

## Effect of Waxing with Paraffin and Modified Atmosphere Packaging on the Storage of Cavendish Banana (*Musa cavendishii* L var. Montel)

RAZALI MUSTAFFA, AZIZAH OSMAN,  
SUHAILA MOHAMED and SALMAH YUSOF

Faculty of Food Science and Biotechnology  
Universiti Putra Malaysia

43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

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### ABSTRAK

Kajian perlakuan lepastuai dengan cecair parafin, 'clingwrap', polietilena berdensiti rendah (LDPE) dengan dan tanpa kalium permanganat ( $KMnO_4$ ) telah dijalankan untuk memanjangkan hayat simpanan buah pisang 'Montel' (*Musa cavendishii* L.) di bawah suhu penyimpanan  $15\pm 1^\circ C$  dan juga suhu ambien ( $27\pm 1^\circ C$ ). Buah-buah yang dibungkus di dalam LDPE dengan  $KMnO_4$  telah masak dalam jangkamasa 60 hari selepas dituai pada minggu 12 dari mulanya pengeluaran jantung. Ini diikuti oleh perlakuan dengan 'clingwrap' (42 hari), cecair parafin (36 hari), kawalan pada suhu  $15\pm 1^\circ C$  (24 hari) dan kawalan pada suhu ambien ( $27\pm 1^\circ C$ ; 18 hari). Peratus kehilangan berat buah, warna kulit dan isi buah telah meningkat dengan sangat bererti ( $P < 0.01$ ) bagi semua perlakuan di sepanjang masa penyimpanan. Selain daripada itu, nilai tekstur dan kandungan tanin buah pula menurun dengan sangat bererti ( $P < 0.01$ ). Peningkatan jumlah pepejal larut (TSS) dan gula adalah pertahan pada mulanya tetapi beransur-ansur meningkat di akhir masa penyimpanan. Walau bagaimanapun, nilai pH, kandungan-kandungan asid tertitrat (TA), asid askorbik (AA) dan kanji bagi buah-buah dari semua perlakuan didapati tidak seragam semasa penyimpanan. Terdapat perbezaan yang sangat bererti ( $P < 0.01$ ) dalam pengeluaran etilena ( $C_2H_4$ ) dan karbon dioksida ( $CO_2$ ) bagi buah-buah dari semua perlakuan semasa penyimpanan. Oleh yang demikian, didapati bahawa buah yang dibungkus dalam polietilena berdensiti rendah (LDPE) dengan  $KMnO_4$  merupakan perlakuan yang terbaik untuk memanjangkan hayat simpanan buah pisang 'Montel'.

### ABSTRACT

Postharvest treatment with liquid paraffin, clingwrap, low density polyethylene (LDPE) with and without potassium permanganate ( $KMnO_4$ ) was studied to extend the shelf life of 'Montel' banana (*Musa cavendishii* L), under refrigeration ( $15\pm 1^\circ C$ ) and at ambient temperature ( $27\pm 1^\circ C$ ). The fruits packed in LDPE with  $KMnO_4$  ripened within 60 days after harvesting at week 12 from flower emergence. This was followed by treatments with clingwrap (42 days), liquid paraffin (36 days), control at  $15\pm 1^\circ C$  (24 days) and control at ambient temperature (18 days). The percentage weight loss, peel and pulp colours of fruits increased significantly ( $P < 0.01$ ) for all treatments during the storage period. On the other hand, the texture values and tannin content of the fruit decreased significantly ( $P < 0.01$ ). The rise in total soluble solids (TSS) and sugar was slow initially but gradually increased at the end of the storage period. However, pH, titratable acidity (TA), ascorbic acid (AA) and starch contents of fruits from all treatments were found to be inconsistent during storage. There is a highly significant ( $P < 0.01$ ) difference in the production of ethylene ( $C_2H_4$ ) and carbon dioxide ( $CO_2$ ) found from fruits of all treatments during storage. Fruits packed in low density polyethylene (LDPE) with  $KMnO_4$  was found to be the best treatment to extend the storage life of 'Montel' banana.

### INTRODUCTION

Storage of dessert bananas at temperatures below  $13^\circ C$  result in chilling injury symptoms such

as retarded development of yellow colour (Kim and Lee 1962; Olorunda *et al.* 1978) and failure to ripen (Haard and Timbie 1976), whereas

storage at 13°C is limited to two weeks (Salunkhe and Desai 1984). Modified atmosphere (MA) storage is a method which can be used in conjunction with refrigeration to enhance storage life of some fruits and vegetables (Kader *et al.* 1989). Bananas can be successfully stored in sealed polyethylene bags (Scott and Roberts 1966). As a result of respiration, an atmosphere high in CO<sub>2</sub> and low in O<sub>2</sub> will ensue with time. There are many factors affecting the respiration rate such as temperature, stage of development, fruit injury and many others (Phan *et al.* 1975). Ethylene is of great importance in postharvest physiology because it is intimately involved in the ripening of fruits and is sometimes called the ripening gas (Ryall and Lipton 1979). Refrigeration at 10-14°C alone is only sufficient to preserve the greenness of the banana for 10-34 days (Abdullah *et al.* 1990). Effect of surface treatment of 'Montel' banana with paraffin and various techniques of modified atmosphere have never been reported. Therefore, the objective of this work was to study the effect of these treatments on the physico-chemical characteristics of 'Montel' banana harvested at week 12 after flower emergence during storage.

## MATERIALS AND METHODS

### Fruit Source

Banana bunches were harvested at week 12 after flower emergence. The harvested fruits were immediately transported from UPM experimental plot to the laboratory of the Faculty of Food Science and Biotechnology, UPM for further evaluation. Three hands (2nd, 3rd and 4th hands from the top) were taken from each bunch. Only fruits that were free from mechanical injury were used in this study. Changes in texture and pulp colour were obtained from 8 individual fruits from each hand at each observation. The same individual fruit samples were used as composite samples for the determination of all the other chemical characteristics. Continuous assessment of percentage weight loss and change in peel colour were obtained from three other (2nd, 3rd and 4th) hands. Observations were made at every 6 day intervals and experiments were done in triplicates.

### Postharvest Treatments

Banana hands were randomly selected from the bunches and subjected to different postharvest treatments as below:

- control at optimum temperature (15±1°C; 85-90% RH),
- control at ambient temperature (27±1°C; 55-85% RH),
- fruits dipped for 1 min in liquid paraffin and followed by air drying,
- fruits wrapped in commercial clingwrap of 0.01 mm thickness,
- fruits packed and sealed in low density polyethylene (LDPE) bag of 0.05 mm thickness, and
- fruits packed and sealed in LDPE bag with an inclusion of a cement block impregnated with saturated KMnO<sub>4</sub> solution.

All treated fruit hands except the control at ambient temperature were stored at 15±1°C; 85-90% RH.

### Physical Analysis

The following parameters were determined: fruit weight, peel and pulp colours and hardness. Fruit weight was determined using an electronic top pan balance (model 4000C Precissa). Fruit peel and pulp colour measurements were taken at four different positions of the fruit using Hunter Lab (model Minolta CR-300). The firmness measurements were performed on 3 different places of the fruit using an Instron Universal Testing Machine Model 1140 with an 8 mm diameter plunger and a drive speed of 100 mm min<sup>-1</sup>. The load cell force range used was 0-50 kg.

### Chemical Analysis

Analyses of the chemical parameters were carried out on the following day after the fruit pulp were blended and kept in the freezer (-20°C). The sample extraction and preparation methods for sugar analysis were carried out according to Wills *et al.* (1980). Sugar was analysed by HPLC using method of Hunt *et al.* (1977). Titratable acidity (TA) and ascorbic acid (AA) were analysed according to the methods of Ranganna (1977). Samples prepared for TA were also used to determine pH (AOAC 1980). For the estimation of titratable acidity, 10 g of homogenised fruit pulp samples were heated to boiling in a beaker with distilled water for 30 min. The volume was made up to 100 ml and a 5 ml aliquot was titrated against 0.1 M NaOH, with phenolphthalein as indicator. The results were expressed as percentage malic acid. The puree extracted was taken to measure the solu-

ble solids content of the fruit using an Otago hand refractometer (0-32°Brix).

The amount of starch was determined by the method of SIRIM (1992) with some modification. For starch extraction, the weighed sample (2.5 g dried sample) of banana pulp was heated with 150 ml of 80% ethanol for 1 hr. The solution was then centrifuged for 10 min at 3000 rpm and the residue was washed with 50 ml distilled water. The pellet was considered to be starch. It was then heated in the oven for 3 hrs to remove the ethanol and to gelatinise the starch. The gelatinised starch was then hydrolysed with 2.5% hydrochloric acid for 2 hrs. The prepared solution was titrated using Fehling solution A and B and starch was calculated based on the reducing sugar released from the hydrolysis.

Sugars were determined by HPLC using a Waters 600 Controller liquid chromatograph with a Model 410 RI detector, a Hibar prepacked stainless steel column (300 X 3.9 mm i.d.) packed with 10 µm µBondapak-NH<sub>2</sub>, and with acetonitrile and distilled water (80/20; v/v) as eluent. The solvent mixture was degassed for 20 min under sonicator. Fructose, glucose, sucrose and maltose (1-5%; w/v) were used as calibration standards. Ten grams of the fruit material were heated with 60 ml of 85% methanol on a steam bath for 30 min, filtered through Whatman No. 1 filter paper into a round bottom flask and the residue was similarly re-extracted twice with 60 ml portions of methanol. The filtrate was evaporated to less than 10 ml under vacuum at 50°C in a rotary evaporator and made up to 10 ml in a volumetric flask. The solution was then filtered through a Sep-Pak C<sub>18</sub> cartridge and a 0.45 µm membrane filter, using a syringe. The injection volume was 10 µl.

#### *Detection of Ethylene and Carbon Dioxide*

One hand from each postharvest treatments was used for this continuous assessment. After measuring the volumes of the fruits, they were sealed in 4900 ml dessicator with inlet and outlet septa for 4 hrs. Amount of ethylene produced were detected for each postharvest treatment during storage time by injecting 1000 µl of the gas sample (under a static system) into a 5890 Hewlett Packard gas chromatograph fitted with flame ionization detector (FID) and a stainless steel column (254 mm X 3.175 mm OD) packed with 80-100 mesh Haye Sep D. Simultaneously,

carbon dioxide was detected using a different detector (thermal conductivity detector; TCD), although the same column was used. The flow rate of the purified helium gas was 30 ml min<sup>-1</sup> and the oven temperature was 40°C. Experiments were done in triplicates.

#### *Statistical Analysis*

For data analyses, the SAS (Statistical Analysis System) programme was used (SAS INSTITUTE 1985). The values obtained were subjected to analyses of variance and tested using the Duncan's Multiple Range Test (DUNCAN).

### RESULTS AND DISCUSSION

Bananas packed in LDPE with KMnO<sub>4</sub> ripened within 60 days after harvesting at week 12 from flower emergence. This was followed by treatments with clingwrap (42 days), liquid paraffin (36 days), control at 15°C (24 days) and control at ambient (18 days). However, bananas packed in LDPE (without KMnO<sub>4</sub>) gave the same storage life as with LDPE (with KMnO<sub>4</sub>). Bananas stored in sealed polyethylene (PE) bags are known to have a longer storage life than those stored without bags (Scott and Roberts 1966; Chiang 1967; Smock 1967; Woodruff 1969; Liu 1970). Polyethylene bags delayed ripening and the use of potassium permanganate (KMnO<sub>4</sub>) further extended the storage life of bananas by about two weeks, by reducing deterioration of the fruit due to softening during storage (Scott *et al.* 1970; Wills *et al.* 1981).

Fig. 1-3 show that the peel colour of bananas from different postharvest treatments differ very significantly ( $P < 0.01$ ). The peel colour of fruits was dark green at the early and then started to change during storage time until day 60 where the peel colour change to bright yellowish. Maximum colour development can be attained by rapid ripening at temperatures up to 24°C at high humidity, although this would reduce shelf life (Marriott 1980). There was also a highly significant ( $P < 0.01$ ) difference in pulp colour of fruits from different postharvest treatments during storage (Fig. 4-6). The pulp colour of fruits was white creamy at the early storage and then started to change during storage time until day 60 where the pulp colour change to slightly bright yellowish as similarly reported by Wainwright and Hughes (1989). Bananas that were not sealed in polyethylene bags became ripe after seven days of storage, while all fruits

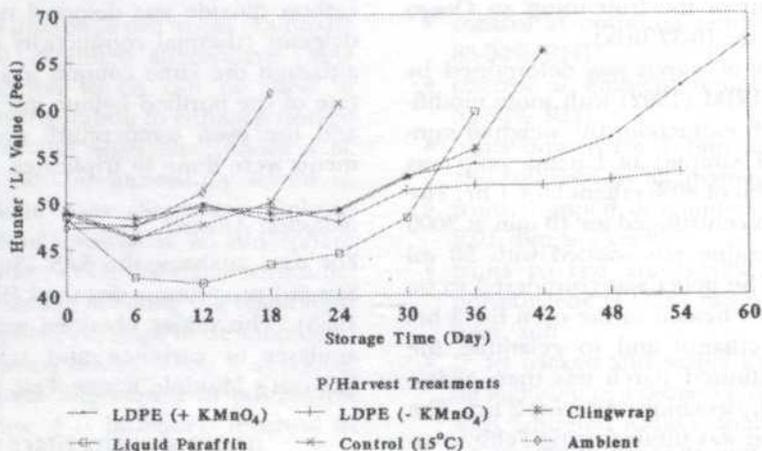


Fig. 1. Effect of postharvest treatments on Hunter 'L' value of 'Montel' banana peel during storage

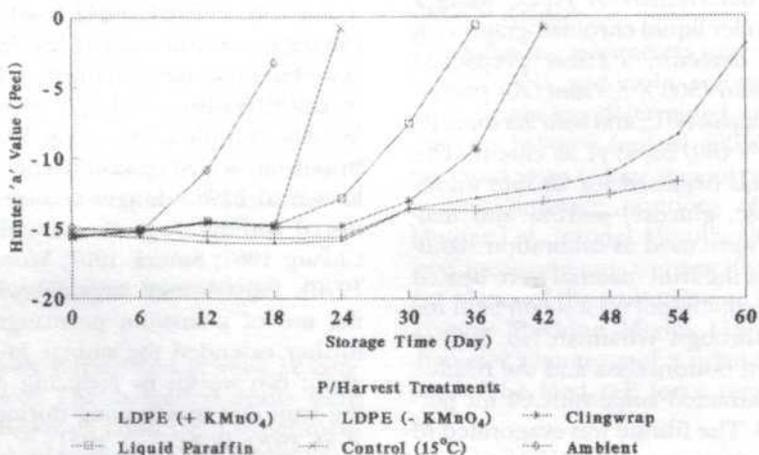


Fig. 2. Effect of postharvest treatments on Hunter 'a' value of 'Montel' banana peel during storage

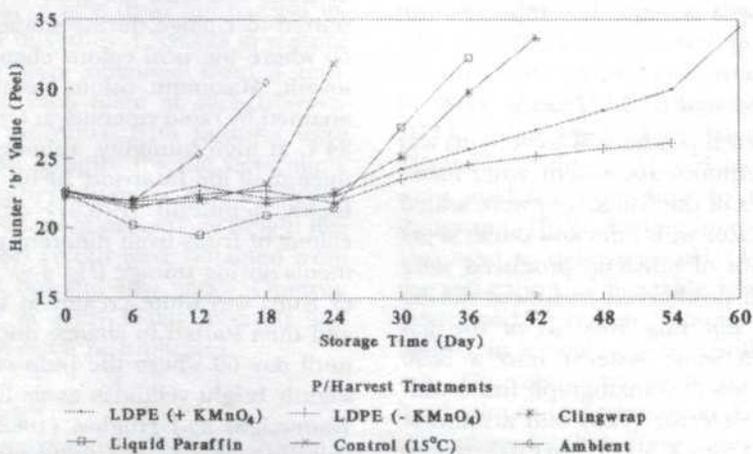


Fig. 3. Effect of postharvest treatments on Hunter 'b' value of 'Montel' banana peel during storage

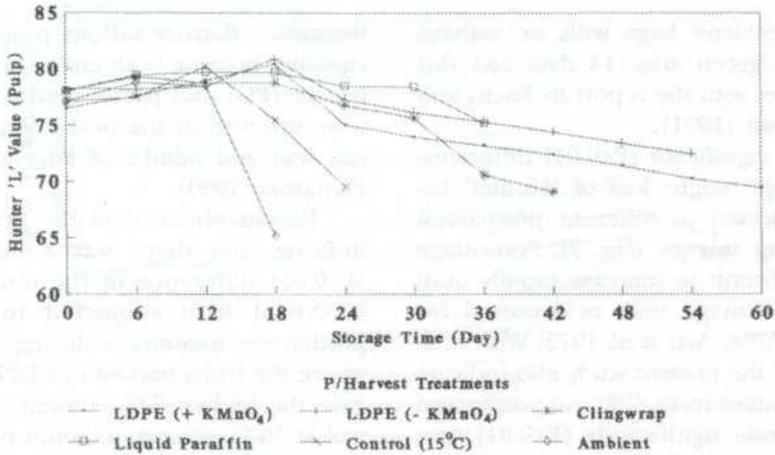


Fig. 4. Effect of postharvest treatments on Hunter 'L' value of 'Montel' banana pulp during storage

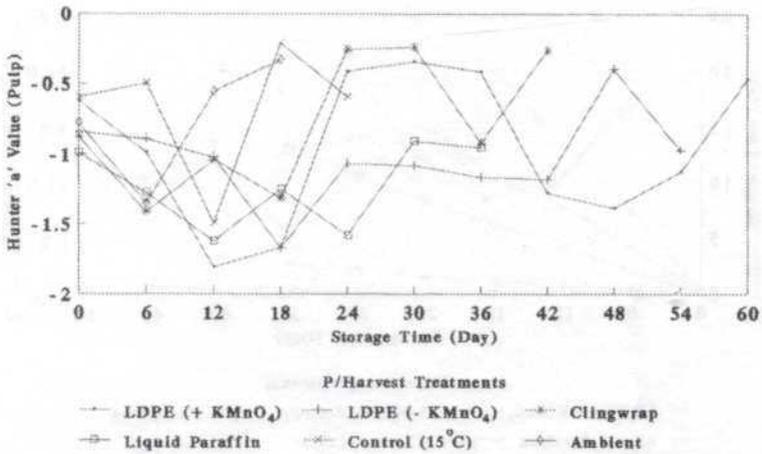


Fig. 5. Effect of postharvest treatments on Hunter 'a' value of 'Montel' banana pulp during storage

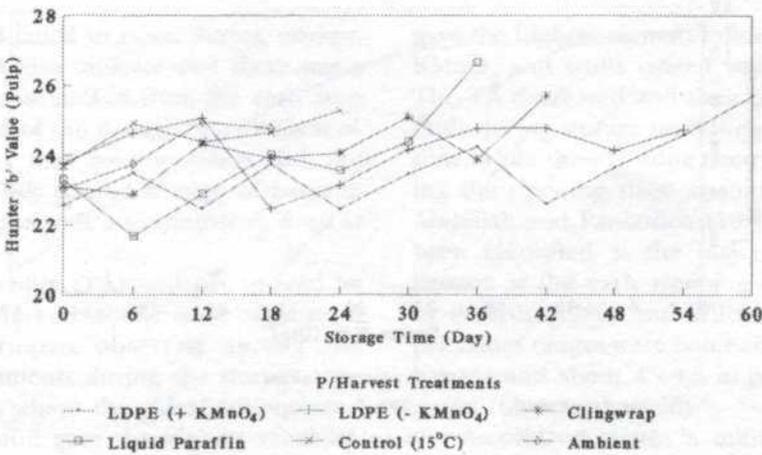


Fig. 6. Effect of postharvest treatments on Hunter 'b' value of 'Montel' banana pulp during storage

sealed in polyethylene bags with or without  $KMnO_4$  was still green after 14 days and this observation agrees with the report by Fuchs and Temkin-Gorodeiski (1971).

There was a significant ( $P < 0.01$ ) difference in the percentage weight loss of 'Montel' banana when subjected to different postharvest treatments during storage (Fig. 7). Percentage weight loss was found to increase rapidly until the end of the storage time as reported for other bananas (Abou Aziz *et al.* 1975; Wills *et al.* 1981). Results of the present study also indicate that the fruit firmness from different postharvest treatments decrease significantly ( $P < 0.01$ ) during storage (Fig. 8). However percentage weight loss was negatively correlated ( $r^2 > 0.5$ ) with

firmness. Banana softens progressively during ripening because both enzymes the polygalacturonase (PG) and pectin methyl esterase (PME) were involved in the pectin degradation in the cell wall and middle of lamella (Abdullah and Pantastico 1990).

Results obtained in the present study also indicate that there was a highly significant ( $P < 0.01$ ) difference in the total soluble solids (TSS) of fruit subjected to the different postharvest treatments during storage (Fig. 9), where the fruits packed in LDPE (with  $KMnO_4$ ) gave the highest TSS content followed by control at 15°C, clingwrap, liquid paraffin and control at ambient. Fruits wrapped in LDPE (without  $KMnO_4$ ) had the lowest TSS content and the

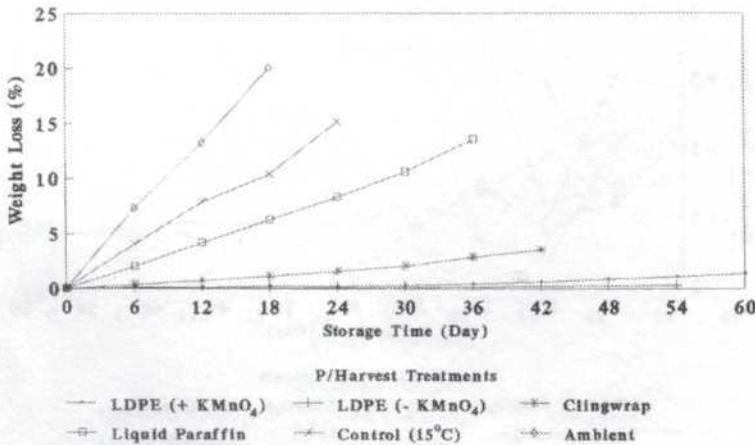


Fig. 7. Effect of postharvest treatments on percentage weight loss of 'Montel' banana during storage

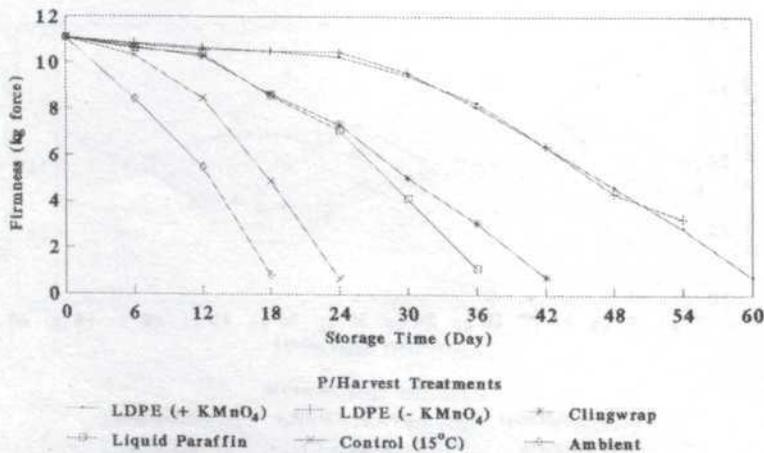


Fig. 8. Effect of postharvest treatments on firmness of 'Montel' banana during storage

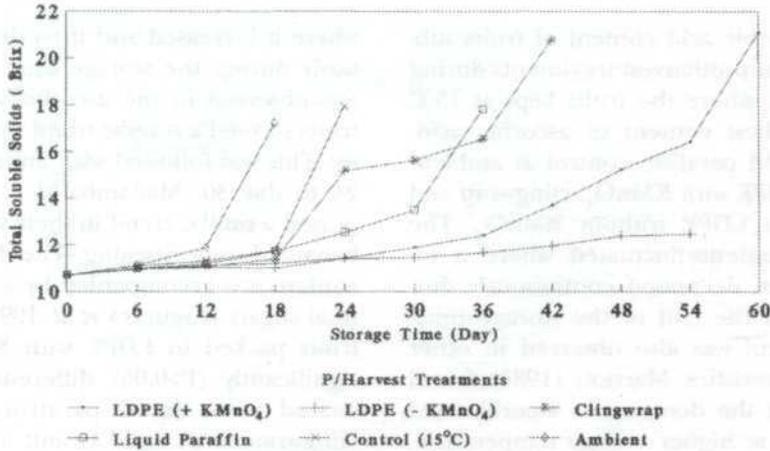


Fig. 9. Effect of postharvest treatments on total soluble solids of 'Montel' banana during storage

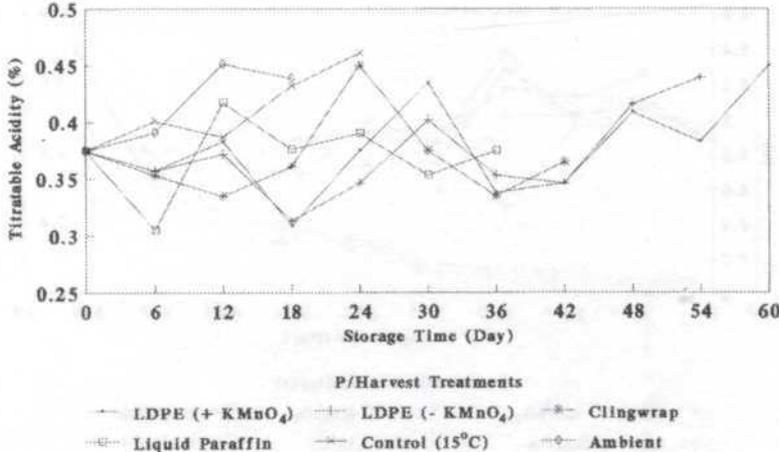


Fig. 10. Effect of postharvest treatments on titratable acidity of 'Montel' banana during storage

fruits rotted and failed to ripen during storage. Results obtained also indicate that there was a continuous increase in TSS from the early storage until the end of the storage time. Wills *et al.* (1983) reported that soluble solids did not change significantly during storage of bananas in fiber-board trays with a polyethylene wrap at 2-8°C.

Titratable acidity (TA) and pH showed an irregular pattern and there were significant ( $P < 0.01$ ) differences observed among the postharvest treatments during the storage time (Fig. 10 and 11), where the pH of fruits coated with liquid paraffin gave the highest value followed by the control at 15°C and LDPE (with  $KMnO_4$ ). However, the TA of fruits kept at 15°C

gave the highest content followed by LDPE with  $KMnO_4$  and fruits coated with liquid paraffin. The TA decreased and then increased continuously during storage until the end of the storage time, while the pH value decreased when reaching the ripening stage as similarly reported by Abdullah and Pantastico (1990). Malic acid has been identified as the major acid present in banana at the early ripening stage as reported by Forsyth (1980) and Wills *et al.* (1983). The pH values ranges were between 5.0-5.8 for green banana and about 4.2-4.8 in postclimacteric bananas (Simmonds 1966).

Ascorbic acid was a minor constituent of fruits (Wills *et al.* 1989). In the present study, there was a highly significant ( $P < 0.01$ ) differ-

ence in the ascorbic acid content of fruits subjected to different postharvest treatments during storage (Fig. 12), where the fruits kept at 15°C showed the highest content of ascorbic acid, followed by liquid paraffin, control at ambient temperature, LDPE with KMnO<sub>4</sub>, clingwrap and fruits packed in LDPE without KMnO<sub>4</sub>. The ascorbic acid content fluctuated where it increased and then decreased continuously during storage until the end of the storage time. This similar trend was also observed in other chemical characteristics. Marriott (1980) found in his study that the decrease in ascorbic acid content is rapid at higher storage temperature.

From Fig. 13, it can be seen that the starch composition of the fruits was found to fluctuate

where it increased and then decreased continuously during the storage time. A similar trend was observed in the ascorbic acid content but fruits showed a reverse trend with titratable acidity. This was followed with an increase from day 24 to day 30. Madamba *et al.* (1977) also reported a similar trend in their study of 'Lakatan' banana during ripening. The decrease in starch content was accompanied by an increase in the total sugars (Esguerra *et al.* 1992). However, the fruits packed in LDPE with KMnO<sub>4</sub> were not significantly (P>0.05) different with the fruits coated with liquid paraffin, wrapped with clingwrap, kept at 15°C and ambient temperature. A similar trend was reported by Esguerra *et al.* (1992).

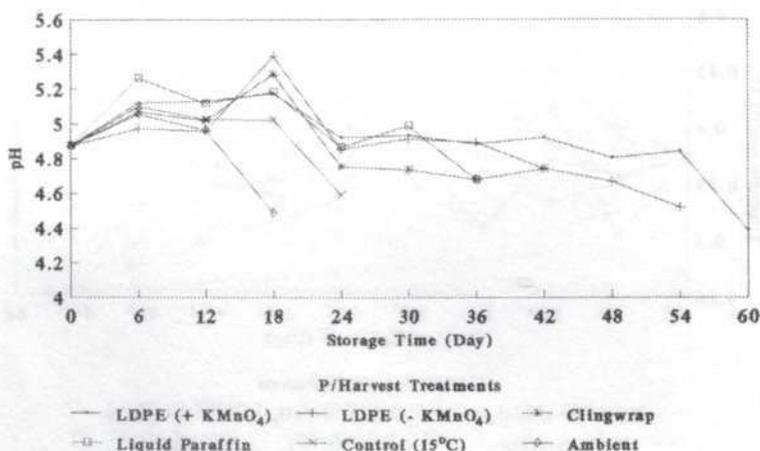


Fig. 11. Effect of postharvest treatments on pH of 'Montel' banana during storage

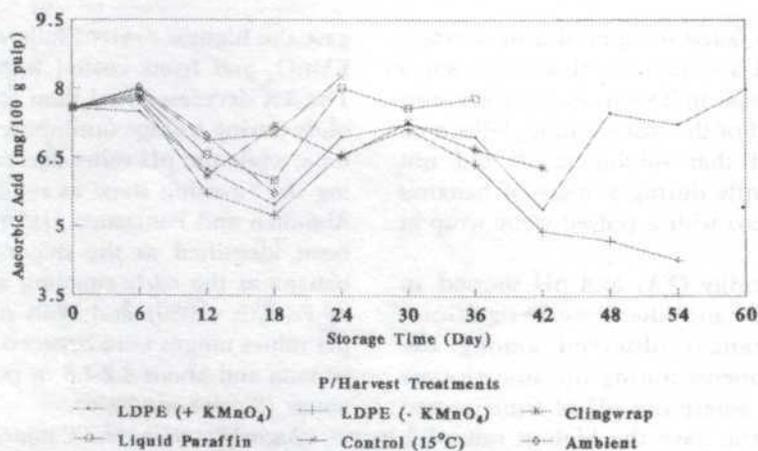


Fig. 12. Effect of postharvest treatments on ascorbic acid of 'Montel' banana during storage

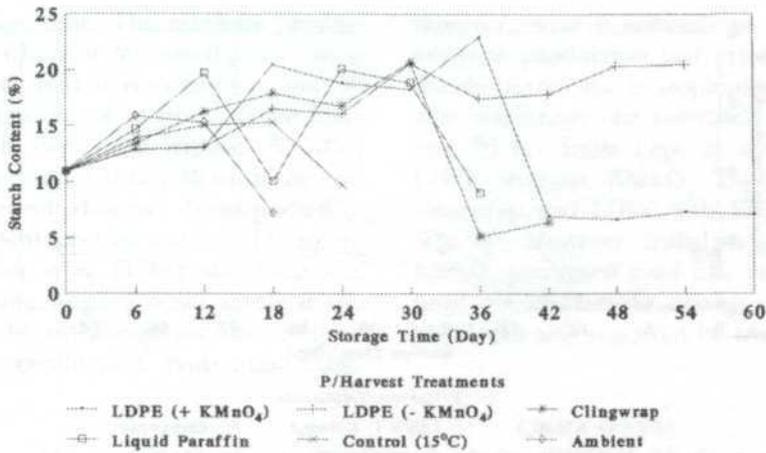


Fig. 13. Effect of postharvest treatments on starch content of 'Montel' banana during storage

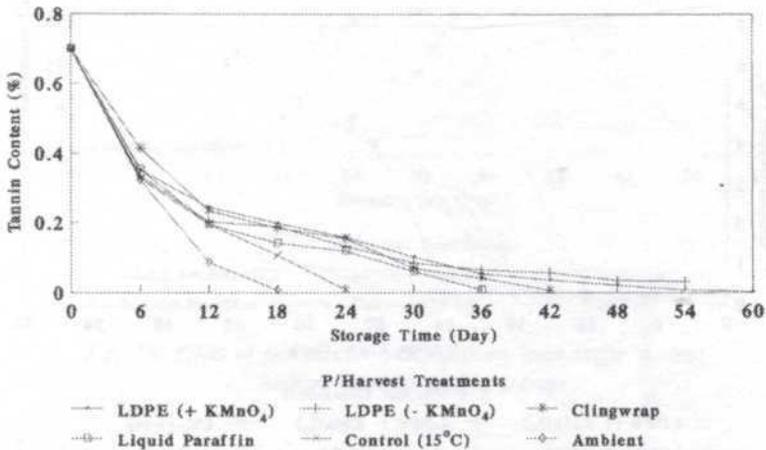


Fig. 14. Effect of postharvest treatments on tannin content of 'Montel' banana during storage

The tannin content of fruits from different postharvest treatments decreased drastically ( $P < 0.01$ ) during storage (Fig. 14) and a similar trend was also reported by Goldstein and Swain (1963). The other component that affects the taste of fruits is the sugar content. There is a highly significant ( $P < 0.01$ ) difference in the sugar content of 'Montel' banana from different postharvest treatments during storage (Fig. 15-18). The total sugar increased from day 0 until the end of the storage time (Fig. 18) as similarly reported by Madamba *et al.* (1977) and Munasque and Mendoza (1990). There were an irregular increase in fructose (Fig. 15), glucose (Fig. 16) and sucrose (Fig. 17) at the early storage but the increase was rapid with ripening.

Broughton and Wu (1979) reported that there was no decrease in sugar with prolonged storage even after the "eating ripe" stage had been passed. The level of glucose increased with post-ripened storage of 'Embun' and 'Rastali' bananas (Broughton and Wu 1979), as it did in other bananas (Spencer 1966; Simmonds 1966). From the figures, it can be seen that the sucrose content was the highest individual sugar compared to the other sugar contents and a similar result was reported by Wills *et al.* (1983) who found that the sucrose content was always the major sugar present in 'Cavendish' banana.

There were significant ( $P < 0.05$ ) differences in ethylene (Fig. 19) and carbon dioxide (Fig. 20) production among the different postharvest treat-

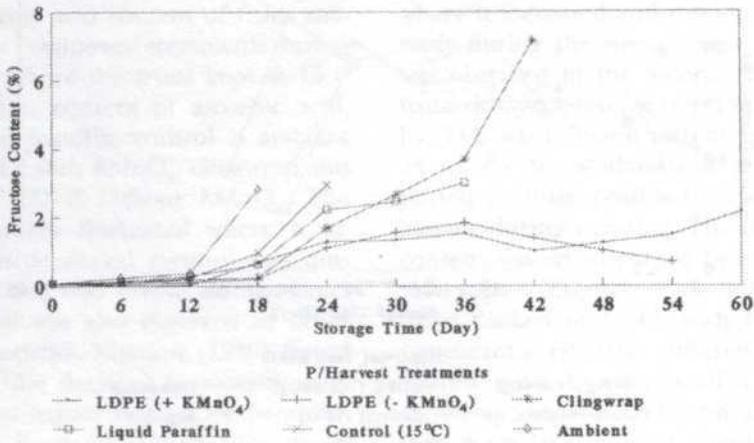


Fig. 15. Effect of postharvest treatments on fructose content of 'Montel' banana during storage

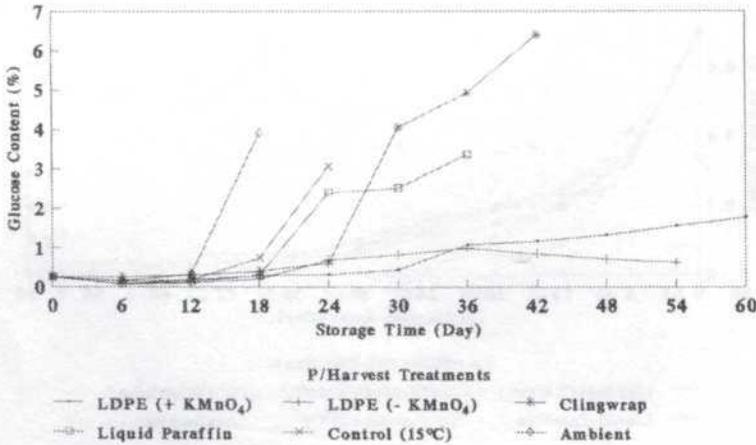


Fig. 16. Effect of postharvest treatments on glucose content of 'Montel' banana during storage

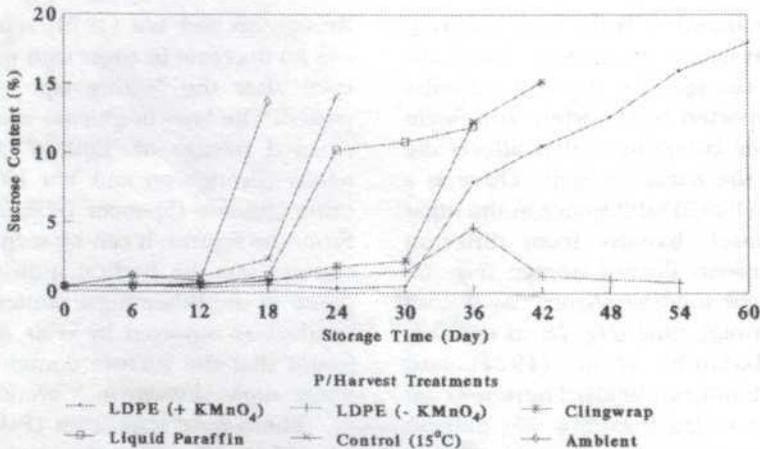


Fig. 17. Effect of postharvest treatments on sucrose content of 'Montel' banana during storage

ments with storage time. The ethylene production fluctuated, where it increased from day 0 until day 24 and then it decreased at day 36 (Fig. 19). The amount of ethylene from fruits packed in LDPE (with and without  $\text{KMnO}_4$ ) started to increase again at day 42 until the end of the storage period. However, fruits packed in LDPE without  $\text{KMnO}_4$  rotted and failed to ripen. According to Biale *et al.* (1954) and Burg and Burg (1962), some tropical fruits ripen at the climacteric without any abrupt increase in their rate of ethylene production. With most fruits,

however, there is evidence of some increase in ethylene production just prior to the onset of the climacteric rise in respiration (Mapson 1969). The respiratory rate increased at day 18, 24, 30 and 36 for fruits kept at ambient,  $15^\circ\text{C}$  and LDPE without  $\text{KMnO}_4$ , liquid paraffin and clingwrap and LDPE with  $\text{KMnO}_4$ , respectively (Fig. 20). However, fruits packed in LDPE with  $\text{KMnO}_4$  increased gradually at day 48 onwards until the end of the storage period. A similar trend was also reported by Marriott (1980).

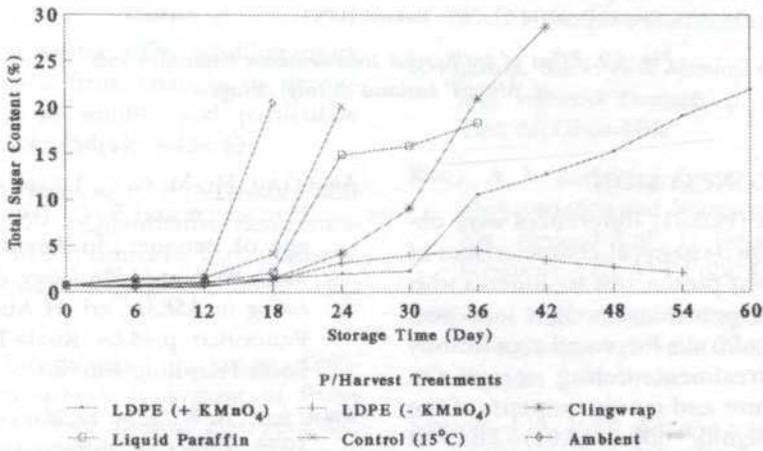


Fig. 18. Effect of postharvest treatments on total sugar content of 'Montel' banana during storage

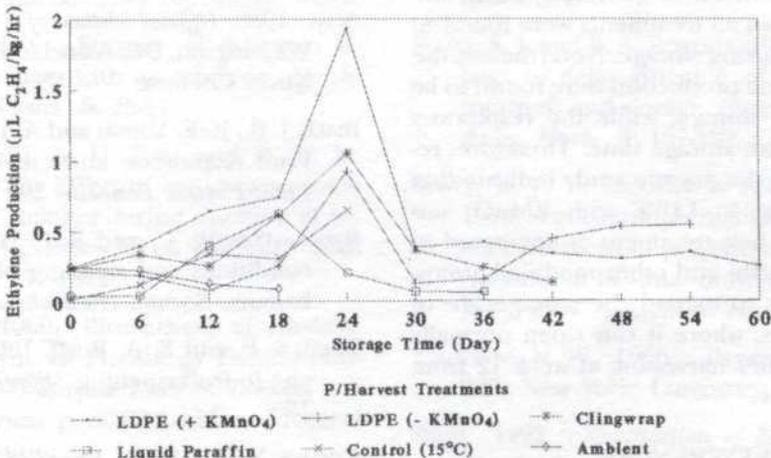


Fig. 19. Effect of postharvest treatments on ethylene production of 'Montel' banana during storage

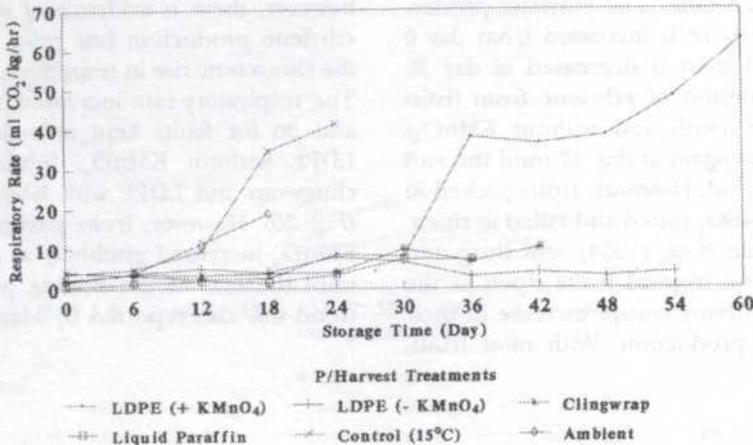


Fig. 20. Effect of postharvest treatments on respiratory rate of 'Montel' banana during storage

**CONCLUSION**

Highly significant ( $P < 0.01$ ) differences were observed in the physico-chemical characteristics of fruits from different postharvest treatments with storage time. The percentage weight loss, peel and pulp colours of fruits increased significantly ( $P < 0.01$ ) for all treatments during storage. On the contrary, texture and tannin contents of the fruits decreased significantly ( $P < 0.01$ ). The rise in total soluble solids (TSS) and sugar were slow initially but gradually increase rapidly at the end of the storage period. However, pH, titratable acidity (TA), ascorbic acid (AA) and starch contents of fruits from all treatments were found to be inconsistent during storage. Nevertheless, the pattern of ethylene production were found to be irregular during storage, while the respiratory rate increased with storage time. Therefore, results obtained in the present study indicate that the fruits packed in LDPE with  $KMnO_4$  was found to be the best treatment as compared to waxing with paraffin and other modified atmosphere packaging to extend the storage life of 'Montel' bananas, where it can ripen normally within 60 days after harvesting at week 12 from flower emergence.

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