

Potassium permanganate effects in postharvest conservation of the papaya cultivar Sunrise Golden

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Abstract – The objective of this work was to evaluate the effects of KMnO_4 on the extension of postharvest life of 'Sunrise Golden' papaya, stored under modified atmosphere and refrigeration. Fruit with up to 10% yellow peel were harvested in a commercial orchard in Linhares, state of Espírito Santo, Brazil. Sets of three fruit (unit mass of 289.9 ± 18.5 g) were wrapped in low-density polyethylene films (28 μm thick) containing sachets of KMnO_4 at 0, 0.5, 1, 1.5, and 2 g per bag. The bags were sealed and stored at $10.4 \pm 0.9^\circ\text{C}$ and $90 \pm 5\%$ relative humidity for 25 days. After this period, the fruit were removed from the bags and maintained at $21 \pm 0.8^\circ\text{C}$ and $90 \pm 5\%$ relative humidity until complete ripening. Four days after bag sealing, CO_2 concentration stabilized in all treatments, and was higher in bags without KMnO_4 . In all treatments, fruit reached the climacteric respiratory peak on the third day after bag removal, coinciding with peel color index of 3.5. Increasing the KMnO_4 dose reduced the losses in fruit fresh matter, consistency and pulp electrolyte leakage. Potassium permanganate was effective in maintaining the fruit at the pre-climacteric stage during the 25-day storage, and did not interfere with normal ripening after bag removal.

Index terms: *Carica papaya*, ethylene absorber, modified atmosphere, ripening, shelf life, storage.

Permanganato de potássio na conservação pós-colheita da cultivar de mamão Sunrise Golden

Resumo – O objetivo deste trabalho foi avaliar os efeitos do KMnO_4 na extensão da vida pós-colheita da cultivar de mamão Sunrise Golden, armazenada em atmosfera modificada e refrigeração. Frutos com até 10% da área superficial da casca amarela foram colhidos em pomar comercial em Linhares, ES. Conjuntos de três frutos (massa unitária de $289,9 \pm 18,5\text{g}$) foram acondicionados em filmes de polietileno de baixa densidade (28 μm de espessura), com sachês de KMnO_4 nas doses de 0, 0,5, 1, 1,5, e 2 g por embalagem. As embalagens foram hermeticamente fechadas e armazenadas a $10,4 \pm 0,9^\circ\text{C}$ e $90 \pm 5\%$ de umidade relativa (UR), por 25 dias. Após esse período, os frutos foram retirados das embalagens e armazenados a $21 \pm 0,8^\circ\text{C}$ e $90 \pm 5\%$ de UR até o completo amadurecimento. A concentração de CO_2 estabilizou-se, em todos os tratamentos, no quarto dia após o fechamento das embalagens e foi maior nas embalagens sem KMnO_4 . Os frutos de todos os tratamentos atingiram o pico climatérico respiratório no terceiro dia após a retirada das embalagens, o que coincidiu com o índice de cor da casca 3,5. O aumento da dose de KMnO_4 resultou em menor perda de matéria fresca do fruto, menor perda de consistência e menor extravasamento de eletrólitos da polpa. O KMnO_4 foi eficiente em manter os frutos no estágio pré-climatérico, durante os 25 dias de armazenamento, e não interferiu no amadurecimento normal após a retirada da embalagem.

Termos para indexação: *Carica papaya*, absorvedor de etileno, atmosfera modificada, amadurecimento, vida de prateleira, armazenamento.

Introduction

Papaya is a tropical fruit with a considerable economic potential for internal and external market (Souza et al., 2005). It is rather perishable with small postharvest life, even when kept under refrigeration, thus the importance to study alternatives to increase its durability (Morais et al., 2008). Papaya high

perishability is a result of its high water content and high-to-very high respiratory rate, which results in high heat production during storage and easily damaged soft structure (Balbino, 2003). It is a climacteric fruit, whose transformations resulting from the ripening occur rapidly after harvesting the physiologically mature fruit, triggered by elevation of ethylene evolution and increases in respiratory rate.

To enhance the postharvest life of papaya, it is necessary to use technologies that reduce or remove the ethylene of the storage environment, and this can be achieved by using products such as KMnO_4 . This product oxidizes the ethylene produced by the fruit during ripening, extending the pre-climacteric period and the post-harvest life (Resende et al., 2001). The oxidation of ethylene by KMnO_4 leads to the formation of water and CO_2 (Sorbentsystems, 2005).

Refrigeration is one of the most important methods used to delay the processes of senescence. When combined with modified atmosphere, it causes ripening delay and keeps fruit according to market needs (Chitarra & Chitarra, 2005). Modified atmosphere is a quite versatile, relatively simple, and low cost technology that can be applied to various types of fruit and vegetables (Neuwalde et al., 2005). Its efficacy can be increased by combining it with ethylene absorbers, such as potassium permanganate (KMnO_4). According to Cenci et al. (1999), applying KMnO_4 on 'Sunrise Solo' papaya, stored at 10°C over 28 days, reduced consistency loss during storage.

The effects of the absorption of ethylene on post-harvest life enhancement are less evident than the ones of low temperature. In avocado stored at 7°C , the CO_2 concentration inside the packaging with ethylene absorber was slightly lower than in the packaging without this absorber, while at 3°C , CO_2 concentration in packaging was slightly higher, when ethylene absorber was used (Zamorano et al., 1994).

Strawberries packed with PVC film containing KMnO_4 , stored at 1°C , showed decreased respiratory rate and increased storage life from 20 to 30 days, maintaining sugar/acid ratios, soluble solids content and firmness acceptable for consumption (Hao & Hao, 1993).

Experimental conditions used by several authors (Hong et al., 1996; Bhadra & Sen, 1997; Kim & Wills, 1998; Chaves et al., 2007) vary regarding polyethylene film thickness, use of bag perforations, temperature, ethylene absorbers usage etc. Nevertheless, all of them concluded that polyethylene film packing, together with ethylene absorbers and low temperatures led to a considerable increase in fruit shelf life, by increasing CO_2 concentration, reducing water loss and respiration, inhibiting ethylene activity and, consequently, reducing the metabolism of the fruit.

The objective of this work was to evaluate the effect of different doses of KMnO_4 on the extension of postharvest life of 'Sunrise Golden' papaya, stored under modified atmosphere and refrigeration.

Materials and Methods

Fruit were obtained from a commercial orchard in Linhares ($19^\circ23'28''\text{S}$, $40^\circ04'20''\text{W}$, and 33 m altitude), in the northern region of the state of Espírito Santo, Brazil.

'Sunrise Golden' papayas were harvested at ripening stage 1, i.e., with up to 10% of the surface area presenting yellow color, on January 02, 2006. After harvest, the fruit were transported to the packinghouse where they were selected according to size and ripening stage (Martins & Malavasi, 2003). Fruit presenting physical flaws and physiological disturbances were discharged. Normal healthy fruit were washed in running water, treated with 1% aqueous chlorine solution, placed in cardboard boxes and transported to Universidade Federal de Viçosa, Laboratório de Análise de Frutas, in Viçosa, MG, Brazil, reaching their destination approximately 20 hours after harvest.

New selection and standardization were done in the laboratory, using only fruit with 289.90 ± 18.49 g mass. Selected fruit were immersed in fungicide solution Prochloraz (Sportak 450 CE, Hoechst Schering AgrEvo UK Ltd., England), at 49.5 g 100 L^{-1} of water, for 5 min, and air-dried.

Sets of three fruit were packed in hermetic low-density polyethylene bags (35 cm high x 25 cm wide, and 28 μm thick), from which air was partially removed with a vacuum cleaner. Expanded vermiculite sachets impregnated with KMnO_4 at five doses (0, 0.5, 1.0, 1.5, and 2 g per bag) were placed inside each bag. After being packed, fruit were stored during 25 days in a cold chamber, at mean temperature of $10.4 \pm 0.9^\circ\text{C}$ and air relative humidity of $90 \pm 5\%$. After this period, the fruit were removed from the bag and kept in the chamber at mean temperature of $21 \pm 0.8^\circ\text{C}$, until complete ripening. Samplings were made in the beginning of the storage, in the day that fruit were removed from the bags (on the 25th storage day), and after 1, 2, 3, 5 and 6 days of bag removal.

The analyses conducted were: CO_2 evolution and CO_2 concentration inside the polyethylene bags, determined by gas chromatography; peel color

evolution, determined by visual scale described by Martins & Malavasi (2003), with increasing values of 1 to 5 attributed according to yellow peel surface area percentage; fresh matter loss, determined by gravimetry, considering the difference between fruit initial weight, and weight obtained in each sampling period; pulp consistency, determined by applying force, using a 12 mm diameter gauge of a digital penetrometer Shimpo model DFS 100 (Digital Force Gauge) until the tissue no longer presented resistance; and electrolyte leakage, performed according to Serek et al. (1995), with modifications. A portion of the peel was removed from the median region of the fruit without injuring the pulp, and also a pulp cylinder per fruit (1.14 cm diameter per 1-cm thick) using a metallic cork borer. The cylinder was washed in distilled water and superficially dried with absorbing paper, followed by a 2-hour incubation in assay tubes containing 15 mL distilled water, under ambient conditions. Electric conductivity of the water was measured with a Schot model CG 853 conductivity meter. Later, the assay tubes containing the pulp cylinders were autoclaved (121°C at 1.5 atm) for 30 min, and electric conductivity was measured again. Finally, the total soluble solids (TSS) content was measured with the help of a manual refractometer Atago model N1, with reading range from 0 to 32°Brix.

The experiment was placed in a completely randomized design, in split plot arrangement, with three replicates and three fruit experimental unit. Plots consisted of KMnO_4 doses, and the split plots of the six sampling days after fruit removal from the bags. The Dunnett test was carried out at 5% probability to compare treatment means from the beginning of storage and from the day the fruit were removed from the bags.

To analyze the CO_2 concentrations inside the bags, another experiment was set up with the five previously used KMnO_4 doses and five replicates, with a three-fruit experimental unit in a completely randomized design. Silicon septa were made and pasted on the bags. The gas bubbles formed inside silicon septa were removed with a 1-mL hypoderm syringe. The analyses were conducted at 4, 8, 12 and 24 hours and after 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 21, 24 and 25 storage days. Descriptive statistical analysis was made.

Results and Discussion

Carbonic dioxide concentration increased until the 4th day in all treatments, and the bags without KMnO_4 accumulated more CO_2 (Figure 1). The bags with 1.5 g of KMnO_4 maintained a lower concentration of CO_2 during most part of the experimental period. From the 8th to the 12th storage day, a reduction in CO_2 concentration was observed in all treatments, remaining stable until the 24th day.

Oliveira-Júnior et al. (2004) worked with 'Sunrise Golden' papaya in cardboard boxes coated with films (LDPE – 30 μm thick) containing nine fruit with 2.5 g of $\text{KMnO}_4 \text{ kg}^{-1}$, stored at ambient temperature for 12 days; these authors observed that the concentration of CO_2 stabilized at 9.6% in bags without KMnO_4 . According to them, treatment with KMnO_4 presented decreasing CO_2 concentration tendency reaching 11.5% of CO_2 , at the 2nd day of storage, and 8.2% in the 12th day.

From the 1st to the 24th day of storage, it was observed that CO_2 concentration inside the bags ranged between 5 and 10% in KMnO_4 treated fruit, which, according to Gomez et al. (1999), is considered excellent for papaya storage under modified atmosphere, temperature varied between 10 and 15°C. However, in treatments without KMnO_4 , CO_2 concentration inside the bags was above 10% in the 3rd storage day, which may cause

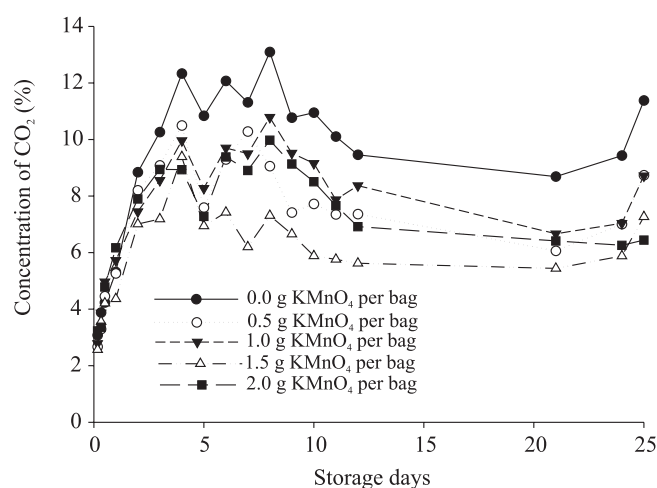


Figure 1. Carbon dioxide concentration inside the 'Sunrise Golden' papaya bag treated with different doses of KMnO_4 , during 25 days of storage at $10.4 \pm 0.9^\circ\text{C}$.

physiological disorders in papaya, such as change from aerobic to anaerobic respiratory route (Taiz & Zeiger, 2009). This type of respiration produces modifications in the flavor and aroma of the fruit, and breaks the structural components of the tissues, causing softening (Chitarra & Chitarra, 2005).

Carbon dioxide evolution had statistical difference in treatments 0 and 0.5 g of KMnO_4 per bag, between means at the storage beginning and after 25 days (Table 1). Fruit treated with 0 and 0.5 g of KMnO_4 had their metabolism accelerated during storage, probably as a result of greater accumulation of ethylene in the bags. The opposite occurred in the three largest doses, highlighting the efficiency of KMnO_4 in removing ethylene from the ambient.

The fruit from treatment without KMnO_4 had higher CO_2 evolution in the three first days after bag removal (Figure 2). In this treatment, climacteric rise in the respiration began after bag removal, while in the treated fruit it occurred between the 2nd and 3rd days. In all treatments, climacteric peak occurred on the 3rd day after bag removal, and nontreated fruit had higher CO_2 evolution at the climacteric peak. This higher CO_2 evolution can be explained by the physiological stress caused by high concentration of this gas inside the bag (Figure 1), during refrigerated storage (Chitarra & Chitarra, 2005). Fruit in treatments reached the postclimacteric phase beginning at the 3rd day, although their peel had not yet reached full yellow coloration (Figure 3 A).

Peel color index (Table 1) did not show statistical difference between means at the storage beginning and after 25 days in all treatments, indicating that these fruit remained unripe during the 25 days of storage. This result is similar to the one reported by

Silva (1995), who observed completely green fruit after 21 days of storage, working with 'Sunrise Solo' Improved Line 72/12 stored at 10°C and packed in low density polyethylene film.

After bag removal, a sigmoid evolution of the peel color index was observed according to the evaluation day, for each KMnO_4 dose (Figure 3 A). In treatment without KMnO_4 , peel color index evolved quickly, while in the others it was slower, suggesting the effect of KMnO_4 even after sachet and bag removal. In this treatment, color index was 4.3, in the 3rd day of evaluation, while in other treatments color index was 3.5, in that same day. In commercial terms, this difference is advantageous, since the fruit could remain for longer periods on the supermarket shelves, resulting in a longer commercialization and consumption period. On the 6th day of storage, fruit of all treatments showed peel color index above 4.5, considered acceptable for consumption.

The fresh matter loss showed statistical difference between means at the storage beginning and after 25 days, in all treatments (Table 1), since zero fresh matter loss was considered to occur in the beginning of storage. However, fresh matter loss was small in all treatments. According to Rocha (2005) and Galvão et al. (2008), this can be explained by the low temperature used in storage, which decelerates metabolism and turns the plastic film denser and less permeable to water vapor; consequently, relative humidity becomes higher inside the package, reducing transpiration.

Fresh matter loss increased along the evaluation days, at each dose of KMnO_4 (Figure 3 B). This is explained by the process of ripening, because the cellular membranes lose their permeability as the fruit ripe, increasing transpiration and respiration

Table 1. Carbon dioxide evolution, peel color index (CI)⁽¹⁾, fresh matter loss (FML), pulp consistency (PC), electrolyte leakage (EL), and total soluble solids content (TSS) of 'Sunrise Golden' papaya treated with different doses of KMnO_4 , after 25 days of storage.

Treatment	CO_2 production (mg CO_2 kg ⁻¹ per hour)	CI	FML (%)	PC (kPa)	EL (%)	TSS (°Brix)
0.0 g KMnO_4 per bag	117.48*	1.4	0.941*	2,205	14.929	10.8*
0.5 g KMnO_4 per bag	122.79*	1.2	1.046*	2,443	12.432	10.7*
1.0 g KMnO_4 per bag	108.09	1.2	1.089*	2,553	11.207	10.7*
1.5 g KMnO_4 per bag	80.29	1.0	1.176*	2,440	9.604	10.4
2.0 g KMnO_4 per bag	107.30	1.0	1.126*	2,561	11.749	9.9
Storage beginning	94.64	1.0	0.000	2,540	9.389	9.4

⁽¹⁾Determined by visual scale described by Martins & Malavassi (2003). *Value different from the observed at the storage beginning, by the Dunnett test, at 5% probability.

(Figure 2) and, consequently, augmenting fresh matter loss.

The treatments with 0 and 1 g of KMnO_4 per bag had greater fresh matter loss throughout the evaluation days, corresponding to 2.86 and 2.54%, respectively, on the 6th day after bag removal. Fruit in all treatments had fresh matter loss above 2% on the 6th day after bag removal, but such loss is not sufficient to cause wilting neither to hinder fruit commercialization.

Cenci et al. (1999) worked with 'Sunrise Solo' papaya sold in cardboard boxes without plastic film, containing 12 fruit and two sachets of 1 g each of KMnO_4 , and concluded that the use of ethylene absorber reduced mass loss 22.5% in average compared to fruit without KMnO_4 . In addition, mass loss in the nontreated fruit ranged from 14.7 to 33.8% over 31 storage days (27 days at 10°C + 4 days at 20°C).

The pulp consistency did not show statistical difference between means at the storage beginning and after 25 days in all treatments (Table 1). The fact that this variable did not differ after 25 days of storage in treatment without KMnO_4 shows that refrigeration and modified atmosphere were efficient in inhibiting loss of pulp consistency. Different results were found by Cenci et al. (1999), who reported that fruit exposed to ethylene absorber had smaller consistency loss during 31 storage days compared to the nontreated fruit.

The nontreated fruit had a more softened pulp on day 0 and an accelerated posterior reduction in consistency

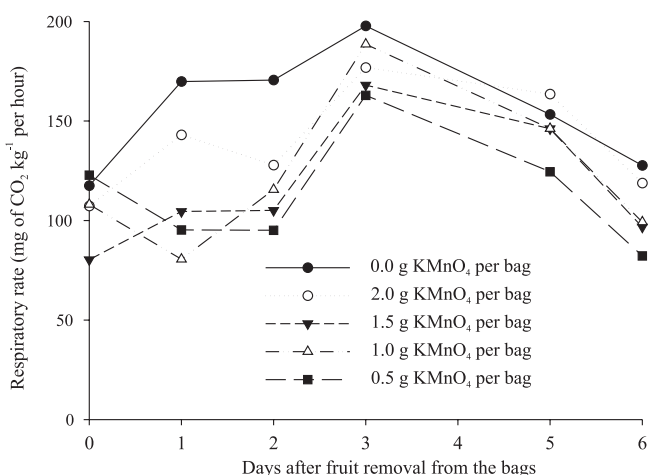


Figure 2. Respiratory rate after fruit removal from the bags of 'Sunrise Golden' papaya treated with different doses of KMnO_4 and kept at 21±0.8°C.

(Figure 3 C). The treated fruit kept their consistency high until the 2nd day after bag removal, reducing it rapidly after that. The more marked consistency reduction after the 2nd day for the treated fruit coincided with the start of the climacteric rise in respiration (Figure 2). These results agree with those obtained by Paull & Chen (1983), who studied the relation between consistency loss, respiration, ethylene evolution and peel color change of 'Sunrise Solo' papaya; these authors found strong relation between these factors and fruit climacteric peak.

Fruit without KMnO_4 had consistency of 545.13 kPa on the 3rd day of evaluation, while the treated fruit, at the same day, had consistency mean of 1,536.68 kPa, indicating the effect of KMnO_4 even after bag removal. These results are in accordance to Oliveira-Júnior et al. (2004), who observed higher pulp consistency in fruit treated with KMnO_4 , with visible reduction on the first six days, but remaining constant until the end of the refrigerated storage.

Similarly to pulp consistency, the variable electrolyte leakage had no statistical difference between means at the storage beginning and after 25 days in all treatments (Table 1), indicating that cellular membrane kept integrity in the 25 days of storage under refrigeration. Electrolyte leakage showed an exponential behavior in function of the evaluation days, in each dose of KMnO_4 , with the treatment with 2 g of KMnO_4 per bag presenting the smallest loss of membrane selective permeability (Figure 3 D). Electrolyte leakage in the fruit without KMnO_4 treatment remained stable until the 5th day (25%), and then abruptly increased, reaching around 60% on the 6th day. In treated fruit, electrolyte leakage was stable until the 3rd day, with mean value of 17%, and from then on increased progressively until reaching values between 40 and 50%, on the 6th day.

Membrane selective permeability loss was related to color development and pulp consistency loss. Treatments that maintained membrane selective permeability were also efficient in delaying color development and in reducing pulp consistency loss. The results pointed to an effect of KMnO_4 in delaying fruit senescence.

Treatments with 1.5 and 2 g of KMnO_4 per bag had total soluble solids content statistically equal at the storage beginning and after 25 days, while fruit treated with 0, 0.5, and 1 g of KMnO_4 per bag had statistically superior means after 25 days of storage (Table 1), which

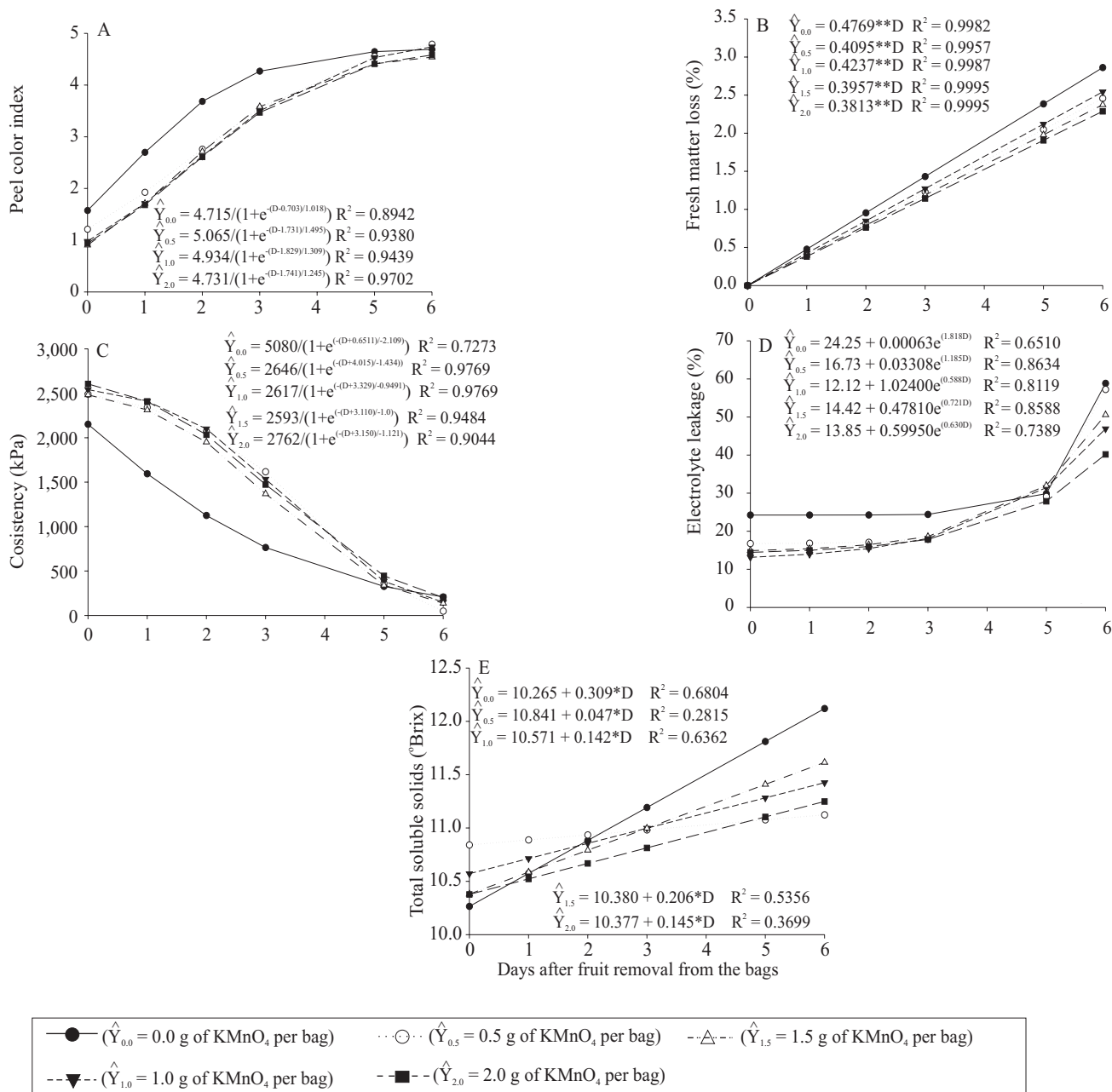


Figure 3. Peel color index (A), determined by visual scale described by Martins & Malavasi (2003), fresh matter loss (B), pulp consistency (C), electrolyte leakage (D) and total soluble solids content (E) of 'Sunrise Golden' papaya treated with different doses of $KMnO_4$ and kept at $21 \pm 0.8^\circ C$, after fruit removal from the bags.

indicate an anticipated ripening in these treatments. According to Balbino (2003), papaya has the characteristic of accumulating low contents of starch (less than 1%) during ripening. After bag removal, the content of total soluble solids showed linear increasing behavior, along the evaluation days, for each dose of $KMnO_4$ (Figure 3 E). A higher content of soluble solids

was observed in the fruit without $KMnO_4$, indicating accelerated ripening, while in treated fruit, $KMnO_4$ effect had a slower evolution of the total soluble solids content. These results are in accordance to the ones obtained by Assis & Steineker (2003) and by Corrêa et al. (2005).

Conclusions

1. Refrigeration combined with fruit wrapping with low density polyethylene film preserve and maintain fruit appearance and some quality attributes during storage for 25 days.

2. Potassium permanganate delays fruit ripening, and the dose 0.5 g of KMnO_4 per bag is sufficient to preserve papaya for 25 days.

Acknowledgements

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