Effect of Thermal Treatments in Storage Period and Morphological Characteristics of Date Palm Fruits cv. Barhi

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Abstract:

This research was conducted to investigate effect of thermal treatments and storage conditions in the quality of date palm fruits. The results showed that the –5°C treatment reduced the rate of ripening , as gradual and limited increases in ripening percentage were observed during storage at both 4°C and 25°C, compared with the 60°C treatment, which caused a pronounced acceleration in ripening, particularly under room temperature storage, where the ripening percentage reached its highest levels.

A results also revealed a gradual decrease in fruit weight lose with increasing storage duration across all treatments. However, the lowest weight loss was recorded in fruits treated at –5 °C and stored at 4°C, whereas fruits treated at 60°C stored at 25°C exhibited the highest weight loss.

Total soluble solids (TSS) and total sugars increased progressively with storage duration in all treatments, with the greatest increases observed in fruits treated at 60°C stored at 25°C. In contrast, total phenolic compounds and tannin content decreased significantly and progressively during storage time. The treatment at -5°C and stored at 4°C recorded the lowest decrease, while the treatment at 60°C with storage at room temperature recorded the highest decrease.

The treatment at -5°C with refrigerated storage resulted in significantly improved taste, texture, color, and overall acceptability, along with a decrease in astringency. In contrast, the heat treatment at 60°C with storage at 25°C led to a deterioration in sensory qualities and a decrease in overall acceptability. These results indicate that the cold treatment at -5°C with refrigerated storage is the optimal method for preserving fruit quality and extending life.

Keywords: Date palm, Thermal treatments, Storage , Morphological, Sensory Evaluation

Introduction:

The date palm trees (*Phoenix dactylifera* L.) is one of the most ancient fruit trees, and has been grown in desert oases for millennia. Its fruit has a high nutritional value and is considered a perfect food owing to their high contents of carbohydrates, fibers, lipids, antioxidants as well as its high commercial value [26, 18, 6]. Date palm fruits can be divided into five major stages of ripening: Hababouk, Kimri, Khalal, Rutab and Tamar. The fruits at Khalal, Rutab and Tamar are generally acceptable for eating [1].

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The date palm tree propagation has expanded recently because of the importance of nutritional and financial value of their product and the significance of this tree in stabilizing the ecological balance in dry and sub-dry areas [28]. Worldwide, date palm occupies a total cultivated area of about 12.9 million dunums with a production of around 9.65 million ton annually. Iraq is the fifth largest producer of dates in the world [13].

A fruits of date palm at the Khalal stage are subjected to many problems during storage and marketing, mainly the short period of this stage and the ripening of huge masses of fruits simultaneously, which obligate the farmers to hasten harvesting for obtaining suitable returns. In addition, the shortening of the Khalal stage with transition into the Rutab stage with softening and higher sugar content increases susceptibility to decay and eventually market loss [5, 2, 14].

Fruits lose very mobs after harvesting and specific treatments are required to enhance the uniformity of moisture in the fruit and to prolong shelf life during storage and marketing [4]. To minimize the causes of spoilage of date fruits, appropriate storage methods have been elaborated to increase the storage life as well as the marketing efficiency. Several researches have been carried out in the field of thermal treatment, refrigerated storage and controlled atmosphere storage [23].

Storage in cold (near 0°C) atmosphere with good relative humidity management was found to minimize moisture loss and retard the progress to the Rutab stage and thus fruit quality was maintained for longer duration as compared with the higher temperature storage [7]. [3] confirmed that modified gaseous atmosphere (elevated CO_2 , reduced O_2) packaging, at a storage temperature of around 4°C, helps in minimizing the discoloration and microbial activities in the cultivars 'Khalas' and 'Sukkari' compared to the normal atmospheric packaging-storage.

Another report showed that freezing at very low temperature (−18°C or below) inhibited microbial growth and reduced the enzymatic reaction leading to fruit decay, which allowed a longer preservation when combined with refrigerated storage [10].

Despite the effectiveness of some of these techniques in extending the Khalal stage, many of them are costly and impractical for local farmers. Since the Khalal stage plays an role in extending the marketing period improving economic returns, the development of simple, effective, and low-cost techniques represents a key research priority. Therefore, this study aims to extend the Khalal stage of date palm fruits cv. Barhi through the application of thermal treatments and the adoption of different storage methods.

Materials and Methods:

1. Plant Materials.

The Date palm fruits , cultivar Barhi, were harvested at the Khalal stage the end August from a private orchard located in Abu Al-Khasib, southern Iraq. Healthy, disease-free fruits of uniform size and weight were selected as much as possible.

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The fruits were randomly divided into two main groups.

The first group was treated at −5 °C and designated as (a), while the second group was treated at 60 °C and designated as (b) for 3 minutes. Each main group was further subdivided into two subgroups, with each subgroup consisting of three replicates. The fruits were placed in perforated paper bags and stored either at 4 °C (cold storage) or at room temperature (25 °C) for a period of two months. Physical and physiological characteristics were evaluated at 15-d intervals and included the following: time to and from the rutab stage, percentage of maturity, weight, and moisture content.. Biochemical characteristics were also determined, including total soluble solids (TSS), titratable acidity (TA), total sugars, total phenolic content, and tannins, in addition to sensory qualities: color, texture, flavor, firmness, astringency, overall accepted.

2.Maturity Percentage(%).

The maturity percentage of the fruits was estimated by calculating the ratio of ripe to unripe fruits.

3.Weight(g).

A sensitive digital balance was used to determine weight loss. Fruit weight loss was estimated by calculating the difference between the initial weight before applying the treatments and the final weight.

4.Relative humidity(%)

Relative humidity was measured was measured using a moisture analyzer (SKZ111C-4, China).

5.TSS(%)

Total soluble solids were estimated using a hand refractometer model (CETI, Belgium) according the method of [27].

6.Titratable Acidity (%).

Titratable acidity was determined as a percentage according to the method described by[31]

7. Total Carbohydrates (mg g^{-1}).

The method described by him [34]was used to estimate total carbohydrates.

8. Total Phenolic Content(mg kg^{-1}).

The total soluble phenolics were estimated according to the method described by [22]. using a spectrophotometer. Absorbance readings of the samples were taken at wavelength 725nm and plotted against a standard curve prepared using gallic acid.

9. Tannin (%).

The tannin content was measured based on the protocol described in [8]. The samples were titrated using potassium permanganate with indigo carmine as a color indicator. The results were expressed as a percentage (%).

10.Sensory Evaluation

The sensory evaluation was estimated according to the method described in [20]) by a trained panel consisting of 10 members. Samples were evaluated using a scoring scale ranging from 1–3 = poor, 3–5 = acceptable, 5–7 = good, and 7–10 = excellent, based on sensory attributes including color, flavor, texture, firmness, and astringency.

Experimenta lDesign and Statistical Analysis

The experiment was designed using complete randomized blocks (CRBD) and the results were analyzed using Anatomical Structure Variance Analysis, SPSS. The averages were also analyzed and significance was tested by the least

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significant difference (RLSD) test at the level of (0.05) [29].

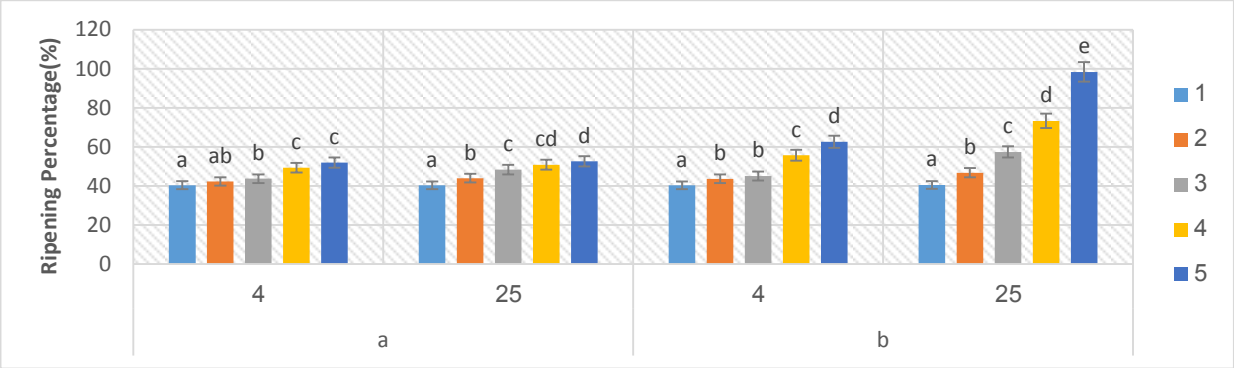
Results:

Ripening Percentage

The results in Figure 1 indicate that the cold treatment at –5 °C (a) resulted in limited increases in ripening percentage with the progression of storage periods, whether under refrigerated storage or room temperature conditions. The ripening percentage in the control treatment ranged from 40.33–40.37%, and gradually increased to reach 52.0% under refrigerated storage and 52.67% at room temperature at the end storage . This indicates that the cold treatment reduced the rate of ripening development regardless of storage temperature.

In contrast, the heat treatment at 60°C (b) showed a pronounced effect in accelerating the ripening process, and this effect was more evident at higher storage temperatures. The ripening percentage increased from 40.33–40.50% in the control to 62.6% under refrigerated storage, while a sharp increase was observed under room temperature storage, reaching 98.4% at the end storage

Figure 1 Effect of thermal treatments and storage duration on the Ripening Percentage of date palm fruits.



a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen

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Fruit Weight:

Data in Figure 2 indicate showed that all treatments exhibited a gradual decrease in fruit weight with increasing storage duration. Fruits stored at 4°C and treated at –5°C (a) recorded the lowest reduction in weight, where the average fruit weight decreased from 5.99 g in the control treatment at the beginning of storage to 5.26 g after two months of storage. Under storage at 25°C within the same treatment, the reduction was relatively greater, with fruit weight declining from 5.98 g at the beginning of storage to 5.20 g at the end of the storage period. Notably, the rate of

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weight loss in this treatment was relatively slow.

In contrast, fruits treated at 60°C (b) showed a marked decrease in fruit weight. The weight of fruits stored at 4°C decreased from 5.98 g in the control treatment at the beginning of storage to 5.18 g at the end of the storage period. The weight loss was more pronounced in fruits stored at 25°C, where fruit weight declined to 3.92 g at the end of storage compared with 5.98 g in the control at the beginning of storage, representing the highest rate of weight loss among all studi treatments.

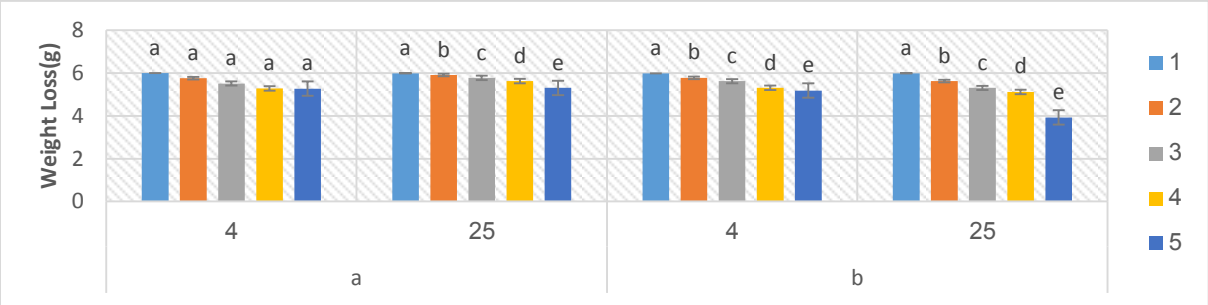

Figure 2 Effect of thermal treatments and storage duration on fruit weight of date palm
a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen

TSS:

The results presented in Figure 3 showed that the TSS content of date palm fruits increased gradually with storage duration across all treatments, with clear differences depending on the thermal treatment and storage temperature. In the –5 °C treatment (a), alowest TSS values were recorded, in the control treatment reaching 55.63% under refrigerated storage (4°C) and 55.66% under room temperature storage (25°C) atthe beginning during the storage period. These values increased progressively with continued storage, reaching 57.47% at refrigerated storage (4°C) and 57.90% at room temperature (25°C) at the end storage .

In contrast, treatment at 60°C (b) recorded higher TSS values compared with treatment (a) during the same storage periods. The TSS values in the control treatment initially ranged between 55.63% and 55.67%, then increased gradually with storage duration, reaching 57.93% at 4°C and 58.40% at 25°C at the end storage.

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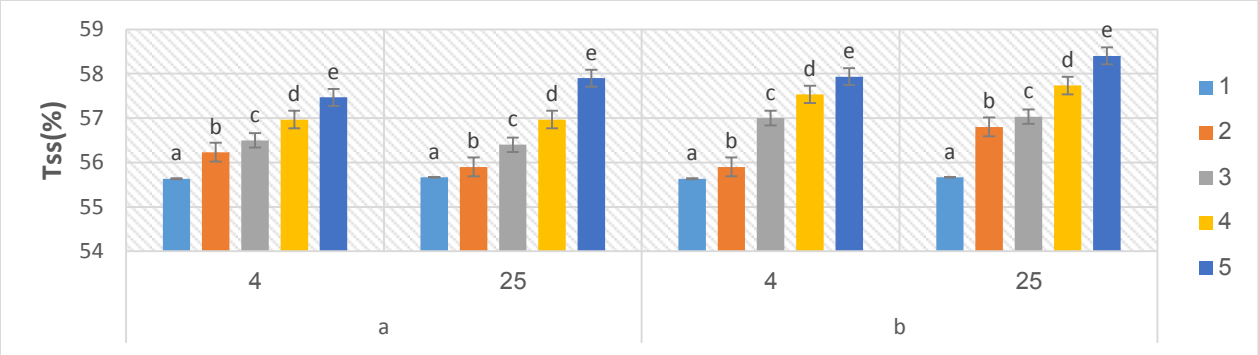

Figure 3 Effect of thermal treatments and storage duration, on total soluble solids content date palm fruits.

a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen

Total Carbohydrates:

Figure 4 showed gradual increases in total carbohydrate content of the fruits during the storage period. Fruits treated at –5°C and stored at 4°C exhibited a moderate increase in carbohydrate content, rising from 50.51 mg g^{-1} in the control treatment at the beginning of storage to 52.94 mg g^{-1} at the end the storage period. This indicates that refrigerated storage maintained carbohydrate levels within a gradual and balanced range without sharp increases. By contrast, the room temperature (25°C) fruits exhibited a more pronounced total carbohydrate increase than those under refrigerated, rising from 50.51 mg g^{-1} at the beginning of storage to 54.63 mg g^{-1} after 2 months of storage.

Similarly, fruits treated at 60 °C stored at 4°C showed a progressive increasein carbohydrate content, rising from 50.53 mg g^{-1} at the beginning of storage to 54.60 mg g^{-1} at the end storage period. However, fruits stored 25°C recorded the highest total carbohydrate content, with values increasing from 50.52 mg g^{-1} at the beginning of storage to 55.86 mg g^{-1} at the end of the storage period, representing the highest value recorded among all treatment

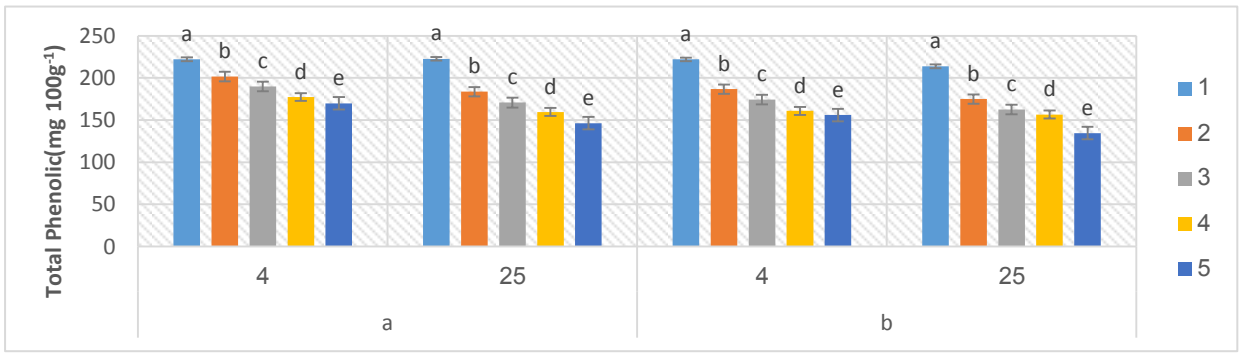

Figure 4 Effect thermal treatments , storage period ontotal Carbohydrates in date palm fruits

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a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen.

Total Phenolic Compounds:

As shown in Figure 5 a gradual and significant decrease in total phenolic compound content with increasing storage duration across all treatments. In the –5°C treatment (a), the highest phenolic content was recorded in the control treatment, reaching 222.15 and 222.70 mg kg^{-1} under storage at 4 °C and 25 °C, respectively. These values decreased progressively with continued storage, reaching 169.84 mg kg^{-1} at 4 °C and 146.36 mg kg^{-1} at 25 °C at the end storage .

In 60 °C treatment (b), fruits showed the same trend of gradual decline in total phenolic content; however, the values were generally lower compared with treatment (a) during the same storage periods, particularly in storage 25°C. The phenolic content decreased from 222.03 mg kg^{-1} in the control treatment at 4 °C to 155.91 mgkg^{-1} at end storage. Similarly, under storage at 25 °C The concentration was reduced from 213.81 mg kg^{-1} to 134.52 mg kg^{-1}, representing the lowest level recorded among all treatments.

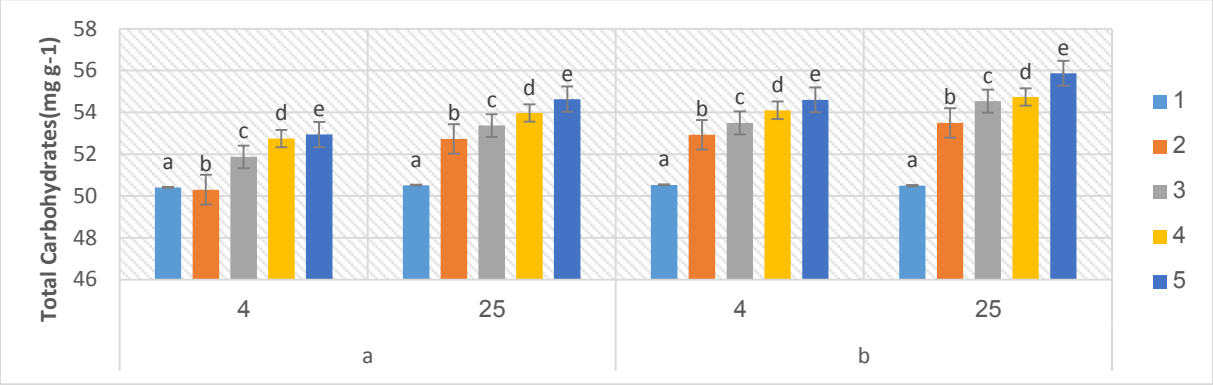

Figure 5 Effect of thermal treatments and storage duration on total phenolic content of date palm fruits

a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen

Tannin Content

The results showed that tannin content in the fruits gradually decreased with increasing storage duration across all treatments. In the –5°C treatment (a), fruits stored under refrigerated conditions (4°C) recorded the highest tannin content in the control treatment at 0.313%, which then declined to 0.293%–0.236% by the end of the storage period. Under room temperature storage (25°C), tannin content started at 0.310% in

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the control treatment and decreased to reach 0.220%–0.273% at the end of storage

In the 60°C treatment (b), fruits stored at 4 °C showed tannin content of 0.316% in the control treatment, decreasing to 0.273%–0.223% with continued storage. Fruits stored 25°C exhibited the highest initial value in control (0.320%), followed by lower values reaching 0.276%, and ultimately the lowest value of 0.163% at the end of the storage period.

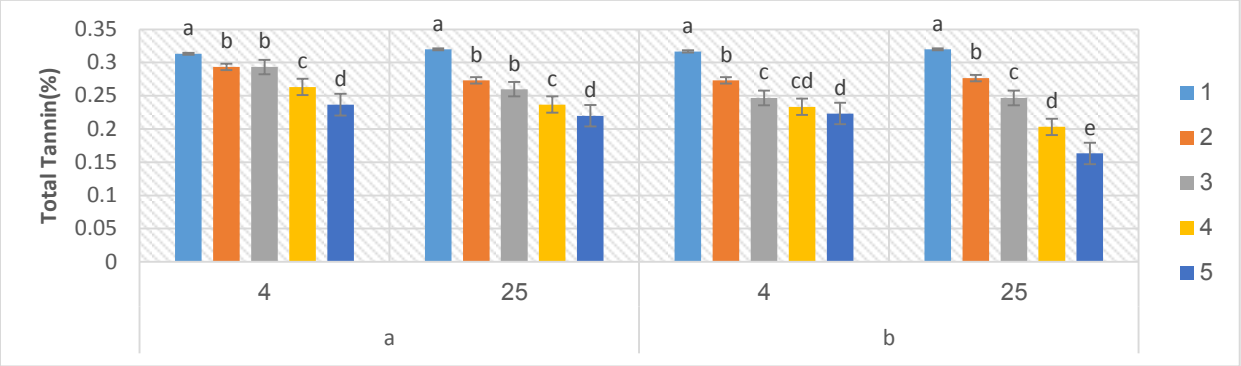

Figure 6Effect of heat treatments, storage duration on the total tannin
a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen

Sensory Evaluation

Fruits treated at –5 °C (a) and stored under refrigerated conditions (4°C) showed a gradual improvement in taste (Figure 7A), with values increasing from 7.33 in the control treatment to 9.67 at the end of storage, compared with 7.00–8.33 for fruits stored at room temperature (25°C). Similarly, texture scores (Figure 7B) in this treatment increased from 7.67 to 9.67, while declining to 6.00 under room temperature storage, especially following the 60 °C thermal treatment (b).

Astringency (Figure7C) decreased gradually with storage, ranging from 7.33 to 9.67 in the –5 °C / 4°C treatment, but dropped to 5.67 in the 60 °C / 25 °C treatment. Overall acceptability (Figure 7D) was highest for the –5°C refrigerated treatment, increasing from 7.67 to 10.00, whereas it declined to 5.67 in the 60 °C / 25 °C treatment. Color scores (Figure 7E) were also highest in the –5 °C / 4 °C treatment at 9.43, compared with a reduction to 5.33 in the 60°C/25°C treatment.

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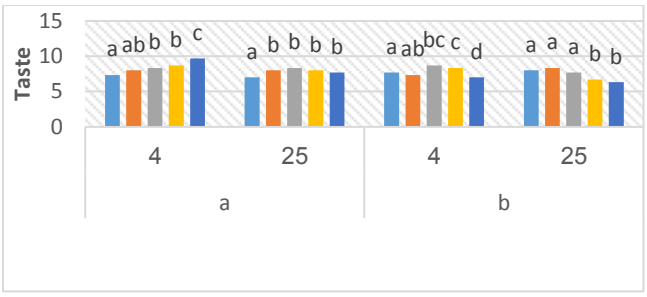

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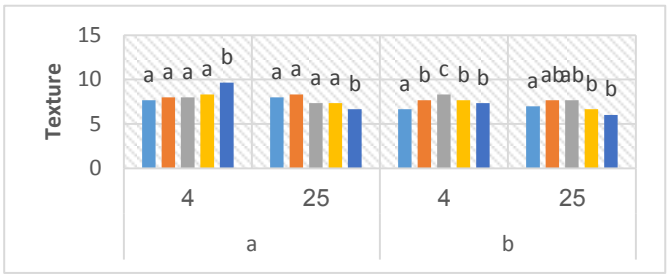

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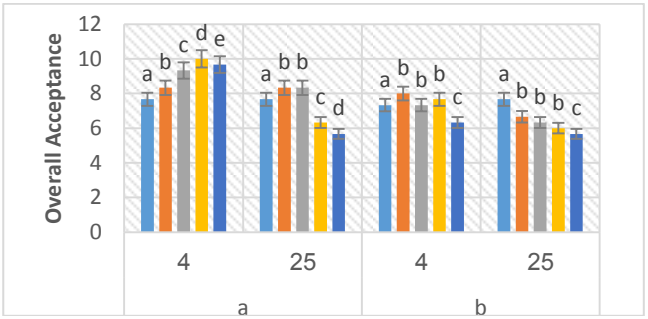

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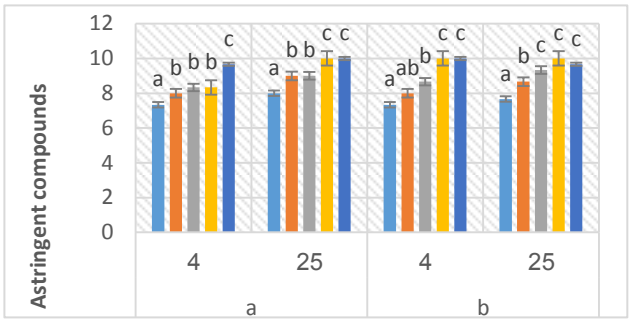

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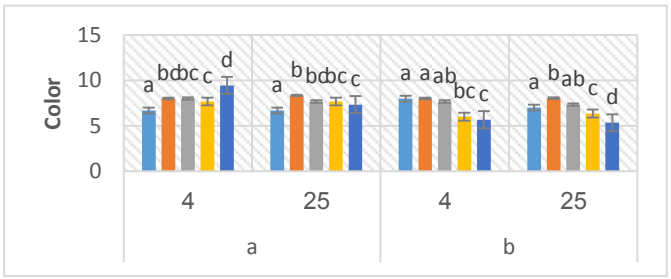

E

Figure 7 Effect of heat treatments and storage duration on the sensory attributes of date palm fruit

a = thermal treatment at −5°C; b = thermal treatment at 60°C; 4 =. refrigerated storage temperature; 25 = room storage temperature. Each column = results after 15 days, Column 1 = control treatment. Means followed by the same letters are not significantly differen

Discussion:

The gradual and significant increase in fruit ripening percentage with prolonged storage can be attributed to the activation of metabolic pathways within fruit tissues after harvest, particularly the production of ethylene, which stimulates numerous enzymes involved in the ripening process, such as those responsible for Carbohydrates breakdown and cell wall It is limited in oranges. At higher storage temperatures (25 °C), respiration and metabolic rates are elevated, accelerating ripening compared with refrigerated storage [10].

High-temperature treatment (60 °C) also contributes to the acceleration of these processes by enhancing ethylene production and activating the metabolic network associated with ripening, resulting in a greater increase in ripening percentage during the same storage periods, especially

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under room temperature storage. This aligns with previous studies [2,16].

Regarding the gradual decrease in fruit weight with extended storage, this can be attributed to increased metabolic activity in fruit tissues after harvest, primarily through respiration and transpiration. Both processes consume stored substances and convert water into vapor lost to the surrounding environment.

Thermal treatment at 60 °C may induce structural changes in the fruit peel and cuticular wax layer, such as increased peel permeability or alterations in surface wax layers, facilitating postharvest water loss. Disruptions in the wax layer accelerate transpiration, which explains why fruits treated at 60 °C exhibited the highest rates of weight lose, especially when stored at higher temperatures (25 °C) [17]. This weight loss serves as a clear physiological indicator of tissue deterioration under the influence of temperature and storage conditions. Recent studies also indicate that controlling temperature and humidity can significantly reduce weight loss and extend postharvest shelf life [18].

The gradual increase in total soluble solids (TSS) content during storage is attributed to a series of metabolic and physiological changes in fruit tissues. Endogenous enzymes break down complex carbohydrates, such as starch, into soluble sugars, raising sugar concentration in the cell sap. Additionally, water loss from tissues concentrates the remaining sugars, leading to increased TSS values. Higher storage temperatures further enhance this metabolic conversion, accelerating carbohydrate degradation into simple sugars, which explains why fruits subjected to 60 °C treatments recorded higher TSS values compared with –5 °C treatments. These These findings agree with studies by [13] and [36].

The gradual increase in total sugar content during storage across all treatments is also attributed to metabolic conversions, where complex carbohydrate compounds (starch and large polysaccharides) are converted into simple sugars through the activity of hydrolytic enzymes, such as invertase, α-amylase and β-amylase. This leads to a gradual rise in soluble sugar concentration during storage, particularly under conditions that enhance enzyme activity. Similar patterns have been observed in fruit storage studies, such as pear, where total sugars increased until mid-storage before declining due to consumption during respiration and advanced metabolic aging [22].

The significant decline in total phenolic content during storage may result from the activation of oxidative enzymes, as well as metabolic reactions within tissues that oxidize these compounds into non-measurable forms like free phenolics [33]. This agrees with findings by [19] and [31].

Tannins, being complex phenolic compounds, are prone to oxidation and heat-induced reactions during storage. At higher storage temperatures, the oxidation and degradation of phenolic compounds, including tannins, are accelerated, resulting in decreased content over time. This is consistent with recent literature indicating that phenolic degradation increases with higher temperatures and oxygen exposure, reducing these compounds in stored foods [25, 26].

Regarding sensory attributes, fruits treated at –5 °C and stored under refrigerated conditions (4 °C) maintained higher levels

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of taste, texture, color, and overall acceptability compared with fruits stored at 25 °C. This suggests that cold storage slows metabolic and enzymatic activity and limits the loss of sensory compounds, consistent with [34].

In contrast, storage at 25 °C combined with 60 °C thermal treatment accelerated respiration and oxidation of compounds responsible for flavor, texture, and color, leading to a decline in sensory scores over time, as observed by [19]. The gradual decrease in astringency under higher temperature treatments can be attributed to the breakdown and transformation of phenolic compounds during ripening and storage, as noted by [12].

Conclusion:

Results the type of thermal treatment and storage temperature were the most influential factors on the are ripening and quality of the date palm fruit during storage. >Cold treatment have been shown to delay ripening and reduce weight loss and retard a balanced accumulation of total soluble solids (TSS), total sugars, and while modulating a decreasing rate of phenolic compounds and tannins. Such effects favorably affected the sensory characteristics and the acceptability index of the fruits.

On the contrary, the high-temperature treatment at 60 °C, especially with storage at room temperature (25 °C), promoted ripening, increased weight loss, triggered a sharp increase in sugars and TSS, and induced significant reductions in phenolic compounds and tannins as well as quality loss in terms of sensory parameters. Hence, it would be concluded that cold treatment (–5 °C) in combination with refrigerated storage is a suitable technique for preserving quality of date palm fruits and for prolonging their

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References:

[1]

Abdelkarim, D. O., Mohamed Ahmed, I. A., Ahmed, K. A., Younis, M., Yehia, H. M., Zein El-Abedein, A. I., et al. (2022). Extending the shelf life of fresh Khalal Barhi dates via an optimized postharvest ultrasonic treatment. Plants 11, 1–17.

[2] Abu-Shama, H. S., Abou-Zaid, F. O. F., & El-Sayed, E. Z. (2020). Effect of using edible coatings on fruit quality of Barhi date cultivar. Scientia Horticulturae, 265, 109262.

[3] Ahmed, A. R., Aleid, S. M., & Mohammed, M. (2023). Impact of modified atmosphere packaging conditions on quality of dates: Experimental study and predictive analysis using artificial neural networks. Foods, 12(20), 3811.

[4] Ahmed, Z. F., Al Shaibani, F. Y., Kaur, N., Maqsood, S., & Schmeda-Hirschmann, G. (2021). Improving fruit quality, bioactive compounds, and storage life of date palm (*Phoenix dactylifera* L., cv. Barhi) using natural elicitors. Horticulturae, 7(9), 293.

[5] Alsawmahi, O. N., Al-Juhaimi, F., Alhamdan, A. M., Ghafoor, K., Adiamo, O. Q., Mohamed Ahmed, I. A., et al. (2018). Phenolic, tannin, antioxidant, color, and sensory attributes of Barhi date (Phoenix dactylifera) fruit stored in modified atmosphere packages. J. Food Biochem. 42:e12576.

[6] Alqahtani, N. K. (2024). Valorization of the potential use of date press cake (date syrup by-product) in food and non-food applications: a review. Front. Sustain. Food Syst. 7:1340727

[7] Alqahtani, N. K., Ali, S. A., & Alnemr, T. M. (2025). Quality preservation of date palm (*Phoenix dactylifera* L.) fruits at the Khalal stage: a review on current challenges, preservation methods, and future trends. Frontiers in Sustainable Food Systems, 9, 1558985.

[8] AOAC.(1980). Official Methods of Analysis; Association of Analytical Chemists: Arlington, VA, USA.

[9] Asrey, R., Sharma, S., Barman, K., Prajapati, U., Negi, N., & Meena, N. K. (2023). Biological and postharvest interventions to manage the ethylene in fruit: a review. Sustainable Food Technology, 1 (6), 803–826.

[10] Assous, M. T. M., El-Shafei, W. K. M., Lewaa, L. M., & Gadalla, E. G. (2022). Effect of Physical Methods on Date Fruits Insects and Microbes. Asian Research Journal of Agriculture, 15(4), 124-133

[11] Diaz-Montaña, E. J., Barbero-López, M., Aparicio-Ruiz, R., García-González, D. L., & Morales, M. T. (2024). Impact of Frozen Storage on Sensory, Physicochemical, and Volatile

[12] El-Gawad, A., Mahmoud, G., Zaki, Z., & Kotb, H. (2025). Effect of Tragacanth Gum and Polyethylene Packaging on Postharvest Storage of. Horticulture Research Journal, 3(7), 59-75.

[13] FAO (2024). Available online at: https://www.fao.org/faostat/en/#data/QCL (Accessed December 21, 2024).

[14] Ghafoor, I., Rahman, M. H. U., Hasnain, M. U., Ikram, R. M., Khan, M. A., Iqbal, R., ... & Sabagh, A. E. (2022a). Effect of slow-release nitrogenous fertilizers on dry matter accumulation, grain nutritional quality, water productivity and wheat yield under an arid environment. Scientific Reports, 12(1), 14783.

[15] Ghafoor, K., Al-Juhaimi, F. Y., Babiker, E. E., Mohamed Ahmed, I. A.,

Shahzad, S. A., and Alsawmahi, O. N. (2022b). Quality attributes of refrigerated Barhi dates coated with edible chitosan containing natural functional ingredients. Foods [Online] 11, 1–16

[16] Gidado, M. J., Nagoor Gunny, A. A., Gopinath, S. C., Adam, T., M. Abdul Kader, M. M., & Oyeniyi, O. A. (2023). The Effects of Storage Conditions on Postharvest Physiology of Fruits: A Review. In International Conference on Biomass Utilization and Sustainable Energy (pp. 425-439). Singapore: Springer Nature Singapore.

[17] Gidado, M. J., Gunny, A. A. N., Gopinath, S. C., Ali, A., Wongs-Aree, C., & Salleh, N. H. M. (2024). Challenges of postharvest water loss in fruits: Mechanisms, influencing factors, and effective control strategies–A comprehensive review. Journal of Agriculture and Food Research, 17, 101249.

[18] Huang, H., Li, X., Ye, R., & Luo, Y. (2026). Phytochemicals, volatile and non-volatile compounds changes in post-ripening of harvested Akebia trifoliata fruit under different storage conditions. Postharvest Biology and Technology, 231, 113950.

[19] Hussain, M. I., Danish, S., Naqvi, S. A., Jaskani, M. J., Asghar, M. A., Khan, I. A., ... & Muscolo, A. (2024). Physiological, biochemical, and comparative genome analysis of salt and drought stress impact on date palm (*Phoenix dactylifera* L.): tolerance mechanism and management. Plant Growth Regulation, 104(3), 1261-1283

[20] Ismail, B., Haffar, I., Baalbaki, R., & Henry, J. (2001). Development of a total quality scoring system based on consumer preference weightings and sensory profiles: application to fruit dates (Tamr). Food quality and Preference, 12(8), 499-506. Hua, C., Zhang, Y., Qiu, X., Lu, R., Li, J., & Xin, Y. (2025). Evaluate the Impact of Temperature Fluctuations During Transportation on the Quality of Chinese

[21] Kaur K, Dhillon WS, Mahajan BV.(2013). Effect of different packaging materials and storage intervals on physical and biochemical characteristics of pear. J Food Sci Technol. Feb;50(1):147-52.

[22] Melo, E. D. A., Maciel, M. I. S., Lima, V. L. A. G., Leal, F. L. L., Caetano, A. C. D. S., & Nascimento, R. J. (2006). Antioxidant capacity of vegetables commonly consumed. Food Science and Technology, 26, 639-644.

[23] Mohamed MA., Mustapha, K.(2020). Study the effect of postharvest heat treatment on infestation rate of fruit date palm (*Phoenix dactylifera* L.) cultivars grown in Algeria. J Nut Sci . 1(1): p.39.

[24] Mrazkova, M., Sumczynski, D., & Orsavova, J. (2023). Influence of Storage Conditions on Stability of Phenolic Compounds and Antioxidant Activity Values in Nutraceutical Mixtures with Edible Flowers as New Dietary Supplements. Antioxidants, 12(4), 962

[25] Salazar-Orbea, G. L., Garcia-Villalba, R., Bernal, M. J., Hernandez-Jimenez, A., Egea, J. A., Tomas-Barberan, F. A., & Sanchez-Siles, L. M. (2023). Effect of storage conditions on the stability of polyphenols of apple and strawberry purees produced at industrial scale by different processing techniques. Journal of Agricultural and Food Chemistry, 71(5), 2541-2553.

[26] Sarraf, M.; Jemni, M.; Kahramanoˇglu, I.; Artés, F.; Shahkoomahally, S.; Namsi, A.; Ihtisham, M.; Brestic, M.; Mohammadi, M.; Rastogi, A.(2021). Commercial techniques for preserving date palm (*Phoenix dactylifera*) fruit quality and safety: A review. Saudi J. Biol. Sci., 28, 4408–4420.

ISSN 2072-3857

[27] Shirokov , E. P. (1968). Practical course in storage and processing of fruit and vegetable USDA INSF publication, Washington, D.C., : 161 p.

[28] Singh, V., Aggarwal, P., Kaur, S., and Kaur, N. (2022). Intermediate moisture date (*Phoenix dactylifera* L.) based dessert with natural sugars: Phytonutritional profile, characterization, sensory quality, and shelf-life studies. J. Food Process. Preserv. 46:e17237.

[29] Snedecor, G. M. and W. G. Cochran (1986). Statistical Methods. 9th ed., The Iowa State University, American Press, Iowa, U.S.A., pp. 507

[30] Somaly, S., Lika, R., Socheata, C., & Sokra, I. (2026). Optimal storage temperature for fresh fruits: physiological responses, quality retention, and shelf-life extension. Journal of Agriculture and Technology, 2(1), 79-84.

[31] Wang S, Yin X, Tang J. and Hansen J.D. (2004).Thermal resistance of different life stages of codlingmoth (Lepidoptera: Torticidae). J. Stored Products Research. (40): 565-574.

[32] Wang, J., Zhang, H., Hou, J., Yang, E., Zhao, L., Zhou, Y., ... & Li, J. (2023). Metabolic profiling and molecular mechanisms underlying melatonin-induced secondary metabolism of postharvest goji berry (*Lycium barbarum* L.). Foods, 4326.

[33] Wang, L., Zhang, S., Ye, Z., Zhou, H., Shen, S., Zheng, X., & Huan, C. (2025). The effects of chilling (4° C) and non-chilling (12° C) temperatures on storage quality and flavor development of yellow peach fruit. Journal of Food Composition and Analysis, 139, 107094

[34] Watanabe S., Kojima K., Ide Y. and Sasakii S. (2000). Effect of saline and osmotic stress on proline and sugar accumulation in Populus euphratica in vitro. Plant Cell Tissue Organ Cult. 63:199-206.

[35] Yadav, A., Kumar, M., Bangar, S. P., & Siroha, A. K. (2025). Response of pre-harvest application of chemicals on physico-chemical properties of ber (*Ziziphus mauritiana Lamk*.) cv. Gola during storage. Journal of Food Measurement and Characterization, 19(5), 3600-3612.

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