Misan Journal of Agricultural and Environmental Sciences

ARTICLE

The effect of transpiration inhibitors on the storability of dates as a step towards sustainable food security

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ABSTRACT

The study was conducted on Barhi date palm fruits from the 2024 season, collected from an orchard in the Abu Al-Khasib area, south of Basra. The fruits were treated with an evaporation inhibitor (Vapor Gard, abbreviated as V.G.) by dipping them in the product at the beginning of the Rutab (ripe) stage at concentrations of 2% and 4%, in addition to a control treatment (distilled water only). The fruits were then packed in 1 kg transparent polyethylene containers and stored at a temperature of -3 ± 1°C. A completely randomized design was used for a two-factor experiment: treatments (three levels) and storage duration (four levels). The difference between the means was tested using the Least Significant Difference (LSD) test at a significance level of 5%. The results showed that the treatment with V.G. concentration (4) % was superior in reducing the percentage of weight loss, reducing the percentage of spoilage, and the lowest percentage of total soluble solids, with a significant difference compared to the comparison treatment, and it was not significantly different from the treatment with V.G. concentration 2%.

Keywords: *Evaporation inhibitors; Prim; Storage Capacity; Weight loss; Total Soluble Solids*.

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Citation Hachim, A. J., Jasem, F. M., & Abdullah, N. A. (2026). The effect of transpiration inhibitors on the storability of dates as a step towards sustainable food security. ***Misan Journal of Agricultural and Environmental Sciences***, ***26***(**2**): **90-98.** https://doi.org/10.64333/MJAE.26.2.9
Received: 11/05/2026
Accepted: 27/06/2026
Published: 30/06/2026
DOI: https://doi.org/10.64333/MJAE.26.2.9

INTRODUCTION

The date palm (*Phoenix dactylifera* L.) belongs to the palm family Arecaceae, which includes various palm species, the most important of which is the date palm. Date palms are widely cultivated in tropical, subtropical, and subtropical regions of the world. Iraq has more than 600 varieties of date palms, many of which are distinguished by their high-quality fruit, making them an important food and economic resource (Al-Bakr, 1972). Cooled storage of date palm fruits is an important method used today to try to keep the fruit in the Rutab (semi-ripe) stage for as long as possible, thus extending the period during which the fruit can be sold in local markets at this stage. Cooled storage reduces the fruit's biological activities, especially respiration and ethylene production, and also limits the growth of pathogens (Desouki *el al*., 2001). Fruits are essential nutrients in our daily diet, but they are also highly perishable. After harvesting, fruits don't cease to live; they continue their vital processes such as respiration and transpiration (water loss in the form of vapor). This continuous water loss leads to fruit wilting, weight loss and a decline in their market and nutritional value. Therefore, antitranspirants have emerged as a modern and effective technique for preserving fruit quality and extending its shelf life. Anti-transpirant agents have been used as treatments to reduce water loss in fruits or to decrease transpiration from treated vegetative parts (Abdul Qader, 1990). Hamoud and Mawloud (1988) treated date palm fruits of the Jebchab variety with Vapor Gard at a concentration of 4% and observed an increase in the weight and size of the treated fruits, an increase in their moisture content, and a decrease in the percentage of total soluble solids and total sugars. Abdul Jabbar *el al*. (2009) also indicated the role of Vapor Gard wax treatment in reducing weight loss and spoilage in local pomegranate fruits, and their results were consistent with those of Al-Muhammadi *el al*. (2010) regarding local orange fruits. Fruits differ in their behavior during storage, as they are affected by the variety, climatic conditions, and agricultural practices before and after harvesting. All these factors are reflected in their impact on the length of time the fruits remain in storage (Benjamin *el al*., 1985). Ta'een *el al*. (2014) The study found that weight loss, spoilage percentage, total soluble solids, and quantitative and reducing sugars increased with increasing storage time, while sucrose and neutralizable quantitative acidity decreased with increasing storage time. The treatment with Vapor Gard (2.5%) was superior in reducing fruit weight loss, while the highest weight loss was observed in the control fruits. The highest spoilage percentage was found in untreated fruits compared to those treated with Vapor Gard and Relief Stress. The highest percentages of soluble solids, quantitative and reducing sugars, and the lowest percentage of total acidity were also found in untreated fruits. The lowest percentages of soluble solids, total sugars, and reducing sugars were found in fruits treated with Vapor Gard (2.5%), with a non-significant difference compared to those treated with Vapor Gard (2%). The effect of the two treatment methods was not significant on the studied traits, except for the spoilage percentage, which increased significantly with the treatment method. When applied by dipping, the Vapor Gard 2.5% dipping treatment resulted in less weight loss, but this difference was not statistically significant compared to the spray application. Hassan *el al*. (2024) observed that treatment with the VaporGard 3.5% antitranspirant significantly reduced the overall spoilage rate in cucumber fruits. The lowest spoilage rate (0.96%) was observed in fruits treated with the 3.5% antitranspirant, while the highest spoilage rate (11.1%) was recorded in the control group. They also noted a clear effect of storage duration, observing that the overall spoilage rate increased with longer storage periods, reaching 2.59% for cucumber fruits after four weeks of storage. This may be attributed to the accelerated ripening process and the attack of certain fungi. Hassan *el al*. (2024) confirmed that treatment with the VaporGard 3.5% antitranspirant had a significant effect. In reducing the percentage of weight loss of fruits of three varieties of cucumber, the lowest percentage was (3.71%) for fruits treated with the anti-transpirant Vapor Gard concentration of (3.5%), while the highest percentage of weight loss was (4.07%) for fruits treated with the control treatment.

Study Objectives:

1- To improve the storage capacity of Barhi date palm fruits at the Rutab (semi-ripe) stage.

2-To understand the fruit's behavior during storage after treatment with the evaporation inhibitor Vapor Gard (post-harvest).

3- To extend the storage period of the fruit for the longest possible time.

MATERIALS AND METHODS

The Transpiration inhibitors are chemical or natural compounds applied to plants or fruits to reduce water loss through transpiration. In the post-harvest stage, they are typically applied by spraying or dipping to form a thin film on the fruit's surface. These inhibitors are generally divided into:

1-Film-forming inhibitors: These form a physical barrier on the fruit's surface (such as natural waxes, oils, and biopolymers).

2-Physiological inhibitors: These affect stomatal closure (less commonly used post-harvest and more often applied to trees before harvest).

Mechanism of Action of Transpiration Inhibitors on Stored Fruits

Transpiration inhibitors (especially film-forming ones) act as a semi-permeable barrier covering the fruit, and their positive effects are evident in several key aspects:

1-Reducing Water Loss (Weight Loss).

Water constitutes the largest percentage of fruit weight (sometimes exceeding 85%). Evaporation of this water leads to skin shrinkage and loss of freshness and fruit quality. Antitranspirants partially seal the stomata and micropores in the fruit peel, significantly reducing the rate of evaporation and maintaining the fruit's firmness and weight for a longer period.

2-Modifying the Respiration Rate (Modified Atmosphere Effect): The thin layer formed by antitranspirants acts as a regulator of gas exchange; it reduces the entry of oxygen (O_2) into the fruit and limits the exit of carbon dioxide (CO_2). This creates a semi-modified environment inside the fruit, similar to modified atmosphere packaging, which slows down cellular respiration, delays the breakdown of sugars and organic acids, and postpones the fruit's biological aging.

3-Delaying Ethylene Production and Fruit Ripening: Ethylene is the hormone responsible for fruit ripening (especially climacteric fruits such as bananas, apples, and tomatoes). Reducing oxygen levels inside the fruit by antitranspirants inhibits the production of this gas, thus delaying the processes of softening, discoloration, and pectin breakdown.

4- Preserving Nutritional and Aesthetic Components

By reducing metabolic processes, antitranspirants help maintain the overall acidity and sugar levels, preventing the deterioration of oxidation-sensitive vitamins such as vitamin C. They also keep fruits shiny and attractive (a cosmetic and marketing effect).

5-Reducing Disease Susceptibility

Biocoatings used as antitranspirants can sometimes be enhanced with antimicrobial agents (such as chitosan or essential oils), preventing fungal and bacterial penetration of the fruit surface and reducing mold growth during storage.

Modern Trends: Natural Antitranspirants (Edible Coatings).

Previously, there was a heavy reliance on commercial waxes derived from petroleum. However, with increased environmental and health awareness, science is now moving towards edible coatings as a 100% natural and safe option. Among the most prominent are:

1-Chitosan: Extracted from crustacean shells, it has excellent antitranspirant and antifungal properties.

2- Aloe Vera gel: Aloe vera gel has proven highly effective in extending the shelf life of grapes and cherries.

3-Arabic Gum and VaporGard: and other natural extracts.

4-Starch, cellulose, and protein components: natural polymers that form excellent moisture-retaining films.

Challenges and Precautions Despite their significant benefits, antitranspirants must be applied with extreme caution. If the barrier layer is too thick, it may completely block oxygen penetration, forcing the fruit into anaerobic respiration (fermentation). This anaerobic respiration leads to the production of alcohol and acetaldehyde, causing unpleasant flavors and odors, and rapid spoilage. Therefore, selecting the appropriate concentration and type of antitranspirant based on the fruit species is crucial for success. Antitranspirants are a promising biotechnological tool in the handling and storage of post-harvest fruit. By controlling transpiration and respiration rates, these substances offer an economical and environmentally sound solution that reduces significant food waste and ensures that fruit reaches the consumer with high quality, excellent flavor, and full nutritional value, even after extended storage or shipping periods.

The Physiological and Technological Impact of Antitranspirants on Fruit Storage Efficiency.

The post-harvest stage is one of the most critical in food supply chains, where many fruits lose up to 30-40% of their market value before reaching the consumer due to spoilage and wilting. Transpiration is the primarycause of weight and firmness loss, hence the importance of antitranspirants as a key technology for modifying fruit physiology and extending shelf life.

1- ***Deep Physiology: How Transpiration Inhibitors Affect Fruit Vitality***.

To understand the effect of these substances, we must consider the fruit as a living organism that continues to "degrade" after being separated from the parent tree:

A- Gas Exchange Dynamics and Selective Permeability Theory. The goal of applying membrane-based transpiration inhibitors is not to completely isolate the fruit, but rather to create a barrier with selective permeability. This means that water vapor is largely restricted from escaping because its molecules rely on free diffusion through pores and lenticels, and the coating seals these openings Similarly, the membrane allows very limited passage of the gases O_2 and CO_2. This restriction alters the fruit's internal atmosphere, increasing CO_2 concentration and decreasing O_2 concentration.

B- Inhibition of Cellular Respiration: Fruits respire by oxidizing sugars to produce energy, according to the following simplified equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy. When antitranspirants reduce internal O_2 levels, they slow down the rate of these chemical reactions (respiration rate). This slowdown preserves the fruit's stores of sugars and organic acids (such as malic and citric acids) that give the fruit its distinctive flavor.

C- Dominance of the Aging Hormone (Ethylene): The synthesis of ethylene gas (C_2H_4) requires oxygen as an essential cofactor in the final enzymatic steps (conversion of ACC to ethylene). By reducing O_2 levels, the antitranspirant membrane inhibits this physiological cycle, thus delaying the hormonal signals that drive the fruit toward softening and decomposition.

2- ***Effect on fruit quality during refrigerated storage***

The application of antitranspirants directly affects the physical and chemical characteristics of the fruit during its time in cold storage:

A- Maintaining Firmness and Gummability: The cell walls of fruit are broken down by enzymes such as pectin methyl esterase (PME) and polygalacturonase (PG). These enzymes become more active as the fruit ripens and respiration increases. Antitranspirants, by slowing down ripening, preserve pectin bonds; thus, the fruit remains crisp and firm and does not become "mealy" or soft.

B- Preventing Chilling Injury: Some tropical fruits (such as bananas and mangoes) suffer from black spots or tissue damage when stored at low temperatures. The protective membranes of antitranspirants act as a thermal and mechanical insulating layer, reducing the chilling shock to the surface tissues.

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RESULTS AND DISCUSSION

1. Weight Loss (%)

Table (1) shows that weight loss increases with the storage period, reaching (5.39%) after four months of storage. The table also shows significant differences between the treatments in their effect on weight loss. The 4% VG treatment significantly reduced weight loss to 0.75%, but this was not significantly different from the 2% VG treatment. The highest percentage of weight loss was observed in the control group, reaching 4.50%. Regarding the interaction between treatments and storage duration, the table shows that the 4% VG treatment experienced weight loss only in the fourth month of storage (2.53%), a significant difference compared to the 2% VG treatment after four months and the control group. The highest weight loss was observed in the control group after four months of storage (10.22%).

Weight loss can occur due to the depletion of the fruit's nutrient reserves through respiration or other processes. Regarding the loss of water content, fruits lose water through evaporation from their surface, and some is lost through respiration. This loss can be compensated for when the fruits are still attached to the parent plant. However, after harvesting, a significant water loss occurs, leading to wilting, shriveling, and a substantial weight reduction (Al-Ani, 1985; Shirokov, 1988). The weight loss that occurs with increasing storage time may be attributed to the loss of water content in the fruits over time, in addition to the depletion of the fruit's nutritional reserves due to respiration.

These results are consistent with Al-Barrak's (2009) findings for the Braim and Hilali date palm varieties. He observed that the percentage of weight loss in the fruits increases with the storage period. The percentage of weight loss in Braim fruits reached 29.85% after 20 weeks of storage, while the highest percentage of weight loss in Hilali

fruits reached 33.25% after 16 weeks of storage.The superiority of the treated fruits The use of V.G. in reducing weight loss indicates the role of this substance as an anti-evaporation agent in reducing the loss of water content in fruits (Al-Ani, 1985). The wax forms a thin layer on the fruit surface, partially closing the stomata and thus reducing water loss. It also reduces the respiration rate, which is important in reducing weight loss (Mitra, 1997). This result is consistent with Shakir (1998), who observed that the Zahdi date palm fruits treated with V.G. experienced less water loss, with loss beginning after the third month, compared to untreated fruits where water loss occurred in the first month and continued throughout the storage period. It is also consistent with Abdul-Jabbar *el al*. (2009) regarding local pomegranates and with Al-Muhammadi *el al*. (2010) regarding local oranges.

Table (1) Effect of V.G. treatment, storage period, and their interaction on weight loss (%) of Braim date palm fruits at the Rutab stage

Treatment	Storage Period (Month)				Effect of Treatment
	1	2	3	4	
Control	0.33	1.3	6.15	10.22	4.50
V.G.(% 2)	0	0	0.56	3.41	0.99
V.G.(% 4)	0	0	0.46	2.55	0.75
Effect of Storage Period	0.11	0.43	2.051	5.39	

R.L.S.D. 0.05		
Treatment	Storage Period	Treatment× Storage Period
0.27	2.05	0.91

2-Percentage of Spoilage (%)

Table (2) is shows that the percentage of spoilage increased slightly with the continuation of the storage period, and that the fruit did not show signs of spoilage until the third month of storage. The table also shows that the highest percentage of spoilage was in the control group, at (2.26%), a significant difference compared to the other treatments.

The results in the same table also indicate significant differences between the treatments in their effect on the percentage of spoilage. The treatment with 4% V.G. significantly reduced the percentage of spoilage to 0.25%, but it did not differ significantly from the treatment with 2% V.G. The highest percentage of spoilage was in the control treatment, reaching 1.83%. Regarding the interaction between treatments and storage duration, the highest percentage of spoilage was in the control treatment after four months of storage, reaching 4.18%, a significant difference from the other treatments.

Fruits are susceptible to spoilage both before and after storage, which is one of the most serious problems they face after harvest. This spoilage may result from mechanical and physiological damage, as well as microbial infection. The reason for increased spoilage with prolonged storage may be due to the attack of pathogens (bacteria, fungi, and yeasts) on the fruit during storage. (Dementeva and Vegonski, 1988) The reason for the lower spoilage rate in treated fruits compared to untreated fruits may be attributed to the role of the evaporation inhibitor (V.G.) in reducing water loss in the treated fruits and decreasing respiration, thus delaying fruit senescence and reducing spoilage (Al-Ani, 1985). Additionally, these treatments provide a balance of oxygen, carbon dioxide, and ethylene within and around the fruit, and this balance reduces spoilage (Ben-Yehoshua, 1985). They also form a protective layer on the fruit surface that prevents or reduces attack by pathogens, especially fungi. These results are consistent with the findings of several studies conducted on the fruits of the Barhi date palm variety and other varieties. In a study conducted by Benjamin *el al*. (1984) on a number of date palm varieties, they found that the fruits of some varieties, such as Maktoom, Barhi, Qaitaz, Shuwaithi, and Sayer, are susceptible to rot and fermentation. The percentage of damaged fruit in the Qaitaz variety was 100%, followed by Al-Shuwaithi (99%) and Al-Maktoum (91%), while no damaged fruit was found in the Khastawi, Zahdi, and Ahmar Badhinjani varieties throughout the refrigerated storage period.

Shabana and Al-Khaldi (1988) studied the effect of refrigerated storage (-3 ± 1°C) on the fruit of the Saada, Barhi, Anbari, Khasab, Khadrawi, Hadal, Silani, Farsi Ahmar, Braim, and Shukr varieties on the percentage of damaged fruit. They found that the Anbari, Khasab, and Khadrawi varieties showed fungal infections during the five-month storage period, while the Barhi, Hadal, and Shukr varieties suffered from phlociform infections such as peel separation from the fruit flesh. In some cases, peel wrinkling appeared, as in the Saada and Silani varieties, while no infection was found in the Braim and Farsi Ahmar varieties.

And between Al-Issawi (2004) found that a storage temperature of -3 ± 1°C reduced the percentage of damaged fruit to 0.27%, a significant difference compared to 0°C, where the percentage of damage increased to 1.28%. Al-Barrak (2009) indicated an increase in the percentage of damaged fruit for the Braim and Hilali varieties with increasing storage duration. He also noted that a storage temperature of 0°C significantly reduced the percentage of damage to 6.78% for the Braim variety and 8.37% for the Hilali variety by the end of the storage period. Al-Amiri (2010) stated that the percentage of damaged fruit for the Halawi and Sayir varieties increased with increasing storage duration, reaching 42.78% and 46.11% for the two varieties, respectively, after six weeks of storage.

Table (2) Effect of V.G. treatment, storage duration, and their interaction on the percentage of damaged fruit (%) for Braim date varieties at the storage stage Moist

Treatment	Storage Period (Month)				Effect of Treatment
	1	2	3	4	
Control	0	0	3.12	4.22	1.83
V.G.(%2)	0	0	0	1.55	0.38
V.G.(%4)	0	0	0	1.02	0.25
Effect of Storage Period	0	0	1.04	2.26	

R.L.S.D. 0.05		
Treatment	Storage Period	Treatment × Storage Period
1.05	0.87	0.55

3-Total Dissolved Solids (%)

Table (3) shows that the percentage of total dissolved solids increased with the storage period, reaching (61.72%) after four months of storage. This is likely due to the continued water loss from the fruit and the ongoing ripening process.

The same table also shows that the highest percentage of total dissolved solids was found in the control group, significantly higher than the other treatments (57.88%), while the lowest percentage was found in the V.G. treatment. (4)%, with an insignificant difference compared to the treatment with (V.G.) at a concentration of (2%), and a significant difference compared to the other treatments. This indicates the role of the (V.G.) treatment in reducing the loss of water content in the fruits, which negatively impacted their total soluble solids content (Burton, 1982; Miller, 1979).

From studying the interaction between treatments and storage duration, we find that the highest percentage of total soluble solids was recorded in the fruits of the control treatment after four months of storage, with an insignificant difference compared to the fruits of the same treatment after three months and after two months of storage. The (4) % percentage was recorded in the fruits of the treatment after four months of storage and was significant compared to the other treatments.

Soluble solids are a measure of the nutritional value of fruits and include the fruit's sugar, amino acid, and organic acid content. Sugars constitute the largest part of total soluble solids. Studies have shown that the percentage of total soluble solids is low in the early stages of fruit growth and then increases slowly until the end of the physiological ripening stage (khalal). During the final ripening stage (Rutab), there is a rapid increase in the percentage of total soluble solids in the fruit, and this accumulation continues until the tamar stage (Tafti and Fooladi, 2006; 1995; Jassim *el al*., and Abdul Wahid, 1997). Storage experiments with different date palm varieties have shown that soluble solids in the fruit increase with the storage period. This is mainly due to water evaporation from the fruit, in addition to the fruit's progression through ripening. It is known that date palms are climacteric fruits, and the accumulation of soluble solids increases during ripening (Benjamin *el al*., 1985; Yousef and Abu Ali, 1993; Ta'een, 1997; Ta'een, 2005; Al-Barrak, 2009; and Al-Amiri, 2010).

Some studies using evaporation inhibitors have indicated the effectiveness of these substances in reducing the loss of water content in the treated fruit, thus reducing the loss in fruit quality. The fruit and the reduction in weight loss, in addition to the decrease in its solids content compared to untreated fruit, because, as is known, there is an inverse relationship between the concentration of cell juice and the water content of the fruit (Hamoud and Mawloud, 1988, and Shakir, 1998).

Table (3) Effect of treatment with (V.G.), storage duration, and the interaction between them on the percentage of total soluble solids (%) of Braim date palm fruits at the Rutab stage

Treatment	Before storage	Storage Period (Month)				Effect of Treatment
		1	2	3	4	
Control	48.55	49.90	56.15	59.95	65.55	57.88
V.G.%(2)	48.55	46.00	48.80	53.85	59.60	52.06
V.G.%(4)	48.55	44.90	48.80	53.40	59.15	51.56
Effect of Storage Period		46.93	51.25	55.73	61.72	

R.L.S.D. 0.05		
Treatment	Storage Period	Treatment × Storage Period
3.33	3.33	10.29

CONCLUSIONS

The results showed that the 4% V.G. treatment was superior in reducing weight loss and the percentage of spoilage, giving it the lowest percentage of total soluble solids in the fruit. Also, the Fruit quality was improved in fruit treated with V.G. at both 2% and 4% concentrations. The storage period of fruit treated with V.G. at both 2% and 4% concentrations was extended compared to the control. We recommend using V.G. for coating other date varieties and other types of fruits and vegetables. Also, we recommend using other types of natural coatings such as chitosan and aloe vera.

Disclaimer: None

Conflict of interest: The authors declare that they have no relevant financial or non-financial interest to disclose.

Funding disclosure: None

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