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Research Article

Date package and storage conditions play a key role in controlling *Plodia interpunctella* and *Oryzaephilus surinamensis* and preserving date quality

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Abstract: Piarom is considered as one of the most important semi-dried date fruits in Iran which has been highly affected by stored pests. The current study was aimed to evaluate the effects of the modified atmosphere packaging (MAP) and vacuum packaging (VAP) methods on storage pests control and date quality. To do so, Piarom variety were packaged in two package systems, including passive modified atmosphere and vacuum package system. The control samples were kept unpackaged. The packages were kept under two different storage conditions; at 4 °C and 55 ± 10% RH, and 25-27 °C and 70 ± 5% RH for 30, 60, 90 and 150 days. The experiment was carried out based on a completely randomized design arranged in factorial with four replicates. The results showed that Indian meal moth *Plodia interpunctella* (Hübner) and sawtoothed grain beetle *Oryzaephilus surinamensis* (L.) are the most important storage pests with 87.5 and 12.5% contamination, respectively. The passive MAP and VAP reduced the pests infestation rate significantly compared to control. Also, they could better preserve pH (5.88 and 5.85 for MAP and VAP, respectively) than the control (5.78). Changes in water activity in MAP and VAP were almost the same at the two storage conditions *i.e.,* ambient and at 4 °C and was significantly different from the control. The maximum water activity change was observed in control treatment.

Keywords: Date palm, Modified atmosphere, Storage pests, MAP, VAP

Introduction

Dried and semi-dried date fruits such as Piarom are among the export products of the Hormozagan Province (Iran). The Piarom date fruits production has been reported as over 7000 ton per annum (Mohammadpour and Tajeddin, 2017). Insects are the most important factors in reducing dried date quality (Mohammadpour and Karampour, 2009).

The MAP method is the practice of modifying the composition of the internal atmosphere of a package in order to improve the shelf life (Ooraikul and Stiles, 1991). The modification process often relies on lowering the amount of oxygen. Passive MAP is defined as achieving a good balance of the atmosphere on the basis of product breathability and permeability characteristics of packaging. In

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fact, the atmosphere is inactive due to the consumption of oxygen and the production of carbon dioxide during the respiration process. On the other hand, the modified air system is activated by removing ordinary air from the package and generating vacuum and replacing it quickly with a gas mixture instead. In active MAP oxygen can be replaced with nitrogen or carbon dioxide, which can inhibit the growth of bacteria (Ooraikul and Stiles, 1991). The MAP in Iran has been studied by many researchers (Mohammadpour and Tajeddin, 2017; Mortazavi *et al.,* 2007; Karami *et al.,* 2010; Deghanshoar *et al.,* 2008). The effect of passive MAP and VAP on storing Kharak date at 4 °C have been studied by Mortazavi *et al.,* (2007). They found that MAP could effectively reduce fruit weight loss and softening rate whereas VAP just reduced fruit weight loss percentage and wrinkled fruits percentage and failed to reduce softening rate. In a study, the effect of ethylene absorbing pads in MAP method was compared with passive MAP using polyethylene bags at 5 and 15 °C. The results indicated that using ethylene absorbing pads in MAP method, significantly decreased fruit weight loss and softening rate. In addition, passive MAP caused minimal change in qualitative characteristics. Moreover, 5 °C was more effective than 15 °C in preserving fruit quality (Karami *et al.,* 2010). Achour *et al.* (2003) have stated that more moisture was lost in control treatment (ordinary packing) than that in MAP or VAP packing. Furthermore, VAP method at 20 °C increased fruit shelf life from 3.8 months in control treatment to 9 months. The efficiency of MAP method has been also studied by Deghanshoar *et al*. (2008) who found that the MAP could preserve well date fruits quality and prevent stored pests activity compared with cool storage and freezing. In another study, Navarro *et al*. (1998) showed that MAP was more efficient in terms of controlling stored pests activity than the control.

The permeability of packing materials and air composition during storing determine product's shelf-life (Ooraikul and Stiles, 1991). Due to the product's dynamism and also due to many factors that cause changes in the product, it is very difficult to maintain the composition of air at the optimal level, which will prolong its shelf-life. When MAP method is practiced, the level and proportion of gases can be adjusted only by choosing correct packing material with specific permeability characteristic. In MAP method flexible films with varying degrees of permeability to gases and water vapor are used (Ooraikul and Stiles, 1991).

The current study was aimed to evaluate the effects of the modified atmosphere packaging (MAP) and vacuum packaging (VAP) methods on date fruit quality and storage pest control.

Materials and Methods

The date fruits were prepared from two main Piarom producing regions of Hormozgan province including Hajiabad and Tarom. As it was assumed the two regions might be different in terms of infestation rate, the infestation rate was determined in the purchased date fruits and to mitigate the effect of sampling site on infestation rate, the fruits were mixed before implementing the experiment.

Treatments: 30 healthy and uniform dates were put in each plastic bag. In this experiment, semi-dried date fruits (Piarom variety) were packaged using two methods; passive MAP and VAP. The control sample was kept unpackaged. Five-layer polyethylene bags, 80 microns thick, were used to pack the samples. A vacuum machine was used to create a vacuum (Model DZQ Italy).

Sample storage: The packs were stored under two different conditions: at 4 °C and 55 ± 10% RH) and ambient temperature (25-27 °C 70 ± 5% RH) for 30, 60, 90 and 150 days. At the end of each period, the samples were taken out and examined. The number of infested fruits, pH, water activity and fruit color were evaluated before and after treating and storing. The live larvae and pupae were kept up to adult emergence to be identified.

A pH meter device (Metrohm: Swiss) was used to measure acidity of the treated date fruits. The Brix and water activity were measured using refractometric (GHD: Japan) and water activity

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Measuring devices (Model: FA-st lab: Italy), respectively. To study fruit color in the current study, we used a scanner device (HP Scanjet G4010: Canada) for scanning the date fruit images. To do so, the color coordinates of the images were extracted using Image J software V. 1.40g (Fengxia *et al.,* 2001).

The images of date fruits were taken using a scanner. The scanner was covered carefully by a thick and black cloth to prevent any disturbing light which might lower image quality. The color coordinates of the images were extracted in Lab color space using Image j V. 1.40g. The total color difference (TCD) was determined based on changes in the color components (a, L, and b) of the treated dates compared with the fresh samples (l_0 = 23.23, b_0 = 27.7, a_0 = -0.385), calculated according to the following equation:

$$TCD = \sqrt{\left((l_0 - l)^2 + (a_0 - a)^2 + (b_0 - b)^2\right)}$$

Statistical analysis: The experiment was laid out based on a completely randomized design arranged in factorial with four replicates. The first factor was packaging method (at three levels MAP, VAP and control), the second factor was storage temperature and the third factor was storage period. One way analysis of variance (ANOVA) was used to test significant differences between treatments and then means were separated by least significant difference (LSD) test. Statistical analysis was performed by SAS version 9.1.3 (SAS Institute, 1985).

Results and Discussion

The results of qualitative traits in fresh fruits (at the beginning of storage) are presented in Table 1.

Table 1 Fresh fruits' qualitative traits (at the beginning of storing).

Sampling sites	pH	Water activity	Brix (%)	Color (a, b, l)
Hajiabad	6.36	0.567	64	13.98, 18.52, 31.59
Tarom	6.14	0.545	65.2	9, 11.67, 28.86

a: the red/green coordinate; b: the yellow/blue coordinate; l: lightness.

Storage pest's contamination

Since there was no significant differences between the regions in terms of contamination severity before treatment (Table 2), the effect of contamination was not considered as correction coefficient. However, the same number of replicates from each treatment was performed with samples from the two regions, so that each replicate consisted of same number of samples provided from both regions.

Table 2 Status of date infestation, in both sampling sites before packaging, with *Plodia interpunctella* and *Oryzaephilus surinamensis*.

Sampling sites	No. of tested fruits	No. of infested fruits	No. of infested fruits with alive insect	No. of infested fruits without insect	Infestation (%)
Hajiabad	161	17	15	2	10.56
Tarom	154	24	18	5	15.58

Sampling and contamination percentage

All the fruits were removed from the packs at the end of storage period and examined for the presence or absence of contamination and the type of contamination. The analysis of variance revealed that packaging method, storage conditions, storage duration and interaction between them were statistically significant in terms of stored pest control. We also found that the effect of storage time on the number of infested date fruits was significant only after 90 days or 150 days. The results indicated that, irrespective of packaging method, packaging could significantly reduce pest contamination severity compared with control treatment (unpacked samples). Although, there was no significant difference between passive MAP and VAP methods, less contamination was observed in VAP samples (Table 3). The results also demonstrated that *P. interpunctella* and *O.*

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surinamensis were the most important storage pests with 87.5 and 12.5% infestation, respectively. Plenty of literature has identified these pets as the most prevalent pests of date fruits (Mohammadpour and Karampour, 2009). The results also showed that both packaging methods could decrease pests' damage on Piarom date fruits. This damage in unpackaged samples was by far higher than packed samples. These results are in agreement with those reported by Dehghanshoar *et al.* (2008), Jayas (2000), Meyvaci *et al.* (2003) and Bell (2000) who studied the effect of MAP method on insect contamination in dried seeds and fruits. Storing and storage conditions also have a significant effect on pests' damage level, so that cool conditions significantly reduce pests' damage in all treatments. In general, both packaging and storing in cool conditions significantly reduced pests' damage. Although packaging can considerably reduce storage pests' damage, cool condition is essential to keep the product fresh for a long time (Fig. 1). Based on the results, it was found that over time and from the second month onward, pests' damage in unpackaged samples significantly increased and the effect of packing was more obvious, so that by the end of the fifth month this difference was also statistically significant (Fig. 1). Although there was no significant difference between passive MAP and VAP methods, VAP method provided better condition for Piarom date so that reduced pests' damage.

Table 3 Mean (± SE) of infested fruits to the *Plodia interpunctella* and *Oryzaephilus surinamensis* in the different treatments after 5 months.

Treatment	No. of infested fruits
MAP	1.64 ± 0.65b
VAP	0.64 ± 0.46b
Control	22.29 ± 6.5a

MAP: Modified atmosphere packaging.
VAP: Vacuum packaging.
The means with the same letter are not significantly different (LSD test, P < 0.05).

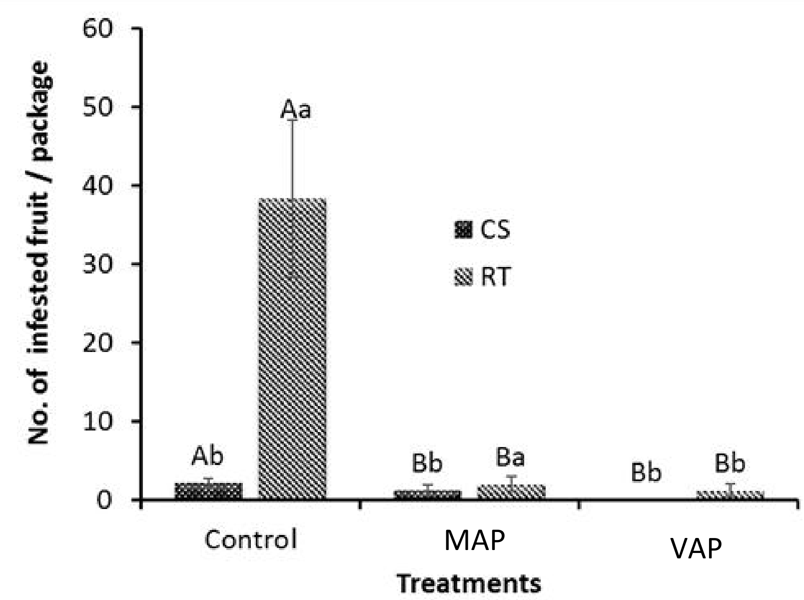

Figure 1 Average infested fruit in two different packages, modified atmosphere packaging (MAP) and vacuum packaging (VAP) compared with control in two storage conditions, cold storage (CS) or room temperature (RT). Means with the same letters (capital letters for the treatments and small letters for the storage condition) are not significantly different (LSD test, P < 0.05).

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Date qualitative traits

pH

The analysis of variance showed that the effect of packaging was significant on pH. In addition, comparison of means indicated that packaging could keep pH within the desired level compared with control treatment (Table 4). Furthermore, the storage temperature effect was also significant on acidity. Storing at 4 °C showed better results in comparison with higher temperature (Table 5). The results demonstrated that acidity was affected by storing period so that acidity decreased with increasing storing period, representing loss of date fruits quality over time. Interaction between temperature and storage period on acidity was also significant. The results suggest that cool conditions (4 °C) have lees impact on acidity during storing period. Interaction between packaging method, temperature and storing period was found to be significant on acidity. Comparison of means showed that over time, until fifth month, passive MAP and then VAP methods were effective in keeping acidity at a stable level. In addition, cool condition (4 °C) could keep acidity more consistent compared with ambient temperature, especially during third and fifth months (Fig. 2).

Table 4 Mean (± SE) of pH in Piarom date in different packaging systems.

Treatment	pH
MAP	5.88 ± 0.05a
VAP	5.85 ± 0.05a
Control	5.78 ± 0.04b

MAP: Modified atmosphere packaging.
VAP: Vacuum packaging.
Means with the same letter are not significantly different (LSD test, $P < 0.05$).

Table 5 Mean (± SE) of pH, water activity, total soluble solids, total color difference (TCD) and number of infested fruits in Piarom dates stored at different temperatures.

Storing condition	pH	Water activity	Total soluble solids (%)	TCD	No. of infested fruits (Five months after storing)
4 °C	5.78 ± 0.04b	0.48 ± 0.13b	64.29 ± 0.26b	5.50 ± 0.35b	1.31 ± 0.37b
Ambient temperature	5.89 ± 0.03ab	0.50 ± 0.1a	65.22 ± 0.35a	6.35 ± 0.43a	15.60 ± 4.50a

Means with the same letters are not significantly different (LSD test, $P < 0.05$).

Water activity

Water activity indicates the amount of free water in the tissue calculated by the ratio of water vapor pressure in the fruit tissue to the vapor pressure of the air saturation at the same temperature as the value between zero and one (Mortazavi *et al.*, 2007). The analysis of variance showed that the temperature and storing period had significant effect on water activity. In addition, comparison of means revealed that lower temperature conserved fruit moisture and caused less change in water activity (Table 5). Furthermore, the results showed that over time, water activity decreased significantly. Interaction between packaging method and temperature also significantly influenced water activity. According to the results, VAP method could conserve fruit moisture better than MAP under both temperature regimes. These results are in agreement with those found by Achour *et al.* (2003) who stated that moisture loss in fruits packaged with MAP method was less than that in unpackaged samples. The maximum water activity change was observed incontrol treatment. The interaction between packing method and storing period had significant effect on fruit water activity. Comparison of means (Fig. 3) shows that in the fifth month of storing, the effect of packing was considerable. Interaction between packing method, temperature and storing period also had significant effect on water activity. Results showed no significant changes in water activity when MAP method was used and samples were kept at ambient temperature, however, in the

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fifth month water activity started to decrease. Moreover, water activity was not affected by VAP until the second month of storage. However, in the third and fifth months when samples were kept at ambient temperature water activity started to decrease. The maximum water activity change was observed in control treatment.

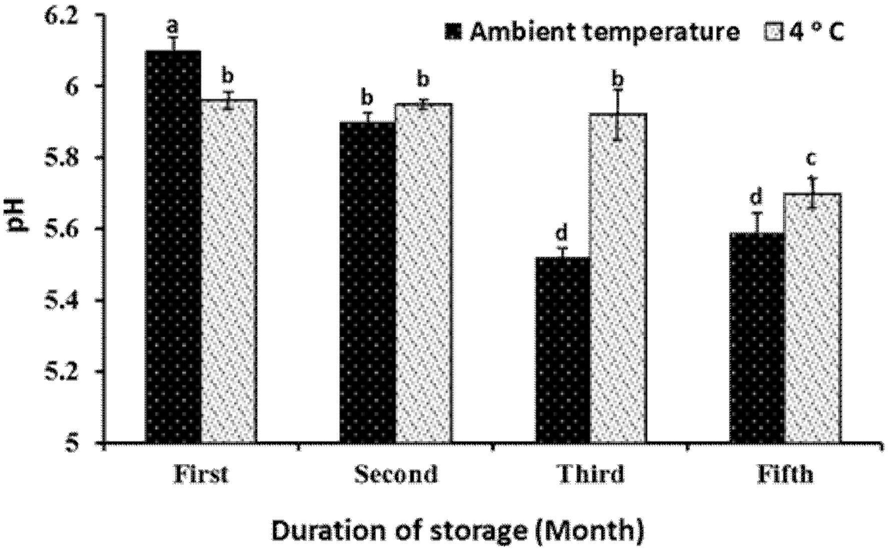

Figure 2 pH of the fruits stored in two different packages, modified atmosphere packaging (MAP) and vacuum packaging (VAP) compared with control (Co) at five storage periods, one to five month storage. Means with the same letters are not significantly different (LSD test, $P < 0.05$).

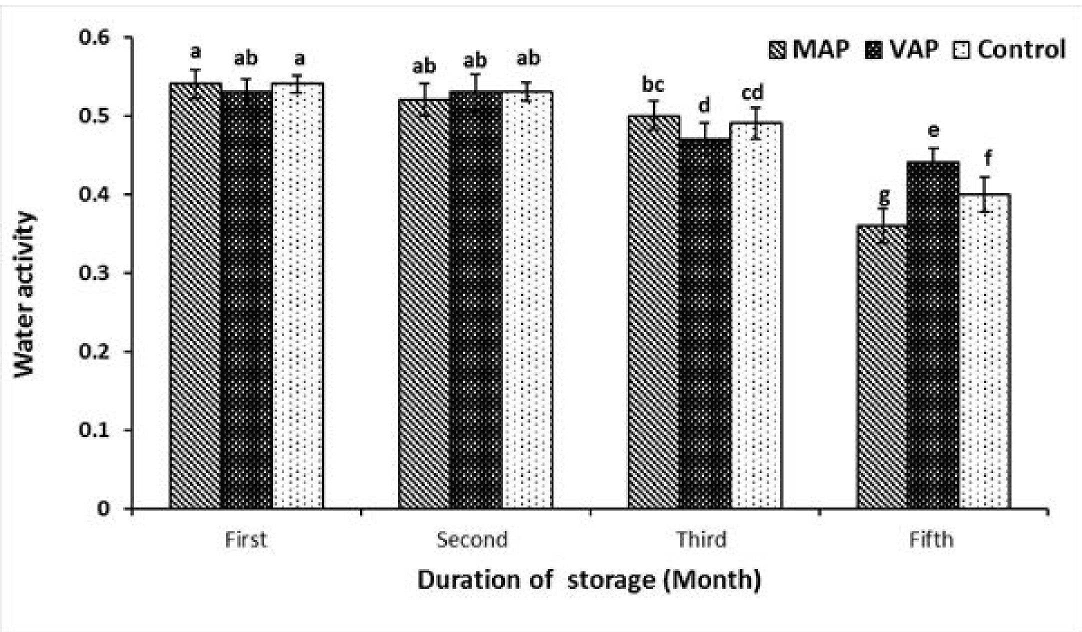

Figure 3 Water activity of the fruits packaged in two different packages, modified atmosphere packaging (MAP) and vacuum packaging (VAP) compared with control (Co) at five storage periods one to five month storage. Means with the same letters are not significantly different (LSD test, $P < 0.05$).

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Total soluble solids (Brix)

The analysis of variance indicated that the effect of storing temperature and storing period were significant on soluble solids percentage. Comparison of means showed that percent soluble solids increased significantly over time. In fact, increase in percent soluble solids is parallel with reduction in samples moisture content (Table 6). Interaction between packaging method and storing period also significantly affected soluble solids percentage. Comparison of means (Fig. 4) showed that the minimum Brix change was observed when MAP method was used. The Brix increased in samples packaged with VAP from the third month onwards. The maximum Brix change was related to control treatment (Fig. 4).

Table 6 Mean (±SE) of pH, water activity and brix in Piarom date at storage times of 1 to 5 months.

Duration of storage (Month)	pH	Water activity	Brix (%)
1	6.03 ± 0.03a	0.53 ± 0.006a	63.9 ± 0.39b
2	5.93 ± 0.01b	0.53 ± 0.004a	64.3 ± 0.21b
3	5.72 ± 0.07c	0.49 ± 0.01b	65.3 ± 0.58a
5	5.65 ± 0.07d	0.40 ± 0.16c	65.5 ± 0.47a

Means with the same letters are not significantly different (LSD test, P < 0.05).

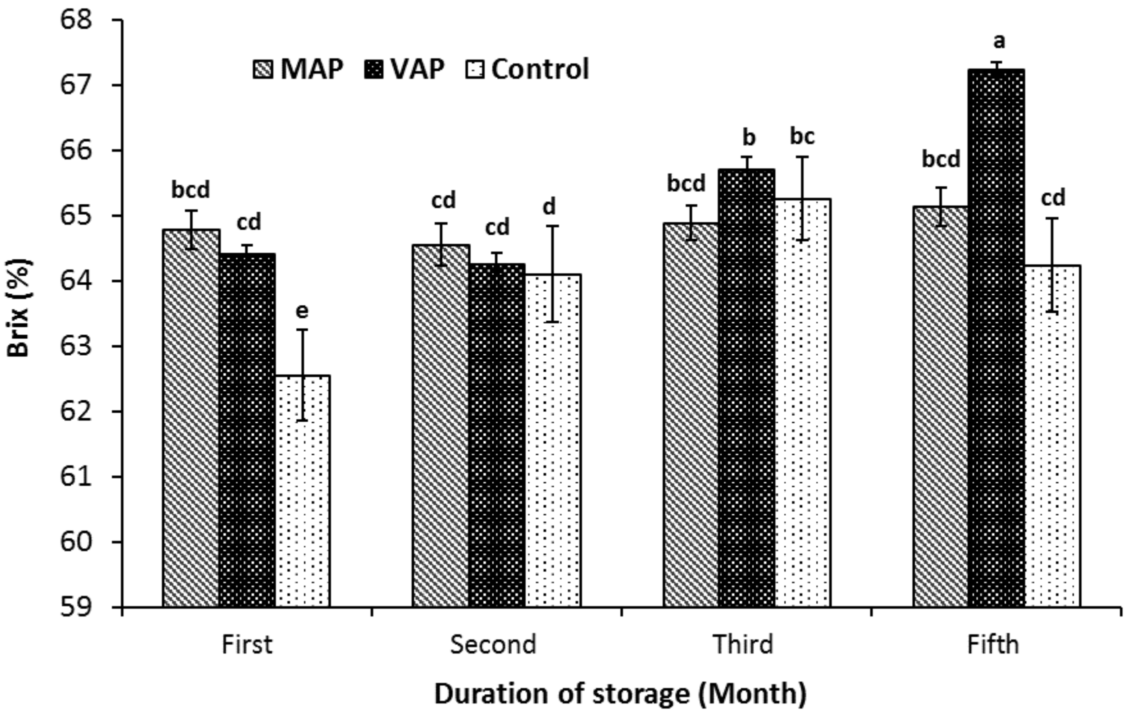

Figure 4 Average brix of the fruits packaged in two different packages, modified atmosphere packaging (MAP) and vacuum packaging (VAP) compared with control at five storage periods, one to five month storage. Means with the same letters are not significantly different (LSD test, P < 0.05).

Fruit color

Gradual change in color is one of the most important post-harvest problems in date fruits during storing period (Mohammadpour and Tajeddin, 2017). Fruit browning can occur by different mechanisms, e.g. enzymatic browning

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as a result of phenolic compounds oxidation or non-enzymatic browning due to caramelization of sugars (Mohammadpour and Tajeddin, 2017). In dates, color change happens in all parts of the fruit. The analysis of variance indicated that packaging method, storage period and temperature have significant effect on fruit color (TCD). In addition, comparison of means showed that the darkest fruits were related to control treatment. There was no significant difference between passive MAP and VAP packaging methods as to fruit color. Furthermore, the darkest fruits were observed after three months of storage (Table 7). The results demonstrated that lower temperature could conserve fruit color better than ambient temperature (Table 5). This result is in line with Ooraikul and Stiles (1991) findings in which they emphasize on greater efficiency of MAP to keep stored product color.

Table 7 Mean (± SE) of TCD in Piarom date in the different packaging methods.

Treatment	TCD
MAP	4.8 ± 0.35b
VAP	5.7 ± o.38b
Control	7.1 ± 0.45b

TCD: Total color difference.
MAP: Modified atmosphere packaging.
VAP: Vacuum packaging.
Means with the same letters are not significantly different (LSD test, $P < 0.05$).

Conclusion

In this study, semi dried Piarom date fruits were packaged using two different methods; passive MAP and VAP. These packing methods were compared with a control treatment as unpacked samples. The packs were stored under two different conditions at 4 °C with and relative humidity of 55-10% and 25-27 °C with relative humidity of 70 ± 5% for 30, 60, 90 and 150 days. The results indicated that *P. interpunctella* and *O. surinamensis* were the most important storage pests with 87.5 and 12.5% contamination, respectively. Both packaging methods reduced storage pests' damage to date samples. From the second month onwards, the damage in the control treatment was higher so that at the end of fifth month a significant difference was observed. Date packaging could keep fruit acidity at desirable level. In comparison with passive method, VAP was more effective in conserving water activity at both storage temperatures. The maximum water activity change was related to control treatment. The minimum soluble solid change was observed in passive MAP and VAP methods. The darkest fruits were observed in control treatment. There was no significant difference between two packaging methods in terms of fruit color. After three months, the darkest dates were observed in the samples kept at ambient temperature. The cold storage is effective in maintaining the bright color of the date fruit.

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تأثیر بسته‌بندی و شرایط انبارداری بر کنترل آفات انباری *Plodia interpunctella* و *Oryzaephilus surinamensis* و حفظ پارامترهای کیفی خرمای پیارم

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چکیده: آفات انباری یکی از مشکلات مهم در نگهداری خرمای پیارم به‌عنوان یکی از مهم‌ترین ارقام نیمه‌خشک خرما در ایران است. هدف از این پژوهش، بررسی تأثیر بسته‌بندی درکنترل دو گونه آفت مهم انباری خرمای پیارم شامل شب‌پره هندی (Hübner) *Plodia interpunctella* و شپشه دندانه‌دار (L.) *Oryzaephilus surinamensis* بود. هم‌چنین اثر بسته‌بندی خرما روی پارامترهای کیفی آن مورد مطالعه قرار گرفت. برای این‌منظور خرمای نیمه‌خشک پیارم در دو نوع بسته‌بندی شامل بسته‌بندی با اتمسفر تغییر یافته غیرفعال و تحت خلاء در کنار تیمار شاهد (بدون بسته‌بندی) مورد مطالعه قرار گرفت. بسته‌ها در دو انبار (چهار درجه سلسیوس با رطوبت نسبی ۱۰ ± ۵۵ درصد و ۲۷-۲۵ درجه سلسیوس با رطوبت نسبی ۵ ± ۷۰ درصد) به‌مدت ۳۰، ۶۰، ۹۰ و ۱۵۰ روز نگهداری شدند. آزمایش به‌صورت فاکتوریل در قالب طرح کاملاً تصادفی با سه تکرار اجرا شد. نتایج نشان داد که شب‌پره هندی با ۸۷/۵٪ آلودگی، مهم‌ترین آفت انباری خرمای پیارم می‌باشد و شپشه دندانه‌دار با ۱۲/۵ درصد پس از آن قرار دارد. بسته‌بندی‌های تحت خلاء و اتمسفر تغییر یافته غیرفعال هر دو به‌طور معنی‌داری تعداد میوه‌های آلوده به آفات انباری خرمای پیارم را نسبت به شاهد کاهش دادند. بسته‌بندی خرما هم‌چنین باعث حفظ بهتر pH در تیمارهای بسته‌بندی نسبت به شاهد شد (۵/۸۸، ۵/۵۸ و ۵/۷۵ به‌ترتیب برای MAP، VAP و شاهد). دمای سرد انبار سبب حفظ بهتر رطوبت خرما و تغییرات کم‌تر فعالیت آبی آن نسبت به دمای محیط شد. بیش‌ترین تغییرات فعالیت آبی در تیمار شاهد مشاهده شد.

واژگان کلیدی: خرما، اتمسفر تغییر یافته، آفات انباری، MAP، VAP