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Effect of Modified Atmosphere Packaging (MAP) on the Alleviation of Chilling Injury and Dietary Antioxidants Levels in 'Solo' Papaya during Low Temperature Storage

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Summary

Mature green 'Solo' papayas individually packed in low-density polyethylene (LDPE), polypropylene (PP) and Pebax-C® films, to create a modified atmosphere (MA) around the fruit, were stored at 7 or 13 °C and 85–90 % relative humidity. The rates of respiration and ethylene production gave an indication of chilling stress. The electrolyte leakage from whole fruit, measured as electrical conductivity, increased with the appearance of slight chilling injury (CI) symptoms and showed proportional increase with the severity of CI. Modified atmosphere packaging (MAP) prevented the development of CI symptoms during storage at 7 or 13 °C for 30 days, but fruits stored at 7 °C failed to ripen normally and showed blotchy appearance due to skin scald, and showed internal injury. LDPE and Pebax-C® packed fruits stored at 13 °C showed higher retention of ascorbic acid, total carotenoids and lycopene after 30 days storage at 13 °C + 7 days in air at 20 °C. However, non-packed fruits stored at 13 °C up to 20 days did not suffer in their ascorbic acid content compared to 30 days storage at both the temperatures. Therefore, individual packaging of 'Solo' papaya in LDPE or Pebax-C® film could prevent the chilling injury at 13 °C for 30 days and maintained the acceptable levels of dietary antioxidants.

Zusammenfassung

Wirkung der Verpackung in modifizierter Atmosphäre (MAP) auf das Vermeiden von Kälteschäden und auf den Gehalt an dietätischen Antioxidantien in Papayafrüchten der Sorte 'Solo' während der Kühllagerung. Reife, grüne Papayas der Sorte 'Solo' wurden, um eine die Frucht umschließende, modifizierte Athmosphäre zu schaffen, einzeln in leichte Folien aus Polyethylen (LDPE), Polypropylen (PP) oder Pebax-C® verpackt und bei 7 bzw. 13 °C und 85–90 % relativer Feuchtigkeit gelagert. Die Respirations- und Ethylenbildungsraten dienten als Indikatoren für den Kältestress. Der Elektrolytverlust der ganzen Frucht, der mittels elektrischer Leitfähigkeit gemessen wurde, stieg mit dem Auftreten von leichten Kälteschäden (CI) an und steigerte sich proportional zur weiteren Ausbreitung der CI. Die Verpackung in modifizierter Atmosphäre (MAP) verhinderte das Auftreten von CI-Symptomen während der 30-tägigen Lagerung bei 7 bzw. 13 °C, jedoch reiften die bei 7 °C gelagerten Früchte nicht normal weiter, sahen aufgrund von Schalenveränderungen fleckig aus und hatten auch innere Verletzungen. In LDPE oder Pebax-C® verpackte und bei 13 °C gelagerte Früchte wiesen nach der Kombination von 30 Tagen Lagerung bei 13 °C + 7 Tagen offen bei 20 °C eine bessere Erhaltung von Ascorbinsäure, Gesamtkarotinoiden und Lykopin auf. Allerdings zeigten nichtverpackte und 20 Tage bei 13 °C gelagerte Früchte im Vergleich zu 30 Tage bei 7 bzw. 13 °C in Folie gelagerten, keine Unterschiede im Ascorbinsäure-Gehalt. Die Einzelverpackung von Papayafrüchten der Sorte 'Solo' in LDPE oder Pebax-C®-Folie kann das Auftreten von Kälteschäden nach 30-tägiger Lagerung bei 13 °C verhindern und ein akzeptables Maß an dietätischen Antioxidantien erhalten.

Key words. electrolyte leakage – ethylene – gas composition – respiration – quality

Introduction

Papaya (*Carica papaya* L.) is a commercial tropical fruit crop of the world. Among several cultivars, 'Solo' is desired for its high productivity, small to medium sized, attractive, delicious and wholesome fruits that are suitable for export. Its highly perishable nature, chilling sensitivity and susceptibility to decay are the major constraints in the postharvest handling and storage during export and retailing (PAULL et al. 1997). Modified atmosphere packaging (MAP) is effective in prolonging the postharvest life of horticultural crops by decreasing O_2 and increasing CO_2 concentrations in the package atmosphere achieved via the interaction

between respiratory O_2 uptake and CO_2 evolution of packaged produce (KADER et al. 1989). The development of a modified atmosphere and high relative humidity inside the package retards senescence and prevents chilling injury (CI). The role of MAP in alleviation of CI is well established in many horticultural crops (WANG 1998). 'Kapoho' and 'Sunrise' papayas individually sealed in high-density polyethylene (HDPE) having thickness of 0.18 mm, have less CI symptoms than unsealed fruits, but developed off flavour (CHEN and PAULL 1986). LAZAN et al. (1990) found that sealing of 'Back Cross Solo' papaya in LDPE film (12.5 µm thickness) maintained modified atmosphere with 12.8 % oxygen and 2.4 % carbon dioxide on the fifth day of storage. The detection and description of CI symptoms in papaya have been subjective and qualitative. The measurement of rate of respiration, ethylene production and electrolyte leakage are objective and quantitative methods to study the responses to chilling in papaya (CHAN et al. 1985).

'Solo' papaya is a rich source of dietary antioxidants such as carotenoids, lycopene and ascorbic acid. The increase in ascorbic acid content of 'Solo' papaya has been reported from 72 mg $100g^{-1}$ at green stage to 102.2 mg $100g^{-1}$ at ripe stage (WENKAM 1979). KIMURA et al. (1991) reported that principal carotenoids in 'Solo' papaya are lycopene (21 µg g^{-1}), ß-cryptoxanthin (9.1 µg g^{-1}) and ß-carotene (2.5 µg g^{-1}). The total yield of pigments in red fleshed varieties of papaya has been reported to be 4.2 mg $100g^{-1}$, out of which lycopene constitutes 63.5 %, whereas it is absent in yellow fleshed varieties. The information on the effect of MAP on the nutritional quality of papaya and other fruits is scanty, but is of prime importance at this juncture when the health benefits of consuming fruit derived antioxidants are increasingly being recognized.

The present study was undertaken to study the effect of MAP on the alleviation of CI and dietary antioxidants levels in Solo papaya during low temperature storage.

Materials and Methods

Papaya (cv. 'Solo') fruits were obtained in February 2003 from a local farmer. The plantation was one and a half year old grown under good management practices. The fully mature green fruits were selected for the experiment and harvesting was done manually in the morning hours and fruits were transported in plastic crates cushioned with newspaper to the laboratory within four hours for further postharvest operations. Fruits of uniform size, shape, and maturity were selected to maintain homogeneity in the experiment whereas those showing surface defects and latent anthracnose infection were culled out. Fruits were washed in running water to remove the adhering latex, dust, and dirt and then dipped in prochloraz fungicide emulsion (250 ppm) for 10 minutes. Fruits were air dried to remove the excess surface moisture and were pre-cooled to their respective storage temperatures. Three different types of packaging films *viz.* low density polyethylene (LDPE), polypropylene (PP) and Pebax-C® were used. Fruits were divided into eight lots, each carrying 40 fruit. Fruits were individually packed in these films of same dimension (20 x 20 cm) and thickness (25 µm) using impulse heat-sealing machine. Lot 1, 2 and 3 were packed in LDPE, PP and Pebax-C® film respectively whereas the fourth lot of non-packed fruit served as the control and were stored in a 'Walk-in' cold room maintained at 7 °C and 85–90 % relative humidity (r.h.). Similarly, lot 5, 6 and 7 were packed in respective films and the eighth lot served as the control and were stored at 13 °C and 85–90 % r.h.

Sampling interval

Fruits were unpacked after 20 and 30 days of storage and transferred to 20 °C (70–80 % r.h.) for additional 6–7 days for ripening. Twenty fruits randomly selected were unpacked from each treatment after these intervals.

Gas composition

The gas composition (% oxygen and % carbon dioxide) inside the MA packs was monitored, at 4 days intervals throughout the storage period using an auto gas analyser (Model: Checkmate 9900 O_2/CO_2 Denmark). The probe of the instrument was pierced through a silicon-teflon septum glued to the film and the in-pack gas composition was recorded as % oxygen and % carbon dioxide.

Respiration and ethylene production rates

The respiration and ethylene production rates of non-packed fruits were measured to study the physiological response of fruits to the low temperature storage. Three replicates single fruit were enclosed in airtight respiratory jars for one hour after which a headspace gas sample was drawn and injected into a gas chromatograph (Hewlett Packard GC model 6890) fitted with Porapak Q column. Carbon dioxide was detected with a thermal conductivity detector (TCD) with N_2 as a carrier gas (at a flow rate of 30 ml min^{-1}). Ethylene was measured using a gas chromatograph (Hewlett Packard GC model 5890 series II) equipped with a flame ionization detector (FID) under similar conditions.

Electrolyte leakage

The electrolyte leakage from the whole fruit was measured by an electrical conductivity meter (Model: Eco Scan CON 5, Singapore). A glass beaker of two litres capacity was filled with 1500 ml of double distilled water and initial electrical conductivity of water was recorded. Then whole fruit was immersed in it for ten minutes and the final electrical conductivity value of water was recorded and expressed as µS kg^{-1} of fruit.

Estimation of dietary antioxidants

Five fruit samples randomly selected were evaluated for chemical composition at harvest. Five fruit samples from each treatment at table ripe stage were analysed to study the levels of dietary antioxidants in fruit pulp. For this, mesocarp tissues were cut into one cm cubes, packed in plastic film and immersed in liquid nitrogen (–196 °C) for ten minutes followed by storage at –40 °C until required for biochemical analysis. The estimation of ascorbic acid, total carotenoids and lycopene was carried out by the methods as suggested by RAN-

GANNA (1986). The estimation of ascorbic acid was done by 2,6-dichlorophenol-indophenol visual titration method, which is based on the reduction of dye by ascorbic acid. For estimation of carotenoids and lycopene, a representative sample weighing 10 g of fruit pulp was ground using a pestle and mortar with acetone until the residual tissue becomes colourless. Then pigments were transferred into the petroleum ether phase by diluting acetone with 5 % sodium sulphate. The extraction of acetone phase with small volumes of petroleum ether was repeated until no more colour is extracted and a known volume was made. The absorbances of samples for carotenoids and lycopene were measured at wavelengths 452 and 503 nm respectively, using a spectrophotometer (Spectronic 1201, USA). The total carotenoids and lycopene content were calculated using their respective standard curves.

Chilling injury and visual quality rating

The external and internal evaluation criteria used for evaluation of fruits were as suggested by CHEN and PAULL (1986):

a) Surface colour estimated as percentage of yellowing,
b) Skin scald- based on surface area affected by brown scald:
   1= none, 2= 5 %, 3= 20 % and 4= 50 % scald,
c) Internal injury including white hard areas and tissue breakdown:
   1= none, 2= slight, 3= moderate and 4= severe.

The severity of disease incidence was categorized into mild, moderate, and severe.

Statistical analysis

The experimental design was completely randomised. The data were analysed by ANOVA and the significance among treatment mean values was determined by Duncan's multiple range test at the $*P < 0.05$ level.

Results and Discussion

Gas composition

The in-package O_2 concentration dropped rapidly in all modified atmosphere (MA) packs and reached 2–6 % within two days, but started to increase slowly with the advancement of storage period (Fig. 1). The increase in O_2 level from second fortnight of storage may be attributed to the reduced respiration rate of fruit due to MA effect. The uptake of O_2 by fruit might have declined due to lower respiration rate, but there was still continuous influx of O_2 across the film due to concentration gradient. GONZALEZ et al. (1990) reported such an increase in O_2 concentration with the advancement of storage period in MA packs of mango and avocado. Simultaneously, a rapid accumulation of CO_2 was observed within two days at both storage temperatures and was found either stable or slightly decreased during storage. LDPE film created a MA containing CO_2 and O_2 levels in the range of 3–7 % and 8–15 %, respectively at both storage temperatures while Pebax-C® film maintained 2–3 % CO_2 and 10–12 % O_2. However, PP film generated an atmosphere slightly higher in CO_2 (8–10 %). The observed variation in gas composition of different MA packs may be due to various factors including package film permeability characteristics, fruit weight, and its respiration rate and respiring surface area. PAULL and CHEN (1989) found that internal CO_2 content of about 7–8 kPa could result in development of off-flavour in ripe 'Sunset' and 'Sunrise' papaya stored for two weeks at 10 °C +2 days at ambient conditions. We also observed that fruit packed in PP film, which created an atmosphere having more than 8 % CO_2, developed off-flavour when ripened after 20 or 30 days storage, while those packed in LDPE and Pebax-C® film did not develop off- flavour upon ripening.

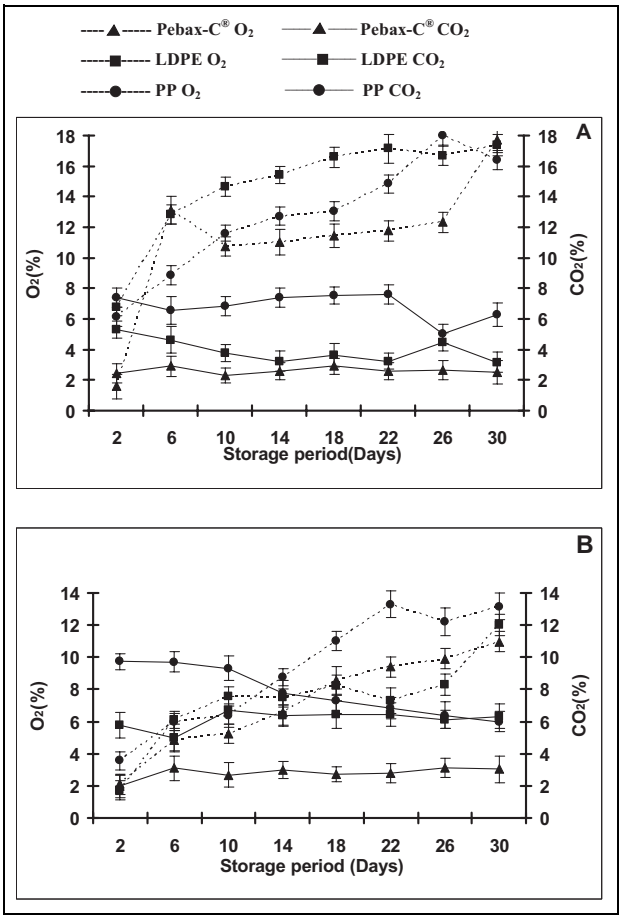


Fig. 1. Gas composition (% oxygen and % carbon dioxide) inside modified atmosphere packs of papaya fruits during storage at 7 °C (A) and 13 °C (B). Each value is the mean of ten replicates. Vertical bars indicate ± standard error.

Respiration and ethylene production rate

The rates of respiration of non-packed fruits stored at 13 °C were comparatively higher than those stored at 7 °C (Fig. 2). The results are in agreement with NAZEEB and BROUGHTON (1978). The continuous increase in rate of respiration after 8 days storage at 7 °C could be associated with the CI. However, the increase in rate of respiration was observed on the day 4 of storage, which followed the appearance of slight CI symptoms on day 5 of storage. Thus, an increase in respiration gave an indica-

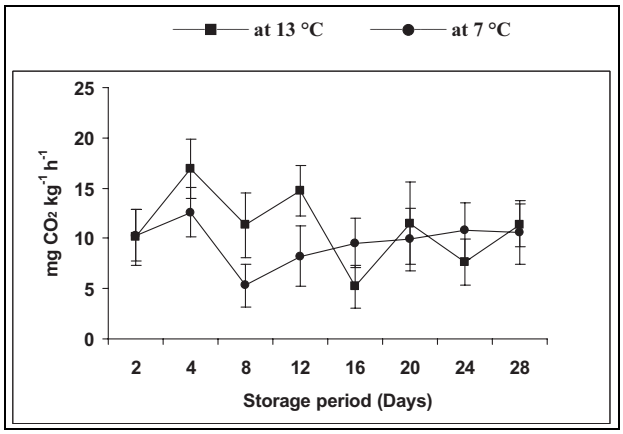


Fig. 2. Effect of low temperature storage on the rate of respiration (mg kg–1 h–1) of non-packed papaya fruit. Each value is the mean of five replicates. Vertical bars indicate ± standard error.

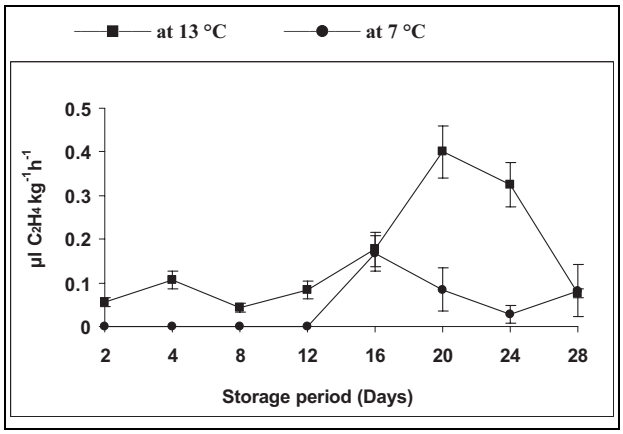


Fig. 3. Effect of low temperature storage on the rate of ethylene production (µl kg–1 h–1) of non-packed papaya fruit. Each value is the mean of five replicates. Vertical bars indicate ± standard error.

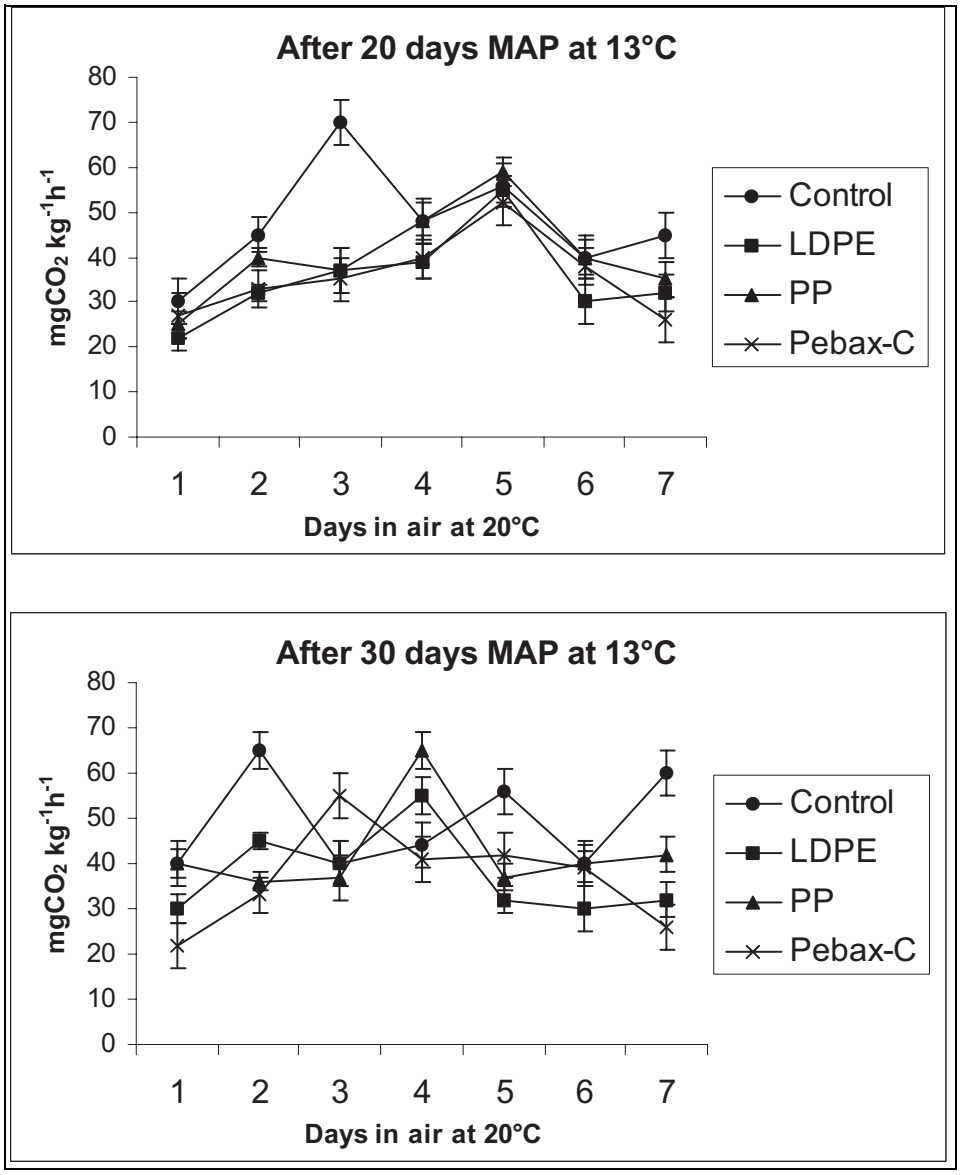


Fig. 4. Effect of modified atmosphere packaging (MAP) on the respiration rates (mg kg–1 h–1) of unpacked fruit after 20 and 30 days at 13 °C. Each value is the mean of five replicates. Vertical bars indicate ± standard error.

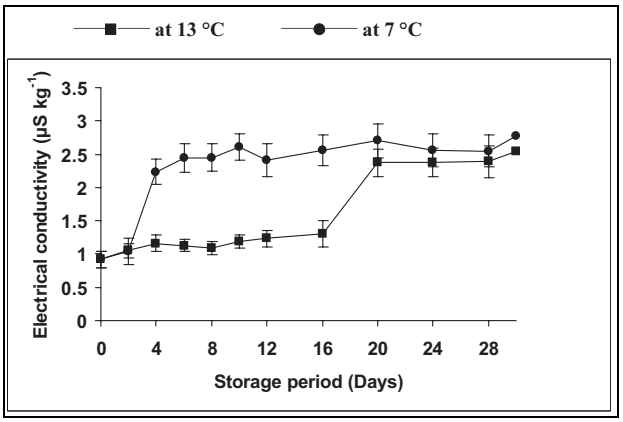


Fig. 5. Effect of low temperature storage on the electrolyte leakage (measured as electrical conductivity µl kg^{-1}) from non-packed whole papaya fruits. Each value is the mean of five replicates. Vertical bars indicate ± standard error.

tion of chilling stress at 7 °C. The same did not hold well for fruits stored at 13 °C, which showed visible CI symptoms after 20 days storage. Ethylene was not detectable up to day 12 of storage at 7 °C, but increased suddenly on day 16 which was found after the severe pitting and skin discolouration of the fruits (Fig. 3). It showed that fruit retained the capacity to convert ACC into ethylene even after severe chilling injury symptoms. Ethylene production rate of fruit stored at 13 °C showed an increasing trend from day 12 onwards with maxima on day 20. The increase in ethylene production at 13 °C on day 20 was coincident with the appearance of severe chilling injury symptoms. The enhancement of ethylene production due to CI has been reported in papaya by CHAN et al. (1985). It can be concluded that ethylene evolution was observed after the fruit has undergone irreversible changes occurring during chilling stress.

MAP significantly affected the rates of respiration of fruits unpacked after 20 or 30 days of storage. MAP of papaya delayed the climacteric peak by 2 or 3 days compared to control (Fig. 4). The amount of CO_2 evolution during climacteric was also lower in MA packed fruits compared to control. The fruits packed in Pebax-C® film showed the minimum amount CO_2 evolution but showed climacteric peak one day earlier than LDPE and PP packed ones after 30 days storage at 13 °C. MAP of mango with LDPE and HDPE also delayed climacteric peak as well as reduced CO_2 evolution by the fruit on the day of climacteric (GONZALEZ et al. 1990). The delay in climacteric by MAP ensures sufficient time period for retailing of fruit at its destination. The respiratory patterns of fruits stored at 7 °C are not shown during ripening period, because fruits showed erratic respiratory behaviour with no clear climacteric peak, which signified their uneven ripening or failure to ripen.

Electrolyte leakage

The non-packed fruits stored at 7 °C had significantly higher electrical conductivity (EC) than those stored at 13 °C (Fig. 5). The non-packed fruits stored at 7 °C showed sudden increase in EC on the day 4, which further increased. The increase in EC of 13 °C stored fruits was observed on day 20 of storage. The increase in EC of whole fruits was coincident with the appearance of chilling injury symptoms. Our results are in agreement with MCCOLLUM and MCDONALD (1991) who found that electrolyte leakage did not increase until visible pitting of flavedo of 'Marsh' grapefruit had occurred. It was observed that the visual rating of CI severity could be correlated with the EC values. The increase in EC during ripening of fruit after shifting to 20 °C was non-significant among different treatments (data not shown).

Table 1. Effect of modified atmosphere packaging (MAP) on 'Solo' papaya chilling injury symptom development[x].

Storage condition	20 days				30 days			
	Electrical conductivity* (µS kg^{-1})	Colour (% yellow)	Skin scald (Score)	Internal injury (Score)	Electrical conductivity* (µS kg^{-1})	Colour (% yellow)	Skin scald (Score)	Internal injury (Score)
At harvest	0.9	10	–	–				
At 7 °C								
Non-packed	2.7 a	72 d	2.5 a	3.5 a	2.8 a	70 c	3.5 a	3.8 a
LDPE	1.2 c	80 c	1.2 c	1.8 b	1.3 bc	75 bc	2.5 c	1.9 bc
PP	1.0 c	85 b	1.0 c	1.5 c	1.1 c	80 b	2.3 c	2.0 b
Pebax-C®	1.3 c	80 c	1.2 c	1.5 c	1.4 b	76 b	2.8 b	1.8 c
At 13 °C								
Non-packed	2.4 b	85 b	1.5 b	1.6 b	2.5 a	78 b	3.0 b	2.1 b
LDPE	1.1 c	95 a	0.8 d	0.6 d	1.1 cd	98 a	1.1 d	1.1 d
PP	1.0 c	93 a	0.7 d	0.6 d	1.0 d	95 a	1.0 d	1.2 d
Pebax-C®	1.1 c	95 a	0.9 d	0.8 d	1.2 cd	98 a	1.1 d	0.9 d

Means in each column followed by the same letter are not significantly different (Duncan, $P<0.05$).
LDPE: low-density polyethylene; PP: polypropylene.
[x]Fruits were evaluated after 20 or 30 days MAP at low temperature + 7 days in air at 20 °C for colour change, skin scald and internal injury.
*Electrical conductivity was measured immediately after storage of 20 or 30 days.

Table 2. Effect of modified atmosphere packaging (MAP) on the dietary antioxidants levels (all in: mg $100g^{-1}$) in 'Solo' papaya during low temperature storage.

Storage condition	20 days MAP + 7 days in air at 20 °C			30 days MAP + 7 days in air at 20 °C		
	Ascorbic acid	Total carotenoids	Lycopene	Ascorbic acid	Total carotenoids	Lycopene
At harvest	72.9	1.6	1.1			
At 7 °C						
Non-packed	60.9 g	2.8 bc	1.9 a	73.5 e	2.8 e	2.1 c
LDPE	79.3 e	2.3 e	1.4 c	78.3 d	3.5 b	2.1 b
PP	74.9 f	2.6 d	1.8 a	63.4 f	2.8 e	1.9 d
Pebax-C®	92.5 d	3.2 a	1.9 a	92.4 b	3.3 c	2.2 b
At 13 °C						
Non-packed	102.4 b	2.6 d	1.8 a	77.8 d	3.2 d	2.1 b
LDPE	112.8 a	2.3 e	1.5 c	102.8 a	3.5 b	2.5 a
PP	98.0 c	3.0 b	1.8 a	83.3 c	3.5 b	2.2 b
Pebax-C®	101.9 bc	2.9 b	1.7 b	102.2 a	3.7 a	2.2 b

Means in each column followed by the same letter are not significantly different (Duncan, $P<0.05$).
LDPE: low density polyethylene; PP: polypropylene.

The EC of MA packed fruit was significantly lower than the non-packed fruits after 20 or 30 days storage at 7 or 13 °C (Table 1). There were no significant differences among different packaging films irrespective of the storage temperature after 20 days; however PP packed fruits stored at 7 °C for 30 days showed significantly lower EC compared to Pebax-C®. There was clear indication of alleviation of CI by MAP as evident from the EC values. Several authors have recognized that electrical conductivity of tissue leachate can be widely used for assessment of chilling injury. CHAN et al. (1985) reported that differences in electrolyte leakage between fruit stored at 5 and 10 °C were not significant until after 7 days storage. We found that EC could not be used as a tool for early detection of CI in papaya fruit. But it can serve as an index of membrane integrity of fruit and thus showing the severity of CI during low temperature storage.

Chilling injury (CI)

The non-packed fruits showed visible symptoms of CI on fifth and fourteenth day of storage at 7 and 13 °C, respectively. The initial symptoms include water soaked areas and small surface pits which increased in size and darkened in colour with the passage of storage period. MA packed fruits did not show any CI symptoms during storage at 7 or 13 °C for 30 days. MAP might have prevented development of CI by maintaining high humidity inside the packs. Water loss had been shown to cause excessive production of active oxygen species (AOS), thus provision of high humidity through MAP prevented chilling-induced oxidative stress (HODGES et al. 2004). However, when fruits were unpacked after 20 or 30 days storage, and shifted for ripening at 20 °C, severe CI symptoms were observed in fruits stored at 7 °C. CI symptoms included pitting, skin scald, internal injury and failure to ripen. MA packed fruits stored at 7 °C showed significantly higher skin scald and internal injury after 20 or 30 days of storage when compared to those stored at 13 °C. Internal injury was observed in the form of tissue breakdown and formation of hard areas in the flesh that did not soften during ripening. No significant differences were observed with regard to skin scald and internal injury, among MA packed fruits stored at 13 °C. MA packed fruits stored at 13 °C for 20 or 30 days showed better colour development and ripened normally in one week. Modified high humidity inside MA packs was responsible for reducing CI while modified gaseous atmosphere did not play crucial role in prevention of CI in papaya (CHEN and PAULL 1986). The disease incidence was rated severe in fruits showing CI symptoms. MAP minimized the spoilage by alleviating CI in fruits stored at 13 °C. It is well established that CI rendered the commodity more susceptible to infections (PAULL 1990).

Ascorbic acid

The fruits stored at 13 °C showed significantly higher ascorbic acid content than those stored at 7 °C. It is clear that CI reduced ascorbic acid content of papaya fruit (Table 2). MA packed fruits (except PP packed) retained higher ascorbic acid content compared to non-packed ones after 20 or 30 days storage at 7 or 13 °C. The LDPE packed fruits, after 20 days at 13 °C + 7 days in air at 20 °C, showed highest ascorbic acid content which was significantly higher than others either packed or non-packed fruits. The non-packed fruits stored at 7 or 13 °C for 30 days and shifted to 20 °C for ripening, suffered great losses in ascorbic acid compared to MA packed fruits. LIANG et al. (1998) found that there is an accelerated loss of ascorbic acid in mango due to CI. The loss of an antioxidant like ascorbic acid due to chilling injury might be possibly to combat chilling-induced oxidative stress in fruit. Chilling temperatures enhanced AOS proliferation and reduced scavenging efficiency through such factors as chilling related inactivation of antioxidants and / or impeded antioxidant turnover. Chilling temperatures altered the equilibrium between AOS gen-

eration and defence mechanisms such that oxidatively induced chilling injury was observed (HODGES et al. 2004). The low ascorbic acid content in PP packed fruits could be due to high CO_2 during storage, which might have hampered its biosynthesis during storage. It was interesting to observe an increase in ascorbic acid content during ripening of 'Solo' papaya (WENKAM 1979). An optimum MA had been useful in reducing oxidative stress by maintaining low O_2 and high humidity around the fruit. The role of CA/MA in retention of nutritional quality of fruits and vegetables is well known (KADER et al. 1989). In our study, MAP supplemented with optimum storage temperature maintained ascorbic acid content in papaya fruit during storage and ripening.

Total carotenoids and lycopene

MAP significantly affected the total carotenoids and lycopene content of ripe papaya fruits. The higher total carotenoids and lycopene content were observed in MA packed fruits stored for 30 days at 7 or 13 °C + 7 days in air at 20 °C compared to 20 days + 7 days in air at 20 °C (Table 2). The increase in total carotenoids and lycopene content can be explained on the basis of in-package atmospheres prevailing during storage. In general, the low oxygen level (<10 %) up to day 18 of storage (Fig. 1) might have resulted in fruits with lower total carotenoids and lycopene content. The increase in oxygen concentration from day 18 onwards positively influenced the total carotenoids and lycopene content. There is very little information available regarding the effect of MAP on carotenoids and other pigments. YANTARASRI et al. (1995) found that in-package O_2 concentration affected the development of peel and pulp colour in mango. The LDPE packed fruits stored at 13 °C for 30 days + 7 days in air at 20 °C showed the highest lycopene content (2.54 mg $100g^{-1}$) which constituted 72.2 % of the total carotenoids. Though carotenoids including lycopene are not much vulnerable to losses during storage and ripening, yet their quantity is important from nutritional point of view.

It can be concluded that MAP of individual papaya with LDPE or Pebax-C® film extended the storage life to 30 days at 13 °C without any chilling injury (CI) symptoms and fruit ripened normally in one week at 20 °C. MAP not only extended storage life and alleviated CI, but also helped in maintenance of antioxidant potential of fruit by retaining acceptable levels of antioxidants like ascorbic acid and lycopene.

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