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Prolonging the postharvest life of papaya using modified atmosphere packaging

Jayathunge, K.G.L.R.[1*], Prasad, H.U.K.C.[2], Fernando, M.D.[1] and Palipane, K.B.[3]

[1]Institute of Post Harvest Technology, Research & Development Center, Jayanthi Mawatha, Anuradhapura, Sri Lanka.
[2]Department of Agricultural Chemistry, Faculty of Agriculture, University of Ruhuna, Sri Lanka.
[3]Department of Food Science and Technology, Sabaragamuwa University of Sri Lanka, Buththala. Sri Lanka.

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The papaya fruit occupies a prominent position among the fruit crops grown in Sri Lanka. The effectiveness of controlling the post harvest diseases of fresh papaya variety 'Rathne' was subjected to different pre-treatments and enclosing in sealed bags made out of 0.075mm low density polyethylene (LDPE) that was evaluated under prevailing ambient conditions (31±2^{o}C and 65±5% RH). As pre-treatments, hot water dipping at 49^{o}C for 20 min. followed by spraying with 1, 3, 5 and 7% ethanol were carried out. The effectiveness of the treatments was determined by measuring the physico-chemical properties and subjective parameters namely, disease index and peel color index. The effectiveness of magnesium oxide (MgO) and potassium permanganate ($KMnO_4$) in modifying the in-package gaseous atmosphere to extend the post harvest life was also determined. The control fruit, which was kept without packaging or any pre-treatment deteriorated after 6 days while hot water dipping and spraying with 5% ethanol followed by packaging in 0.075mm LDPE was effective in extending the post harvest life of papaya up to 12 days under ambient conditions. On the other hand, MgO did not have any influence on altering the CO_2 concentrations in the in-package gaseous atmosphere and hence was not effective as a CO_2 scavenger. $KMnO_4$ was effective as an ethylene scavenger. Papaya enclosed in LDPE bags with $KMnO_4$ after subjecting to hot water dipping (49^{o}C) for 20 min, followed by spraying 5% ethanol was effective in extending the post harvest life up to 12 days.

Key words: Modified atmosphere packaging, postharvest life, papaya.

Introduction

The papaya fruit occupies a prominent position among the fruit crops grown in Sri Lanka. The early bearing habit and a continuous fruit supply

*Corresponding Auther: K.G.L.R. Jayathunge; e-mail: Lasanthi9@hotmail.com

throughout the year makes papaya a popular fruit (Kohli and Reddy, 1988). Papaya is rich in sugars and vitamins, especially carotene and riboflavin (Irulappan, 1992). Moreover, the ripe fruit is priced for its excellent taste and medicinal properties. Hence, consumption of ripe papaya facilitates digestion and relieves constipation. Also, papaya is recommended for splenitis, hemorrhoids, skin diseases, gastro intestinal disorders, hepatic and diseases of upper respiratory tract (Wickramanayake, 1998). However, marketing of fresh papaya is a great problem because of its short post harvest life, which leads to high post harvest losses (Kohli and Reddy, 1988). The post harvest losses reported for papaya are around 46% (www.agridept.gov.lk). Poor post harvest handling during storage, packaging and transportation, incidence of diseases and limited storage facilities are some of the major reasons for such high post harvest losses. Post harvest life of fresh papaya varies from three to six days under tropical climatic conditions prevailing of Sri Lanka, due to enhanced physiological activities such as respiration and other metabolic processors that are associated with deterioration of products.

Several conservation techniques have been used to extend the post harvest life of perishable agricultural commodities. Among these techniques, controlled atmosphere (CA) storage and cold storage with high relative humidity have been found to be effective in extending the post harvest life of these commodities. However, both CA and cold storage are less popular among fruit producers in Sri Lanka due to their high capital and operational costs. As a supplement to these techniques, one of the most widely used techniques to extend the post harvest life of fruits and vegetables is by modified atmosphere packaging (MAP) (Weichman, 1987). MAP is reported to be the most economical and effective method of extending the post harvest life of fruits and vegetables (Roy *et al*, 1995). In MAP, low oxygen and high carbon dioxide environment, created by produce respiration, has been successful in slowing down deterioration and growth of microorganisms in fresh fruits and vegetables due to cell membranes damage (Devece *et al,* 1999). Moreover, anaerobic respiration inside the package enhances production of volatile compounds such as acetaldehyde and ethanol, giving off-odors in fruits and vegetables (Tano *et al,* 1999). Therefore devising a MAP system of optimum gaseous composition for papaya requires selecting a film with correct permeability properties. Furthermore, the use of carbon dioxide and ethylene scavengers such as magnesium oxide, potassium hydroxide and potassium permanganate had been found to be beneficial in creating optimum atmospheric conditions (Cameron *et al*, 1989).

This study aimed to develop a modified atmosphere packaging system to extend the storage life of fresh papaya under ambient conditions by selecting a

suitable pretreatment, suitable carbon dioxide and ethylene scavengers that would establish optimum modified atmosphere conditions.

Materials and methods

Fresh papaya (variety 'Rathne') were harvested at commercial maturity stage based on peel color (25% color break stage) from a commercial farm at Anuradhapura and transported under ambient condition to the laboratory at Institute of Post Harvest Technology (IPHT). Papaya was sorted by size (1 ± 0.1 kg) and appearance. Diseased, damaged and extremely large or small papaya were discarded to minimize biological variability. Physico-chemical properties of firmness, pH, titratable acidity (TA), and total soluble solid (TSS) of fresh papaya were measured as described below.

First experiment was carried out to select a suitable pre-treatment. The experimental treatment structure was a Randomized Complete, Block Design (RCBD) with four treatments namely, 1% ethanol, 3% ethanol, 5% ethanol and 7% ethanol. Fresh papaya was subjected to hot water (49^{o}C) dipping for 20 min. (Kader, 1993) followed by spraying with 1, 3, 5 and 7% ethanol on to the fruits. Pre-treated papaya was air-dried properly, prior to enclosing in the bags made from 0.075 mm low-density polyethylene (LDPE). Fresh fruits were packaged in a surface to weight ratio of 1:1 (cm^2 g^{-1}). The heat-sealed packages were stored under ambient condition (31$\pm$2^{o}C and 65$\pm$5% RH) for twelve days. Papaya without pre-treatment and without packaging were used as the control in the experiment. Packages were opened in triplicates at 3 days intervals and physico-chemical measurements such as firmness, pH, titratable acidity (TA), total soluble solids (TSS), and percentage weight loss and subjective measurements of disease index and peel color index were taken as described below.

Physico-chemical results were subjected to analysis of variance (ANOVA) using the SAS package. Treatment means were separated by comparing the means at $p<0.05$ using Duncan's New Multiple Range Test (DMRT). Subjective measurements were analyzed by Kruscal-Wallis test using the MINITAB statistical packages.

Second experiment, fresh papaya was sorted, dipped in hot water (49^{o}C) for 20 min. (Kader, 1993) and 5% ethanol was sprayed on to fruits, air-dried and packaged (1±0.1 kg per package) in 0.075mm LDPE bags in a 1:1 surface area to weight ratio with CO_2 and C_2H_4 scavengers, MgO and $KMnO_4$ were used as CO_2 and C_2H_4 scavengers, respectively. The treatments were laid out in Randomized Complete Block Design (RCBD) and treatments were fresh papaya packaged with 5g of MgO, 5g of $KMnO_4$, 5g of MgO and 5g of $KMnO_4$ and papaya without scavengers (control. MgO and $KMnO_4$ were kept inside the package in sachets made of 0.0375 mm LDPE. The packages were stored under

ambient conditions for fifteen days. Packages were opened in triplicates at 4 days intervals and physico-chemical and subjective measurements were taken as described below.

Physico-chemical results were subjected to analysis of variance (ANOVA) using the SAS package. Treatment means were separated by comparing the means at $p<0.05$ using Duncan's New Multiple Range Test (DMRT). Subjective measurements were analyzed by Kruscal-Wallis test using the MINITAB statistical packages.

In-package concentration of oxygen, carbon dioxide and ethylene were measured by using a gas chromatograph (Varian, model CP-3800, Australia). Oxygen was measured by using thermal conductivity detector (TCD) while CO_2 and ethylene were measured using flame-ionized detector (FID). Helium was used as the carrier gas at a flow rate of 60 ml/min. Column oven, TCD and FID temperatures were of 70, 140 and 300 ^{o}C, respectively.

Weight loss during storage was determined by measuring the weight of contents of the package initially and then at intervals of withdrawn through out the storage period. Weight loss was expressed as percentage (fresh weight basis).

Flesh firmness was measured in triplicate with a fruit firmness tester (Model CS1-2, Italy) and the values were expressed as force required (1kg) to complete 1 cm penetration.

A sample of fruit was chopped using pestle and motor and juice was extracted using clean piece of cloth. The brix value was obtained using hand held refractometer (Model HR-5, Japan).

TA was determined according to the AOAC (1990) method after homogenization of 5g of cut flesh tissue with 80ml of distilled water and titrate with 0.1N NaOH. The pH of the homogenized sample was measured using the pH meter (Model 230A, USA).

Disease index was determined using a scale of 1 to 5: 1-none, 2-minimal, 3-moderate, 4-less severe, 5-severe.

Peel color index was determined using a scale of 1 to 6: 1-green, 2-color break to 1/4 yellow, 3-1/4 yellow to 1/2 yellow, 4-1/2 yellow to 3/4 yellow, 5-full yellow, 6-over ripe.

Results and discussion

First experiment

In-package CO_2, O_2 and C_2H_4 concentrations were illustrated in Fig. 1. CO_2 concentration increased during storage period of 12 days. The highest CO_2 concentration showed in samples treated by 1% of ethanol at 9th day of storage. It was about 29.7%. Least increment of CO_2 concentration showed in samples

treated with 5% ethanol throughout the storage period and varied from 11.4% to 16.6%. Oxygen concentration gradually decreased and samples treated with 1% ethanol showed lowest oxygen concentration of 1.3% at 9th day of storage. However, samples treated with 5% ethanol showed lower reduction rate of O_2 concentration. Hence, the measured O_2 concentration in samples treated with 5% of ethanol during 12 days of storage was varied from 10.3% to 3%. The C_2H_4 concentration increased in all samples throughout the storage period. It varied from 0.12% to 0.25% in samples treated with 5% ethanol during 12 days of storage. Changes in C_2H_4 concentration showed negative relationship with O_2 concentrations. However, gaseous compositions were not significantly affected by the treatments.

It is evident from Fig. 2 that packaging in LDPE bags led to a marked reduction in weight loss compare to control. At the end of 12 days storage period, control treatment showed 9.7% in weight loss while fruits packed in LDPE bags treated with 1, 3, 5 and 7% ethanol had weight loss about 2.8, 2.6 and 3% respectively. There was a significant difference in weight loss between control and packaged samples.

The initial firmness of papaya was about 20.5 kg/cm. Firmness of papaya was reduced from initial value with increment of storage period (Fig. 2). After 12 days it was about 13 kg/cm in samples treated by 5% of ethanol. However, different concentrations of ethanol did not significantly affect the firmness of papaya. On the other hand, control sample which was kept without packaging became over ripe at 9th day of storage with a firmness value of 0.27 kg/cm.

The change of TSS, TA and pH values with increasing storage period is given in Fig. 3. TSS values of fresh papaya treated with ethanol were not significantly changed from the initial values of 11^{o}Brix while control samples showed rapid increment throughout the storage period and at the end of 9th day TSS content was 13.8^{o}Brix (Fig. 3). The pH value of control samples remained constant while ethanol treated papaya showed rapid reduction throughout the storage period (Fig. 3). The control samples showed slight increment of TA up to ripening and there after it decreased. Ethanol treated papaya showed increment of TA throughout the storage period (Fig. 3).

Effect of pre-treatments on disease incidence is shown in figure 4 and treatment effect was significant at $p<0.05$. The control fruits were infected with fungal diseases and started to deteriorate after ripening. The disease index of samples treated with 5%-ethanol was recorded as 1 (none) up to 9 days of storage and started to deteriorate thereafter. Papaya treated with 1 and 3% ethanol started to deteriorate on 3rd day of storage.

There was no change in the peel color of ethanol treated papaya. It remained at color break stage up to 9 days of storage while control samples

showed color change at 3rd day of storage. Control samples turned to full yellow stage at 6 days of storage. The peel color of papaya treated with 5 and 7% ethanol was recorded as 3 (1/4 yellow to 1/2 yellow) at 12th day of storage (Fig. 4).

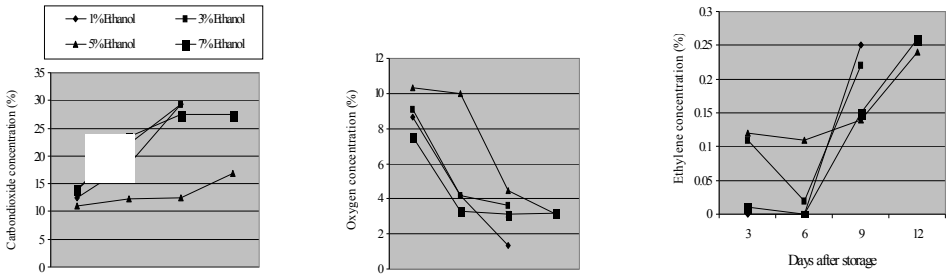

Fig. 1. Effect of ethanol concentration on in-package oxygen, carbon dioxide and ethylene concentration of fresh papaya packaged in LDPE (0.075 mm) bags and stored under ambient condition.

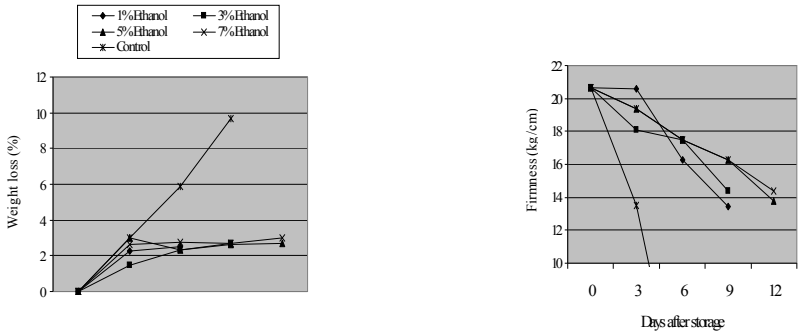

Fig. 2. Effect of ethanol concentration on weight loss percentage and firmness of fresh papaya packaged in LDPE (0.075 mm) bags and stored under ambient condition.

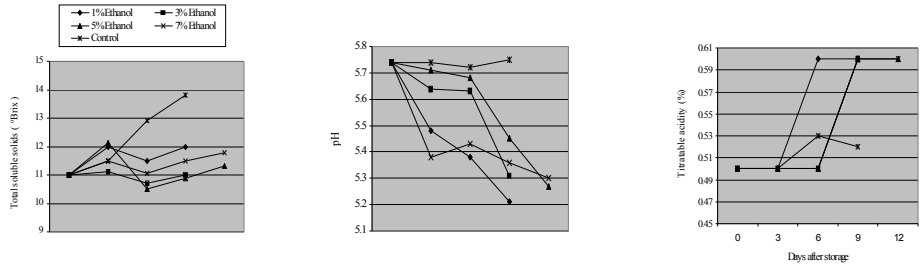

Fig. 3. Effect of ethanol concentration on total soluble solids content, pH and titratable acidity of fresh papaya packaged in LDPE (0.075 mm) bags and stored under ambient condition.

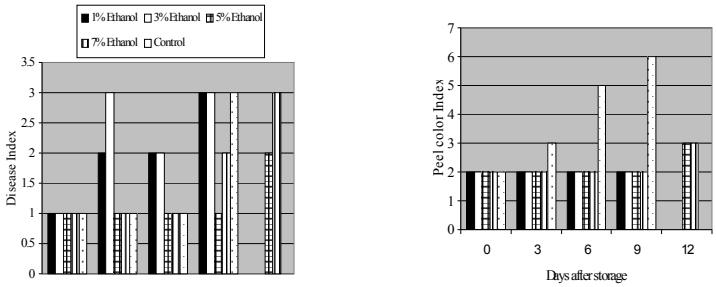

Fig. 4. Effect of ethanol concentration on disease index and peel color index of fresh papaya packaged in LDPE (0.075 mm) bags and stored under ambient condition.

Second experiment

In package CO_2, O_2 and C_2H_4 concentrations are illustrated in Fig. 5. CO_2 and C_2H_4 concentrations increased with increasing storage period while O_2 concentration decreased. In-package CO_2 and O_2 concentrations of control and papaya containing MgO, $KMnO_4$, and MgO with $KMnO_4$ were not significantly different. Papaya packaged with scavengers showed 16.6% CO_2 concentration at 12th day of storage while control sample showed 21.2% on the same day. The lowest O_2 concentration was shown by papaya packaged with MgO after 6 days of storage while the highest O_2 concentration of 3% was shown by the samples packaged with MgO and with both MgO and $KMnO_4$ at 12th day of storage. The effect of $KMnO_4$ as an ethylene scavenger was significant at $p<0.05$. Papaya packaged with $KMnO_4$ and MgO with $KMnO_4$ showed the lowest ethylene concentrations throughout the storage period.

Papaya packaged with MgO showed the highest weight loss after 3 days of storage and was significantly different with other treatments (Fig. 6). After 12 days of storage weight loss of control samples were 3.9% while others were 2.9%.

The initial firmness of papaya was about 20.5 kg/cm. Firmness of papaya was reduced from initial value with increment of storage period (Fig. 6). After 12 days, it was 10.5 kg/cm in control samples while firmness was 16.0 and 15.5 kg/cm in samples packaged with both MgO and $KMnO_4$, and with $KMnO_4$, respectively. Hence, treatments were significantly affected the firmness of papaya.

The change of TA, TSS and pH values with storage period is shown in Fig. 7. The initial TSS content of 11^{o} Brix was not significantly different in samples packaged with MgO, $KMnO_4$ and with both MgO and $KMnO_4$ at 12th day of storage. Control samples showed the highest value of TSS content on the same day. There was no significant change in the pH value from the initial values of 0.5% in all samples including the control. TA in all samples increased

up to 3rd day of storage and then started to decrease and after 9th day of storage it showed constant value.

The effect of MgO and $KMnO_4$ in controlling diseases of papaya is shown in Fig. 8. Samples packaged with $KMnO_4$ and both with MgO and $KMnO_4$ showed no disease incidences up to 12 days of storage, while others started to deteriorate.

Samples packaged with $KMnO_4$ and both with MgO and $KMnO_4$ remained at color break stage up to 15 days of storage. The control samples changed peel color to ¼ to ½ yellow at 12 days of storage while papaya packaged with MgO changed at 9th day of storage (Fig. 8).

Developing a MAP system of optimum gaseous composition for fruits requires a selecting a film which should be permeable to CO_2 and O_2. Even more it should absorb and remove ethylene to establish beneficial in-package concentration of these gases and to avoid anaerobiosis, there by increasing postharvest life of the packaged produce and retain the firmness of fruits and vegetables (Hening and Gilbert, 1975). MAP of fruits helps to lower the respiration activity, delay ripening and softening and reduce incidence of physiological disorders and decay-causing pathogens (Kader *et al*, 1989). Scott (1984) reported that the use of sealed polyethylene bags to develop modified atmosphere might be of commercial value for extending the storage life of kiwifruits. Illeperuma et al, (2000) found that mature 'Kolikuttu' bananas were packaged under modified atmosphere conditions using low-density polyethylene (LDPE-0.075mm) stored at 14°C and 94% RH, extended postharvest life up to 24 days. Previous studies (Zagory and Kader, 1988; Jayathunge *et al*, 2003) have recommended LDPE for packaging of fresh fruits and vegetables. Therefore, in this experiment LDPE (0.075 mm) was used as packaging material to establish modified atmosphere (MA) condition.

Papaya was reported as a climacteric fruit. Climacteric fruits show high production of CO_2 in their respiration process. Respiration is the process by which stored organic matters are broken down into simple products with a released of energy. O_2 is used in this process and CO_2 is produced. Kader, (1993) reported that MAP technique involved either actively or passively controlling or modifying the atmosphere by altering the CO_2 and O_2 concentrations. It has been reported that high CO_2 and low O_2 concentrations created within polythene bags effective to decrease the rate of respiration, there by delaying ripening of 'Kolikuttu' banana under ambient conditions (Illeperuma and Galappaththi, 2000). The experiment showed high CO_2 and low O_2 concentrations at 16% and 3% respectively, under ambient condition (31±2°C and 65±5% RH). Similar to this study, Satyan et al, (1992) reported

that a storage study on 'Williams' bananas packed in polythene tubes revealed higher levels of in-package CO_2 level ranging from 7.5%-22.6%.

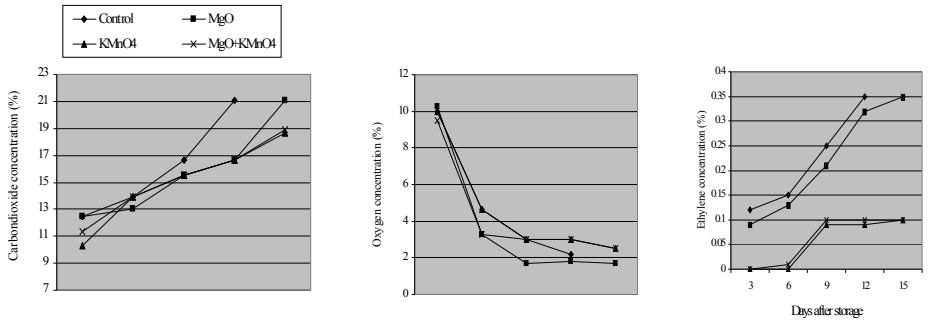

Fig. 5. Effect of carbon dioxide and ethylene scavengers on in-package oxygen, carbon dioxide and ethylene concentration of fresh papaw packaged in LDPE (0.075 mm) bags and stored under ambient condition.

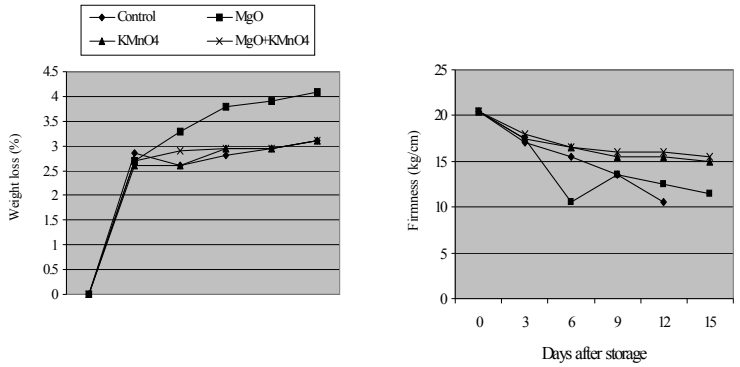

Fig. 6. Effect of carbon dioxide and ethylene scavengers on weight loss and firmness of fresh papaw packaged in LDPE (0.075 mm) bags and stored under ambient condition.

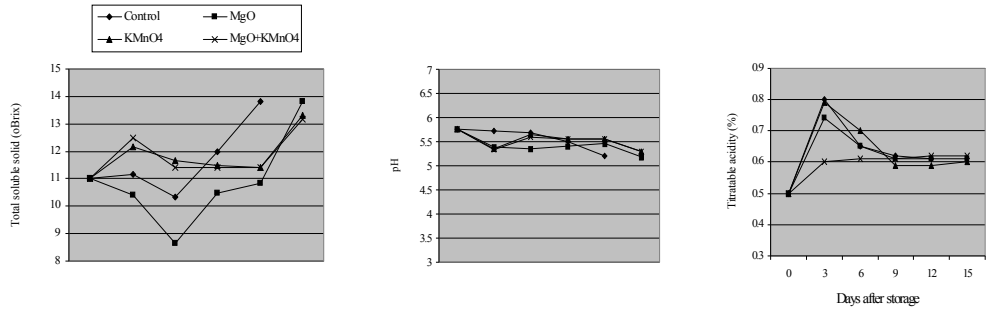

Fig. 7. Effect of carbon dioxide and ethylene scavengers on total soluble solid content, pH and titratable acidity of fresh papaw packaged in LDPE (0.075 mm) bags and stored under ambient condition.

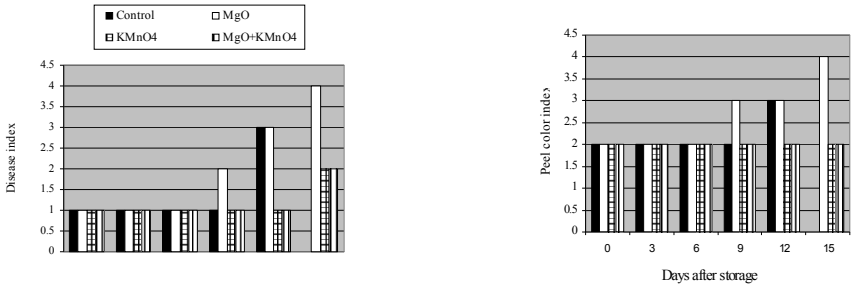

Fig. 8. Effect of carbon dioxide and ethylene scavengers on disease index and peel color index of fresh papaw packaged in LDPE (0.075 mm) bags and stored under ambient condition.

Ethylene is essential to initiate ripening (Reid, 2002). Liu (1970) has suggested that low O_2 concentrations inside the fruits tissues might delay the ripening by inhibiting ethylene synthesis. Kader, (2000) reported that low O_2 and high CO_2 concentration atmospheres reduced the rate of ethylene production. Ethylene production rate can be reduced by lowering O_2 level (less than 8%) and elevating CO_2 level (more than 1%) around the commodity. Ethylene production was reported as about 10-100 µl/kg-hr (Kader, 1993). In this experiment, ethylene production varied from 0.12% to 0.25% in samples, which was kept without scavengers while control, which was kept without packaging, turned to full yellow stage at 4 days of storage. The absorption of ethylene by using $KMnO_4$ lower the ethylene concentration within the packages at 12 days of storage**.** This condition delayed the ripening process**.** Satyan et al, (1992) reported the usage of ethylene absorbents in delaying the ripening process. Hence, in this experiment papaya packaged with ethylene scavengers retained their green color up to 12 days of storage.

Water loss is a main cause of deterioration, resulting in direct quantitative loss as well as losses in appearance, textural and nutritional quality (Kader,

2000). Papaya contains about 90% water by weight (www.agridept.gov.lk). Zagory and Kader (1988) reported that weight loss of papaya is mainly due to moisture loss by transpiration and loss of carbon reserves due to respiration. Papaya packaged in polyethylene bags had lower weight loss than control due to lower respiration rate. Gradual reduction of the rates of weight loss was probably due to saturation of atmosphere within the packages by water. Water loss occurs because of a water vapor pressure gradient and high relative humidity could be effective in minimizing water loss (Kader, 1993).

Firmness of papaya in all experiments showed the same pattern. It was reduced throughout the storage period. Kader (1993) described that breakdown of pectin and other polysaccharides results in softening of fruits.

Experiment results showed that TA, TSS and pH were not significantly changed. These results were similar to results of Illeperuma and Galappattty, (2000), that TA, TSS and pH of banana stored under MA were not significantly affected.

Decay was mentioned as one of the limiting factor for postharvest life of fruits and vegetables. The effects of MA on diseases can be either direct or indirect (Kader, 2000). Control treatment (with out packing) was deteriorated within 6 days of storage. Application of pre-treatments enhanced the postharvest life of papaya. Kader, (1993) reported that preheating papaya for 20 minutes at 49 ^{o}C was effective to control anthracnose of papaya. Exposition of ethanol vapor (1mg/kg) for period of 6-12 hr before storage at room temperature (28-33^{o}C) was effective to extend the storability of green banana significantly (Chen *et al*, 1997). Surface color of papaya is one of most important factor in determining ripening of papaya. MA retained the peel color of papaya in green stage due to lower ethylene production.

In conclusion, papaya enclosed in LDPE bags with $KMnO_4$ after subjecting to hot water dipping (49^{o}C) for 20 min, followed by spraying 5% ethanol was effective in extending the postharvest life up to 12 days under ambient conditions (31 $\pm$ 2^{o}C and 65 $\pm$ 5% RH).

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