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Impacts of smart and active packaging on the quality and storage period of 'Barhi' dates

Ibrahim El-Shenawy Ghounim
Pomology Department, Faculty of Agriculture, Cairo University, 2613, Giza, Egypt
*Corresponding author email: dr.shenawy@hotmail.com

Ibrahim Hmmam
Pomology Department, Faculty of Agriculture, Cairo University, 2613, Giza, Egypt

Khaled Nagy
Food Technology Research Institute, Agricultural Research Center (ARC), Giza, Egypt

Mohammed Ismail
Pomology Department, Faculty of Agriculture, Cairo University, 2613, Giza, Egypt | Food and Agro-Industries Technology Center (FAITC), Ministry of Trade and Industry, Egypt

Abstract---The climacteric nature of 'Barhi' dates makes their shelf life very short after harvest. This research aimed to explore the impact of using different packaging materials along with reducing the negative effects of ethylene gas on the quality of 'Barhi' date fruit by determining the changes in physical and chemical characteristics of stored fruit. For this purpose, 'Barhi' date fruits were picked during the Khalal stage and stored using three different packaging materials [carton boxes (control), low-density polyethylene (LDPE), and equilibrium modified atmosphere packaging (EMAP)] with or without ethylene absorbent sachet (EAS) at 0 °C for 40 days. The results indicated that the EMAP bags with EAS under 0 °C gave the highest quality properties of all studied parameters compared to the control treatment. The control treatment recorded the lowest date fruit quality, which lasted only for 20 days of cold storage before converting to the Rutab stage. Using LDPE with EAS instead of the more expensive EMAP bags could be a cheaper way to keep the quality of 'Barhi' date fruit and make it last longer during cold storage.

Keywords---phoenix dactylifera, Barhi, quality, packaging materials, ethylene, cold storage.

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Introduction

The date palm (*Phoenix dactylifera* L.) is one of the oldest plants cultivated by humans. The palm tree is extremely valuable in terms of both economic and nutritional terms. It is a major fruit tree and the ideal crop to be planted because of its historical usage as a primary source of food and by-products, as well as its ecological advantages in oasis cultivation. Egypt produces more date palm fruit than any other country in the world (Al-Khayri *et al.*, 2015). The annual production of date palms in Egypt has been estimated at 1,603.762 million tons, accounting for almost 18% of global date production. In 2018, it had a fruiting area of 49,000.74 acres (FAO, 2020). Fresh date fruit, particularly 'Barhi', is delicious and regularly consumed during the Khalal maturation stage (first edible stage). Carbohydrates make up most of the chemical components of date fruit. Therefore, dates are a rich source of energy and dietary fiber, as they contain 70% carbohydrates, the majority of which are sugars. One hundred grams of dates provides 32% of the recommended daily amount of dietary fiber (Vinita and Punia., 2016).

There is no doubt that preserving the palm fruit in the Khalal stage after picking is one of the priorities of the storing technology, particularly the soft varieties such as 'Barhi', which is distinguished by its excellent flavor as well as its high price in comparison to other date varieties (Taain, 2005). The Khalal stage of date fruit has firm and crisp properties, and the fruit texture reduced after they switched to the Rutab stage. Any delay in transportation or bad storage conditions causes Rutab spots and surface wrinkling, as well as a loss of flavor and taste (Mortazavi *et al.*, 2007). Because date fruit is perishable and seasonal, it requires a longer shelf life as well as a longer marketable date (Abd El-Hady *et al.*, 2017). The main goal of cold storage of fruit is to slow down the essential activities that occur in fruit, particularly respiration and microbial activities (Fedrov, 1982; Shirikov, 1988). High temperatures after picking and during storage accelerate the appearance of physiological processes, and disease activity as well as increase the pace of consumption of food contained in fruit, reducing their ability to be stored (Saborov and Antonov, 1962; Dementeva and Vegonski, 1988).

The type of packaging is an essential element in preserving fruit since several previous studies have shown a strong link between the type of packaging and the pattern of changes in quality attributes during storage (Jamba, 1996; Taain, 2005). Alternative packaging materials such as low-density polyethylene (LDPE) and equilibrium modified atmosphere packaging (EMAP) have been successfully employed to extend the shelf-life of fresh fruit, but LDPE is more widely available and less expensive than EMAP. In recent years, research on packaging materials has gradually focused on EMAP in various fruits such as feijoa (Castellanos *et al.*, 2016), jujube (Reche *et al.*, 2019), and fig (Cantín *et al.*, 2020), but no studies on date palm have been conducted. The EMAP approach entails modifying the air within the container with a beneficial blend of increased carbon dioxide and decreased oxygen. It is accomplished mostly through the addition and substitution of various gas components (oxygen, carbon dioxide, and nitrogen) to create a gas balance in the package.

The efficiency of this strategy in extending shelf-life is based on various parameters, including the type of product, gas combination, storage temperature, and packing material (Valero and Serrano, 2010). Also, removing ethylene gas from the headspace of the packaging can slow down senescence and make the storage period longer. One of the commercially available approaches for this purpose is ethylene adsorption/oxidation technology (Dobrucka *et al.*, 2017). Therefore, the primary objective of this study was to assess the effectiveness of alternative safe packaging materials and ethylene removal on the quality of 'Barhi' date fruit at the Khalal stage under cold storage conditions.

Materials and Methods

Plant materials

On September 9th, 2019, 'Barhi' dates were harvested after 127 days of pollination at the Khalal stage from uniform date palm trees growing at a private farm located in Ismailia governorate, Egypt (Cairo-Ismailia Desert Road 30°25'38.9"N 32°02'42.3"E). All fruits were picked according to color (light yellow). On the same day, harvested 'Barhi' dates were delivered to the laboratory, and broken fruit, infected or crumbled, were eliminated. Healthy fruits of uniform size and appearance were divided randomly into replicates of 84 fruits, with three biological replicates for each treatment.

Packaging materials

Dates were packaged in carton boxes (control), low-density polyethylene (LDPE), and equilibrium modified atmosphere packaging (EMAP) materials, as described below, then sealed carefully by an FR-770I continuous film sealing machine and life span film (L042) for the store at 0-2 ˚C was used. Carton boxes (28 X 17 X 5.2 cm), from Misr El-Hadara local company, transparent LDPE (20 X 22 cm) kindly provided by the Engineering and Packaging Department, Agricultural Research Center, Giza, and EMAP (29 X 21 cm) from Amcor company, Switzerland.

Ethylene absorbent sachet (EAS)

Ethylene absorbent sachets (Potassium permanganate, GK4/P SACHET, and MANTA, 2.5-<10%, Greenkeeper Iberia SL C/Sierra, Madrid, Spain) were placed alternately in each treatment as post-harvest treatments to maintain 'Barhi' fruit quality under different cold storage temperatures.

Storage condition

All treatments were stored at 0 ˚C with 80-85% RH for 40 days in specific refrigerators (Mod/CHL 1450, Spain).

Fruit quality measurements

Stored 'Barhi' date fruits of each treatment were evaluated for quality parameters at 0, 10, 20, 30, and 40 days. Chemical and physical properties were estimated during storage periods as follows:

- **Weight loss (%)**
  Weight loss percent was calculated as the difference between fruit weight at the start of storage and fruit weight at the inspection dates by Sartorius A.G Germany S.N/ ED32025-CW using the following equation:
  Weight loss % = Initial weight of fruit – Weight at the time of sampling **/** The initial weight of fruit ×100
- **Texture (N/cm²)**
  Date fruit texture was measured by a Brookfield texture analyzer instrument (Model: CT3-10kg, USA) using the TA10 cylinder of 12.7mm diameter. The data was processed using Texture Pro and CT software, and the results were expressed in N/cm^2.
- **Rutab (%)**
  During storage, the number of ripe (Rutab) fruits was periodically recorded and expressed as a percentage based on the formula given below. Fruit that showed softening for about 15% (visually estimated) of its total area was considered rutab.
  Rutab % = number of rutab fruits / total number of fruits × 100
- **Total acidity (TA%)**
  The total acidity of the date flesh was determined as malic acid by titration with a solution of 0.1 N. (NaOH), using phenolphthalein as an indicator. The average amount of sodium hydroxide used in each titration was recorded and total acidity was calculated as gm/100 gm fresh weight (A.O.A.C., 1990).
- **Moisture percent (%)**
  The fruit samples were cleaned and the perianths and seeds were removed, and the date flesh was cut into pieces and dried at 60-65°C for 12 hours in an oven (ON-01E-120, Jeio Tech Co., USA) according to Abd-EI-Rahman (1974).
- **Total soluble solids (TSS/° BX)**
  TSS concentration was estimated using a digital refractometer (Digital Hand-held PAL^{-1}, Japan). Three different readings for each replicate were recorded and the average was calculated (A.O.A.C., 1990).
- **Total sugar (g/100 mg)**
  Total sugar was determined according to Kawamura *et al.* (1967). One gram of fruit dry weight was extracted with 100 ml of natural ethanol. The concentration was calculated as total soluble sugars g/100 mg dry weight.
- **Reducing sugar (g/100 mg)**
  Reducing sugar was determined by using the 3,5-dinitrosalicylic acid (DNS) method using the methanol extract (Miller, 1959). The reducing sugar was calculated as g/100 mg dry weight.
- **Respiration rate (nmol CO_2 kg^{-1} s^{-1})**
  Carbon dioxide (CO_2) was measured using a Headspace Gas Analyzer (OXYBABY® 6.0 WITT-GASETECHNIK, Germany). The respiration rate was calculated according to the equation provided by Lurice and Pesis (1992) and expressed as nmol CO_2 kg^{-1} s^{-1}.
- **Fibers (%)**
  The crude fiber content was determined at 0, 10, and 40 days of storage period according to A.O.A.C. (2005) as the residual of sequential extraction of a defatted sample with 1.25% H_2SO_4 and 1.25% NaOH using DOSI fiber.

Experimental design and statistical analysis

The experiment was designed using a randomized complete block design (RCBD) with three replicates and each replicate contained 84 dates. Each time point was analyzed separately as an independent experiment. Using R statistical environment v4.0.5 (R Core Team 2022), the data were statistically analysed using variance analysis, and the differences between means were separated using Duncan multiple range tests (Duncan, 1955) at a 95% confidence level.

Results and Discussion

Weight loss

Over the period of the 40-day storage period, weight loss of 'Barhi' dates increased gradually in all treatments, as shown in Table (1). Weight loss was shown to be strongly influenced by the type of packages over the storage period under 0 ^{o}C. After 20 days of cold storage, control fruit recorded the highest significant ($p \leq 0.05$) values (65.33 and 67.10%) with ethylene absorbent sachet (EAS) and without EAS, respectively, compared to both LDPE and EMAP treatments. The least significant weight loss within each storage period was observed in fruit stored in EMAP packages at 0 ^{o}C with EAS, with losses of 0.03, 0.27, 0.50, and 1.26% recorded at 10, 20, 30, and 40 days of cold storage, respectively. LDPE packages had the same trend as EMAP, with slightly higher weight loss percentages. Water loss causes changes in texture, shrinkage, and other physical attributes of the fruit, reducing the quality value, increasing decay, and shortening the fruit's shelf life (Paull, 1999). Based on the data gathered, it can be concluded that a slight increase in weight loss across all treatments was mostly produced by biochemical events involving the constituents of fruit cells. Because fruit at Khalal stage has high moisture content and fast metabolism, negative circumstances that encourage evaporation of water from the fruit might lead them to lose weight more quickly (Mortazavi *et al.*, 2007; Ramadan *et al.*, 2020; El-Gioushy *et al.*, 2022). Moreover, weight loss was reduced in dates treated with ethylene scavengers in MAP treatment (Mortazavi *et al.*, 2015). In other date cultivars, the loss of water from the fruit surface to the surrounding atmosphere and the loss of carbon resulting from the production of CO_2 during respiration lead to weight loss (Kamal, 1995; El-Hadidy *et al.*, 2015; Ibrahim and Hamzah, 2019; Rabeh *et al.*, 2022). Fruit water loss depends heavily on relative humidity, so maintaining fruit at a low permeability bag and a lower temperature helps to limit the water loss to a minimum level (Jayathunge *et al.*, 2011).

Texture

At the beginning of the experiment, the measured initial texture of the fruit was 21.63 N/cm^2 as the Khalal stage of 'Barhi' date fruit has a firm and crisp taste, and the texture of the fruit changes when it reaches the Rutab stage. The texture was considerably influenced by the treatments over the storage periods (Table 2). The fruit stored in EMAP at 0 ^{o}C with EAS had gradually decreased values of texture equal to 20.75, 18.70, 16.69, and 14.70 N/cm^2 at 10, 20, 30, and 40 days of cold storage, respectively. After 20 days of storage period, control fruit placed in cartons with and without EAS at 0 ^{o}C had the lowest significant ($p \leq 0.05$) values

(7.14 and 6.48 N/cm^2, respectively), while at the same time point under the same storage conditions, fruit placed in LDPE and EMAP with and without EAS had higher values without any significant differences between them (Table 2). At the end of the storage period, fruit placed in LDPE and EMAP without EAS had values of texture equal to 11.13 and 13.40 N/cm^2, respectively, without any significant differences between them, while fruit placed in LDPE and EMAP with EAS had values of texture equal to 11.29 and 14.70 N/cm^2, respectively, without any significant differences between them.

These findings are consistent with the results of Taain (2005), who found that the cohesiveness of dates stored in PE packaging was higher than that of dates stored in carton packaging. According to Al-Redhaiman (2005a and b); Mortazavi *et al.* (2007); Mortazavi *et al.* (2010), the modified atmosphere packaging (MAP) induced little change in fruit texture up to the Rutab stage. Furthermore, Khalal fruit that loses its firm, crisp feel has lower quality and is thus cheaper priced. The activation of pectin degrading enzymes like poly-galactronase (PG), which hydrolyzes the connection between galacturonic acid residues in pectin, is related to the softening of the fruit texture (Kader and Holcroft, 2018). Even while customers may prefer this softer fruit during later stages of ripening, such as that of the Rutab and Tamr stages, it would not be deemed as 'crunchy' as a Khalal stage fruit, and so would not be an appropriate fruit quality (Al-Eid *et al.*, 2012). Soliman (2020) investigated the effects of postharvest treatments on 'Barhi' date fruit in cold storage and found that texture reduced with storage time, and reached its lowest levels at the end of the storage period.

Rutab

Table (3) shows that the percentage of rutab increased steadily as the storing period was extended in LDPE and EMAP but increased faster in the control treatment. Control fruit reached the Rutab stage faster after 20 days of cold storage. Accordingly, those samples were discarded, and the experiment lasted for 40 days with LDPE and EMAP packages. Stored fruit in carton packages (control) at 0 ^{o}C with and without EAS (63.33 and 66.67%, respectively) after 20 days, while no Rutab was observed with both LDPE and EMAP at this sampling time under the same storage conditions. However, stored fruit in EMAP packages at 0 °C with EAS had a low rate of Rutab with values equal to 4 and 10% after 30 and 40 days, respectively, followed by stored fruit in LDPE at 0 °C with EAS with a value equal to 15% after 40 days. These results are in accordance with those reported on different date genotypes by Taain (2005); Mortazavi *et al.* (2007); Farag *et al.* (2017); El-Dengawy *et al.* (2018); Soliman (2020). Due to the high-water content and active metabolism of Khalal stage fruit, unfavorable circumstances that cause water evaporation from them increase the percentage of Rutab fruit, implying that these treatments slowed enzymatic activities involved in fruit softening and senescence (Kader and Holcroft, 2018). As is generally known, the ripening process is a complex process in which numerous factors contribute to the fruit becoming inedible. Also, managing the ripening process begins with lowering the temperature, as low temperatures decrease respiration rate and ethylene generation, as well as enzyme activity (Novak, 2010).

Total acidity

The results of Table (4) show the effect of package type with and without EAS on the percentage of total acidity of 'Barhi' fruits that were stored at a temperature of 0 °C. At the start of the experiment, the total acidity of 'Barhi' fruit was 0.34%. With increasing storage time at 0 °C, all samples showed a decrease in total acidity. Because the acidity of dates is high in the stage of Khalal and begins to decline with the entry of the ripening stage, because of the high rate of respiration in fruits and the consumption of organic acids (Zahran *et al.*, 2015; Ramadan *et al.*, 2016; Batista-Silva *et al.*, 2018). It was evident that the interplay of treatments and storage duration had a substantial influence on 'Barhi' date acidity values. Therefore, the highest percentage of total acidity was found in the fruit packed in EMAP with EAS at 0°C, as it was recorded at 0.31, 0.28, 0.27, and 0.24% during 10, 20, 30, and 40 days, respectively. After 20 days of cold storage at 0°C, the lowest percentage of total acidity was found with fruit packed in cartons (control) with and without EAS (0.23%, each). The constant decrease in total acidity over the storage period indicated that the changes might be caused by both oxidative and non-oxidative processes (Aleid *et al.*, 2014). The organic acid content of date fruits diminished with storage time, as Taain (2005) reported that the fruit of the 'Barhi' had a reduction in total acidity from the second month of storage in both carton boxes and polyethylene plastic packages. The reason for this is that when the fruit matures, they consume a portion of the organic acids and convert them to sugars (Burton, 1982).

Moisture

Deterioration of quality is heavily influenced by moisture content. The moisture content of all 'Barhi' date fruit samples decreased gradually during storage (Table 5). Compared to the other treatments at each storage period, 'Barhi' dates that were packaged in EMAP with and without EAS at 0 ^{o}C revealed the highest significant ($p \leq 0.05$) content of moisture after 20 and 30 days of cold storage. After 40 days of cold storage under the same storage conditions, there was also an increase in the percentage of moisture but no significant differences between them. The moisture content of 'Barhi' dates in the fresh Khalal stage was high (64.67%) at the start of the picking and then gradually decreased as the maturity stages progressed, reaching 55.33% with LDPE bags at the end of the cold storage period. With EMAP bags, the moisture content of 'Barhi' dates had the same trend as LDPE, with a value equal to 57.00% with EAS and 56.67% without EAS at the end of the cold storage period. These results were in line with the results of Taain (2005); Awad *et al.* (2011); Selim *et al.* (2012); Aleid *et al.* (2014); Al-Saeid *et al.* (2015). Over a five-month period, the moisture content of date fruit bagged in white polythene reduced from 14.1% to 9.7% (Baloch *et al.*, 2006). Taain (2005) showed that the fruit packed in polyethylene packages is more efficient than the fruit packed in carton packages in terms of the moisture content of the fruit. This may be due to the role of polyethylene bags in reducing moisture loss from the fruit.

Total soluble solids

Total soluble solids (TSS) are a factor that has a strong relationship with sweetness, date flavor, and scent intensity. A gradual increase in total soluble solids (TSS) was observed as storage time progressed in all treatments (Table 6). The TSS of 'Barhi' fruit was measured to be 27.93% after harvest. The change in TSS percentage was slow in all treatments at 0 °C from zero to 40 days of cold storage (Table 6). Generally, the differences in the readings were very slight during 0, 10, 20, 30, and 40 days in all treatments. For instance, stored fruit in EMAP with EAS recorded values of 27.93, 28.00, 29.00, 29.33, and 30.67% at 0, 10, 20, 30, and 40 days, respectively. It was also found that the highest recorded value of TSS (31.67%) was with fruit packed in LDPE at 0 °C without EAS after 40 days of cold storage. Similar results were observed with control treatments only after 20 days of cold storage at 0 °C with and without EAS (30.00%, each). The conversion of some insoluble molecules into soluble compounds could be the cause of the increase in TSS (Al-Kahtani *et al*., 1998; Azelmat *et al*., 2005; Afoakwa and Sefa-Dedeh, 2021). The variation in TSS could be due to alterations in the cell wall and hydrolysis of complex carbohydrates by the activities of hydrolytic enzymes during the storage period (Kittur *et al*., 2001). Moreover, the increase in TSS during storage is due to water loss from the fruit, resulting in reduced moisture content. Similar findings were also noticed to decelerate the increase in TSS (Al-Redhaiman, 2005a and b; Mortazavi *et al*., 2007).

Total sugar

The packaging treatments and storage period had a significant impact on total sugar (TA) (Table 7). The gradual increase in TA values for LDPE and EMAP fruit was lower than those for control fruit over the cold storage period. The total sugar content of all investigated 'Barhi' date fruit samples was (20.02 g/100mg) at zero time of storage period, then increased over the storage period. For instance, control, LDPE, and EMAP treatments with EAS at 20 days of cold storage recorded values equal to 29.31, 28.09, and 21.33 g/100mg, respectively. The highest significant ($p \leq 0.05$) content (35.34 g/100mg) of total sugar was recorded in the fruit packed in cartons for 20 days at 0 °C without EAS. At the end of the cold storage period, LDPE also recorded the highest significant ($p \leq 0.05$) content (32.88 g/100mg) of total sugar after 40 days of storage period at 0 °C without EAS. These results agree with that reported by El-Hadidy *et al.* (2015), who reported that the total sugar increased in dates during cold storage. This increase indicates that the polysaccharide compounds in date fruit were hydrolyzed during storage. The results of this study agreed with the study of El-Dengawy *et al.* (2018) and Ramadan *et al.* (2020).

Reducing sugar

During the storage period, the reducing sugar in date fruit slowly increased (Table 8). The reducing sugar content of all investigated 'Barhi' date fruit samples was (15.02 g/100mg) at zero time at ambient temperature. The highest content of reducing sugar was recorded in the fruit packed in cartons at 0 °C without EAS after 20 days of cold storage (28.68 g/100mg). After 20 dyes more, LDPE with EAS recorded 27.95 g/100mg, while LDPE without EAS recorded 27.56 g/100mg.

Packages of EMAP had a similar trend to LDPE with slightly lower values. It was concluded that the 'Barhi' date fruit stored in LDPE bags with and without EAS at 0 °C had the lowest significant ($p \leq 0.05$) values in reducing sugars compared to the two other treatments after 20 days of cold storage. The hydrolysis of sucrose resulted in an increase in the concentration of reducing sugars. These results agree with those reported by Serrano *et al.* (2001); Selim *et al.* (2012); Ramadan *et al.* (2016); Ramadan *et al.* (2020).

Respiration rate

In Tables (9), the respiration rate was estimated based on the CO_2 concentration inside the different packages. Under all storage conditions, the respiration rate gradually decreased as time progressed. The highest respiration rate of fruit was recorded at 0 days of storage with a value equal to 0.186 nmol CO_2 kg^{-1} s^{-1}. Fruit packed in carton boxes (control) produced 0.040 nmol CO_2 kg^{-1} s^{-1} during 10 days of cold storage at 0 °C with and without EAS. These values were decreased in carton boxes after 20 days of cold storage, whether with or without EAS (0.29 nmol CO_2 kg^{-1} s^{-1}, each). After 30 and 40 days of cold storage, the stored fruit in EMAP at 0 °C with EAS recorded the lowest rates of respiration (0.006 nmol CO_2 kg^{-1} s^{-1}, each). During the same two-storage period, the respiration rate recorded the same values in the absence of EAS. Cold storage decreases the bioactivity of fruits, especially respiration rate and ethylene production, and reduces the growth of pathogens. These results agree with the results of El-Hadidy *et al.* (2015), who found that the respiration rate was decreased during the storage period, and this could be attributed to the modification in O_2 and CO_2 proportional inside the different packages as time progressed. The most common EMAP practice is to reduce the oxygen concentration to <1% and C_2H_4 production (Kader *et al.*, 1989; Paulsen *et al.*, 2019; Van de Vondel *et al.*, 2021). Also, accurate measurement of respiration rate is an important factor in the success of the design and operational features of MAP (Fonseca *et al.*, 2002).

Fibers

The fiber content of all investigated 'Barhi' date fruit samples was 1.96% at zero time under ambient temperature (Table 10). Fiber decreased slightly in all 'Barhi' dates during the storage period of 40 days. No significant differences have been detected with or without EAS after 10 days of the storage period in all treatments. The data showed that the lowest significant levels of the fiber were in the fruit packed in EMAP packages at 0 °C with or without EAS (1.89%, each) after 40 days of the storage period. These findings agree with Hui (2006), who found that the total fiber concentration decreases when the date fruit becomes soft at the Rutab stage. Enzymes gradually break down the polysaccharides into more soluble compounds, thus decreasing the fiber concentration and making fruit more tender and softer (Mrabet *et al.*, 2012).

Conclusion

This experiment showed the effectiveness of EMAP and LDPE for the purpose of extending the cold storage period of date palm (cv. Barhi) since the two types of bags gave higher quality properties in all treatments compared to carton boxes, which lasted only for 20 days of cold storage, after which the quality of dates quickly decreased. EMAP bags are eco-friendly bags that are more effective, reasonable, and sustainable for improving the quality of 'Barhi' date fruit at the Khalal Stage. Moreover, EMAP with an ethylene absorbent sachet under a temperature of 0 °C gave the highest quality properties after 40 days of cold storage. Therefore, EMAP bags could be recommended with ethylene absorbent to improve the quality of 'Barhi' date fruit at the Khalal Stage. LDPE with EAS may be a more cost-effective alternative to EMAP bags for this application.

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Tables

Table 1
Changes in weight loss (%) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	0.00	a	0.00	a
	LDPE	0.00	a	0.00	a
	EMAP	0.00	a	0.00	a
10	Control	59.62	a	59.84	a
	LDPE	0.13	b	0.17	b
	EMAP	0.03	b	0.07	b
20	Control	65.33	a	67.10	a
	LDPE	0.43	b	0.45	b
	EMAP	0.27	b	0.41	b
30	Control	ND		ND	
	LDPE	0.87	a	0.87	a
	EMAP	0.50	ab	0.53	ab
40	Control	ND		ND	
	LDPE	2.33	a	2.46	a
	EMAP	1.26	ab	1.87	a

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 2
Changes in Texture (N/cm^2) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	21.63	a	21.63	a
	LDPE	21.63	a	21.63	a
	EMAP	21.63	a	21.63	a
10	Control	16.48	a	16.81	a
	LDPE	19.91	a	19.84	a
	EMAP	20.75	a	20.52	a
20	Control	7.14	b	6.48	b
	LDPE	18.34	a	18.22	a
	EMAP	18.70	a	17.94	a
30	Control	ND		ND	
	LDPE	15.11	a	15.07	a
	EMAP	16.69	a	16.03	a
40	Control	ND		ND	
	LDPE	11.29	a	11.13	a
	EMAP	14.70	a	13.40	a

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 3
Changes in rutab (%) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	0.00	a	0.00	a
	LDPE	0.00	a	0.00	a
	EMAP	0.00	a	0.00	a
10	Control	43.33	a	45.00	a
	LDPE	0.00	b	0.00	b
	EMAP	0.00	b	0.00	b
20	Control	63.33	a	66.67	a
	LDPE	0.00	b	0.00	b
	EMAP	0.00	b	0.00	b
30	Control	ND		ND	
	LDPE	0.00	c	0.00	c
	EMAP	4.00	b	5.00	a
40	Control	ND		ND	
	LDPE	15.00	b	20.00	a
	EMAP	10.00	c	11.33	c

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 4
Changes in acidity (%) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	0.34	a	0.34	a
	LDPE	0.34	a	0.34	a
	EMAP	0.34	a	0.34	a
10	Control	0.26	b	0.25	b
	LDPE	0.34	a	0.34	a
	EMAP	0.31	a	0.31	a
20	Control	0.23	b	0.23	b
	LDPE	0.31	a	0.30	a
	EMAP	0.28	a	0.28	a
30	Control	ND		ND	
	LDPE	0.30	a	0.29	ab
	EMAP	0.27	b	0.27	b
40	Control	ND		ND	
	LDPE	0.24	a	0.24	a
	EMAP	0.24	a	0.24	a

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 5
Changes in moisture (%) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	64.67	a	64.67	a
	LDPE	64.67	a	64.67	a
	EMAP	64.67	a	64.67	a
10	Control	60.67	a	61.33	a
	LDPE	61.00	a	61.00	a
	EMAP	63.00	a	62.33	ab
20	Control	56.00	c	56.00	c
	LDPE	58.67	b	58.33	b
	EMAP	60.33	a	60.33	a
30	Control	ND		ND	
	LDPE	57.00	b	56.67	b

	EMAP	58.67	a	58.33	a
40	Control	ND		ND	
	LDPE	55.33	a	55.33	a
	EMAP	57.00	a	56.67	a

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 6
Changes in TSS (%) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	27.93	a	27.93	a
	LDPE	27.93	a	27.93	a
	EMAP	27.93	a	27.93	a
10	Control	29.67	a	29.67	a
	LDPE	28.00	b	28.00	b
	EMAP	28.00	b	28.00	b
20	Control	30.00	a	30.00	a
	LDPE	29.00	b	29.00	b
	EMAP	29.00	b	29.33	ab
30	Control	ND		ND	
	LDPE	29.67	a	30.00	a
	EMAP	29.33	a	29.53	a
40	Control	ND		ND	
	LDPE	31.33	a	31.67	a
	EMAP	30.67	a	30.87	a

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 7
Changes in total sugar (g/100mg) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	20.02	a	20.02	a
	LDPE	20.02	a	20.02	a
	EMAP	20.02	a	20.02	a
10	Control	22.69	b	23.67	a
	LDPE	21.59	c	21.37	c
	EMAP	20.49	d	20.54	d
20	Control	29.31	b	35.34	a

	LDPE	28.09	b	28.84	b
	EMAP	21.33	c	21.38	c
30	Control	ND		ND	
	LDPE	28.17	b	29.51	a
	EMAP	24.82	c	24.87	c
40	Control	ND		ND	
	LDPE	31.79	b	32.88	a
	EMAP	27.44	d	28.45	c

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 8
Changes in reducing sugar (g/100mg) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	15.02	a	15.02	a
	LDPE	15.02	a	15.02	a
	EMAP	15.02	a	15.02	a
10	Control	17.27	a	17.11	a
	LDPE	16.49	a	16.54	a
	EMAP	17.01	a	17.08	a
20	Control	26.37	a	28.68	a
	LDPE	16.62	b	16.67	b
	EMAP	24.02	a	24.03	a
30	Control	ND		ND	
	LDPE	26.51	a	26.56	a
	EMAP	24.40	b	24.45	b
40	Control	ND		ND	
	LDPE	27.95	a	27.56	a
	EMAP	27.51	a	27.61	a

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 9
Changes in respiration rate of Barhi dates packed in different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	0.186	a	0.186	a
	LDPE	0.186	a	0.186	a

	EMAP	0.186	a	0.186	a
10	Control	0.040	a	0.040	a
	LDPE	0.022	bc	0.026	b
	EMAP	0.014	d	0.018	cd
20	Control	0.029	a	0.029	a
	LDPE	0.013	bc	0.013	b
	EMAP	0.009	c	0.011	bc
30	Control	ND		ND	
	LDPE	0.008	bc	0.009	a
	EMAP	0.006	c	0.006	cd
40	Control	ND		ND	
	LDPE	0.007	b	0.008	a
	EMAP	0.006	d	0.006	c

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.

Table 10
Changes in fiber (%) of packed Barhi dates using different materials with and without ethylene absorbent sachets (EAS) during cold storage at 0 °C

Storage period (d)	Treatment	Ethylene absorbent sachets (EAS)			
		With		Without	
0	Control	1.96	a	1.96	a
	LDPE	1.96	a	1.96	a
	EMAP	1.96	a	1.96	a
10	Control	1.96	a	1.98	a
	LDPE	1.95	a	1.89	a
	EMAP	1.97	a	1.95	a
40	Control	ND		ND	
	LDPE	1.96	a	1.93	b
	EMAP	1.89	c	1.89	c

For each storage period, means of interaction (Treatment × EAS) followed by the same letter are not significantly different at $P \leq 0.05$, according to Duncan´s test. ND means no data.