of palm age and bunch thinning on the carotenoids (mg/100g FW) of Barhi date palm under cold storage during both study seasons

Treatments		Carotenoids, mg/100g FW							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	0.32 b	1.008 bc	1.798 abc	2.668 abc	0.33 b	1.010 bc	1.800 abc	2.670 abc
	10 Bunches	0.21 b	1.619 abc	3.319 abc	5.279 a	0.28 b	1.686 abc	3.386 abc	5.346 a
10 years	5 Bunches	0.56 a	0.634 c	1.344 bc	2.374 abc	0.56 a	0.632 c	1.342 bc	2.372 abc
	10 Bunches	0.25 b	1.262 bc	2.812 abc	4.622 ab	0.29 b	1.303 bc	2.853 abc	4.663 ab

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Regarding carotenoids (Table 13), a similar pattern emerged. The carotenoid content increased as storage time progressed, especially in treatments with 10 bunches, reaching its peak after 30 days. Carotenoids are involved in protecting fruits from oxidative stress during storage, and their increase in response to storage conditions may reflect the fruits' adaptation to cold storage. The higher carotenoid levels in palms with more bunches, particularly in the 10-year-old palms, might indicate a greater need for protection against storage-induced stress, leading to higher synthesis or retention of these pigments.

In palm at 5 years, when 5 bunches were left on the palm, the initial carotenoid content was low at the start of storage (day 0) and gradually increased. The increase in carotenoid accumulation over time can be attributed to metabolic reactions occurring within the fruits during storage, where carotenoids act as antioxidants, protecting the cells from oxidative stress induced by cold storage conditions.

When 10 bunches were left on the palm, there was a more significant increase in carotenoid content during the storage period. Starting with a lower value than the 5-bunch treatment on day 0, it rose markedly by day 30. This substantial increase in carotenoid content may be due to the higher metabolic stress placed on the fruits from the larger number of bunches, which stimulated the production of more carotenoids to counteract environmental and storage-related challenges.

For the palm at 10 years with 5 bunches, the carotenoid content was relatively higher at the start of storage compared to the younger palms, but the increase was moderate. This moderate increase suggests that older palms have a natural ability to produce carotenoids, possibly due to more established physiological processes, but they did not exhibit the same dramatic increase as the palm at 5 years with 10 bunches.

Generally, it can be noticed that, the total flavonoid and carotenoid contents played a crucial role in determining the antioxidant capacity and nutritional value of Barhi dates. The results showed that palms with fewer bunches (5 bunches per palm) and older palms (10 years) produced fruits with significantly higher levels of both flavonoids and carotenoids. Total flavonoids are known for their strong antioxidant properties, which contribute to the fruit's resistance against oxidative stress, while carotenoids enhance the fruit's color and provide additional health benefits due to their provitamin A activity (Sudhersan *et al.* 2015; Alotaibi *et al.* 2023). The higher concentrations of these compounds were also better preserved during the storage period, particularly in fruits from older palms, indicating that proper management practices not only improve the fruit’s quality at harvest but also its storability. This relationship between higher flavonoid and carotenoid levels with fruit quality highlights the importance of these compounds in extending the shelf life and maintaining the nutritional value of Barhi dates (Younis *et al.* 2023).

Tannins and total phenols

Data from Tables 14 and 15 present the changes of tannins and total phenols in Barhi date palm fruits during cold storage over two seasons.

Tannins (mg/g DW)

Palm at 5 years with 10 bunches exhibited significantly higher tannin content throughout the storage period compared to other treatments (Table 14). At the beginning of the storage period, tannin content gradually decreasing over time but remaining higher than in other treatments. This can be explained by the higher stress experienced by palms with more bunches, leading to increased tannin production as a defense mechanism, since tannins are secondary metabolites involved in plant protection.

Table 14. Effect of palm age and bunch thinning on the tannins (mg/g DW) of Barhi date palm under cold storage

Treatments		Tannins, mg/g DW							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	0.65 b	0.588 a	0.490 a	0.382 a	0.66 bc	0.597 a	0.499 a	0.382 a
	10 Bunches	0.99 a	0.883 a	0.733 a	0.529 a	1.0 a	0.892 a	0.742 a	0.538 a
10 years	5 Bunches	0.51b	0.500 a	0.478 a	0.445 a	0.52 c	0.510 a	0.488 a	0.455 a
	10 Bunches	0.76 ab	0.680 a	0.570 a	0.425 a	0.77 ab	0.690 a	0.580 a	0.435 a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Palm at 10 years with 5 bunches showed the lowest tannin content, especially after 30 days of storage. In this case, the reduced number of bunches and the older age of the palms may have resulted in lower stress levels, reducing the need for tannin accumulation. Older palms are more established and capable of managing stress with lower tannin production compared to younger palms.

Total phenols (mg/g DW)

Palm at 10 years with 5 bunches had the highest total phenol content across the storage period (Table 15). The phenol content remained consistently high after 30 days of cold storage. Phenolic compounds are known for their antioxidant properties, which help protect the fruit from oxidative damage during storage. The higher phenol content in older palms with fewer bunches suggests that these palms were more efficient at producing protective compounds, possibly due to their well-developed physiological processes.

Palm at 5 years with 10 bunches showed a significant reduction in total phenols, particularly after 30 days of storage. This dramatic decrease can be attributed to the high fruit load and stress associated with having 10 bunches on younger palms, leading to a faster depletion of phenolic compounds during storage.

Table 15. Effect of palm age and bunch thinning on the total phenols (mg/g DW) of Barhi date palm under cold storage

Treatments		Total phenols, mg/g DW							
		Storage period (days)							
		Season of 2021				Season of 2022			
Palm age	No. of benches	0	10	20	30	0	10	20	30
5 years	5 Bunches	60.24 a	57.00 b	51.67 c	44.27 de	61.30 b	58.06 ab	52.73 cd	45.33 ef
	10 Bunches	50.18 b	40.57 ef	29.63 g	15.54 h	51.44 d	41.83 fg	30.89 h	16.80 i
10 years	5 Bunches	62.49 a	61.30 a	58.34 ab	55.03 bc	64.01 a	62.82 a	59.92 ab	56.61 bc
	10 Bunches	51.81 b	45.40 d	36.90 f	27.27 g	54.70 c	48.29 de	39.79 g	30.16 h

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

In this study, tannins and total phenols were key indicators of the antioxidant capacity and overall quality of Barhi dates, both at harvest and during storage. Tannins, known for their astringent properties, play a role in protecting the fruit against microbial attacks, while total phenols are potent antioxidants that contribute to the fruit's ability to resist oxidative stress and improve its health benefits (Ghanim *et al.* 2024; Najafiniya and Rahkhodaei, 2024).

CONCLUSION

Based on the obtained results, it can be concluded that palm age and bunch thinning significantly influence the quality and storability of Barhi dates in Egypt. Older palms, particularly those with reduced bunches, yielded fruits with superior physical and chemical characteristics, both at harvest and during cold storage. The combination of 10-year-old palms with five bunches per palm led to lower fruit drop, improved fruit weight, higher soluble solid content, and better retention of sugars and phenolic compounds during storage. These findings highlight the importance of optimizing cultivation practices, such as regulating palm age and applying effective bunch thinning techniques, to enhance both yield and post-harvest quality. It is recommended that commercial date palm growers adopt these strategies to improve the marketability and storage life of Barhi dates, ensuring higher profitability and sustainability for this valuable crop. Further research could focus on refining these practices under different environmental conditions to provide more comprehensive guidelines for farmers.

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دراسات ما قبل وبعد الحصاد علي نخيل البلح صنف البارحي

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الملخص

تنبع أهمية هذه الدراسة من تزايد الحاجة إلى تحسين جودة البلح البرحي بعد الحصاد وقدرتها على التخزين في مصر، والتي تُعتبر محصولًا حيويًا للاقتصاد الزراعي. هدفت الدراسة إلى تقييم تأثير عمر النخيل (5 و10 سنوات) وخف السباطات (الي 5 أو 10 عراجين لكل نخلة) على الخصائص الفيزيائية والكيميائية للثمار عند الحصاد وخلال التخزين البارد. أُجريت التجربة على مدار موسمين متتاليين (2021 و2022) في مزرعة بأبو صوير في مصر. تضمنت القياسات عند الحصاد: نسبة العقد، نسبة تساقط الثمار، وزن السباطات، وزن الثمار،الصلابة، محتوى المواد الصلبة الذائبة،السكريات الكلية،الكاروتينات،الفلافونويدات، التانينات، والمركبات الفينولية الكلية. كما تم تقييم الجودة بعد الحصاد خلال فترات تخزين وكانت عند 0، 10، 20، و30 يومًا. أظهرت النتائج أن النخيل الأكبر سنًا (10 سنوات) مع عدد أقل من السباطات (5 عراجين لكل نخلة) أنتج ثمارًا ذات جودة أعلى. وخلال التخزين، أظهرت الثمار من النخيل الأكبر سنًا معدلات فساد أقل واحتفاظًا أفضل بالخصائص الجيدة. وُجد أن تخفيف السباطات يحسن من جودة الثمار سواء عند الحصاد أو خلال التخزين، خاصة من حيث تقليل فقد الوزن والاحتفاظ بالمركبات الفينولية. أخيرا، يمكن لإدارة عمر النخيل وممارسات تخفيف السباطات أن تعزز بشكل كبير جودة وقدرة البلح البرحي على التخزين. تشمل التوصيات المستقبلية تحسين هذه الممارسات على نطاق تجاري لتعزيز القدرة التسويقية وإطالة عمر التخزين لهذا المحصول القيم.