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Maintaining the Colour, Texture and Vitamin C of Cold-stored Pineapples through Shrinkwrapping and Surface-coating with Liquid Paraffin.

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ABSTRAK

Pembungkusan mengecut etylen ketumpatan rendah nenas Moris yang disimpan pada 10°C, 15°C, 20°C dan suhu bilik, dapat mengurangkan kehilangan berat dan tekstur buah. Salutan permukaan dengan paraffin menghalang kehitaman yang berlaku dalam buah semasa penstoran pada suhu rendah dan dapat mengekalkan kandongan vitamin C yang tinggi. Salutan paraffin amat berkesan mengekalkan warna nenas segar dan mengurangkan keasidan. Paduan salutan paraffin dan bungkusan-mengecut didapati paling berkesan mengekalkan kesemua parameter yang dikaji. Nenas kawalan yang tidak diberi rawatan mengalami kehitaman isi, kehilangan berat dan penurunan tekstur yang keterlaluan, menjadi terlalu ranum dan diserang kulat semasa penstoran sejuk. Kehilangan berat didapati berhubung secara negative dengan kandongan asid askorbik dan tekstur pulpa dalam kebanyakan keadaan.

ABSTRACT

Low density polyethylene shrinkwrapping significantly reduced weight loss and texture loss in Mauritius pineapples stored at 10°C, 15°C, 20°C and ambient temperatures. Surface coating with paraffin inhibited internal browning in cold-stored pineapples and helped retain a high vitamin C content in the pineapples during storage. Paraffin coating was most effective at maintaining the colour of fresh pineapples and reducing the acidity. A combination of paraffin waxing and shrinkwrapping was found to be effective in maintaining all the parameters studied. Control untreated pineapples exhibited high weight loss, texture loss, over ripening, fungal attack and internal browning during cold storage. Weight loss was found to be negatively correlated to ascorbic acid content and pulp texture under most conditions.

Keywords: paraffin coating, shrinkwrapping, pineapples, 10°C, 15°C, 20°C, weight loss, texture, internal browning, vitamin C, colour

INTRODUCTION

The main problems encountered during storage of pineapples *(Ananas comosus)* are weight loss, fungal attack, and an internal browning (IB) disorder which reduce saleability. Weight loss (resulting in shrivelling and poor external appearance) can be controlled by storage at high relative humidity or by applying surface coatings together with low temperature. Both methods have problems: too low a storage temperature can cause chilling injury (Paull and Rohrbach 1985), and surface coatings can enhance fungal attack and anaerobic off-flavours (Chace and Pantastico 1975). Ripening is delayed by low temperature storage, surface coatings or post-harvest chemical treatments (Wardlaw 1937). Wax or other coatings applied to the surface of fruits influence their physiology and metabolism by limiting gaseous and moisture exchange (Lowings and Cutts 1982). The occurrence of internal browning together with presence of white fruitlets in Mauritius pineapples were reported by Abdullah and Rohaya (1983) for fruits stored at 8 and 12°C followed by one week at 28°C. Waxing pineapples using mineral oil (liquid paraffin) either before or immediately after exposure to chilling temperatures was equally effective in reducing IB symptoms (Paull and Rohrbach 1985).

This paper reports the effects of paraffin waxing and shrinkwrapping on weight loss, texture, colour, total soluble solids (TSS), vitamin C, pH and titratable acidity in Mauritius pineapples stored at various temperatures.

MATERIALS AND METHODS

Pineapples cv Mauritius were bought from MARDI, Klang. Pineapples were selected at the 90% ripe stage (those which have two rows of yellow-coloured eyes), weighed and subjected to various treatment and storage conditions one day after harvest.

Liquid Paraffin Treatment

Fruits were dipped for 30 seconds in 50% aqueous emulsion of liquid paraffin (BDH Limited, Poole, England).

Shrink-wrapped Packaging

Fruits were wrapped with a double layer of low density polyethylene shrinkwrap (0.04 mm thickness) using 'Hot air tunnel' machine model YPS-105.

Groups of 48 fruits were sorted and stored at 10⁰C, 15⁰C, 20⁰C and at ambient temperature (27 $\pm$ 3⁰C). The untreated fruits were used as control.

Assessment of the Stored Fruits

Fruits were assessed for weight loss, pulp colour, texture, sugar, vitamin C, titratable acidity, TSS and pH. Colour was determined using the Hunterlab Tristimulus Colorimeter, expressed as lightness (L), redness (a), and yellowness (b values), with the yellow tile No. C2-22954 as reference (L = 77.5, a = 3.5, b = 23.0). The Instron Universal testing machine with a probe attachment was used for texture measurements on halved fruit. A drive speed of 50 mm/min and a chartspeed of 100 mm/min were used to determine the yield force. A maximum load of 5 kg was used for penetration of the pulp and 20 kg load was used for penetration through the skin. Vitamin C and titratable acidity were determined according to Ranganna (1977). Total soluble solids were determined by using an Otago Hand Refractometer. pH was determined by using Hanna Instruments 8417 pH meter.

Each result is an average of eight readings from four fruits. Fruits were analysed weekly for storage at 10⁰C, 15⁰C, and daily for room temperature storage. Samples were picked at random for the analysis.

Sensory evaluation of the pineapples was carried out by 10 trained panellists for colour, taste, texture and flavour on a hedonic scale of 1-7 (1 = dislike very much; 7 = like very much).

Variance analysis and Duncan's multiple range test were applied to all data using SAS statistical software.

RESULTS

Weight Loss

At all temperatures, weight loss increased with time *(Fig. 1)*. Highest weight loss was observed in the control pineapples for all temperatures. Weight loss on paraffin-treated fruits was lower than in control samples. Weight loss by shrinkwrapped pineapples was least.

Fruit Firmness

The graphs for both the skin and pulp firmness showed reduced firmness with increasing storage period, under all storage conditions *(Fig. 2)*. This reduction in firmness was least in shrinkwrapped samples and most in paraffin-treated pineapples.

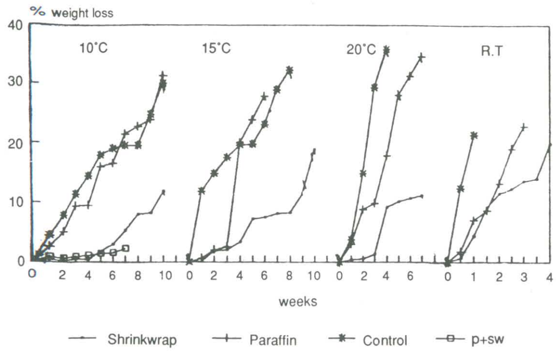

Fig. 1: Weight loss in pineapples stored at 10⁰C, 15⁰C, 20⁰C and room temperature.

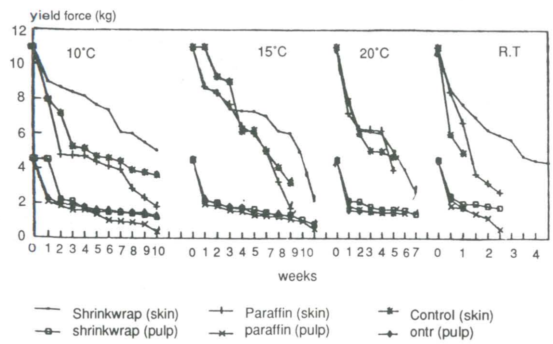

Fig. 2: Texture of pineapples (fruit/pulp) stored at 10⁰C, 15⁰C, 20⁰C and room temperature.

Pulp Colour

After 10 weeks storage at 10⁰C, paraffin-treated pineapples had the highest lightness (L) values, and shrinkwrapped fruits had the lowest values *(Fig. 3)*. The paraffin wax appeared to slow the rate of ripening of the pineapples, hence delay the change of colour from yellow to orange compared to shrinkwrapped, or control fruits. The pulp of the shrinkwrapped fruits tended to be more orange as can be seen also by the higher (a+b) values than the controlled or paraffin-treated fruits.

Black heart disorder was found most prominent in controlled fruits. The approximate times taken (weeks) for pineapples to develop black heart at the various temperatures of storage and

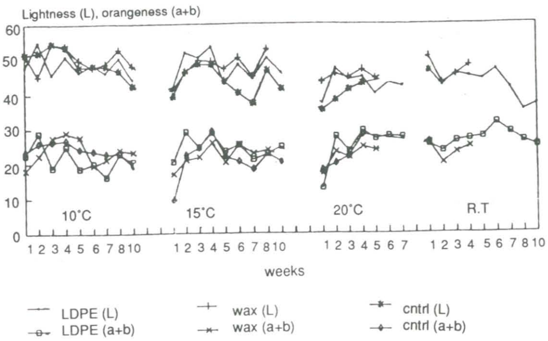

Fig. 3: Colour changes in pineapples stored at 10ºC, 15ºC, 20ºC and room temperature.

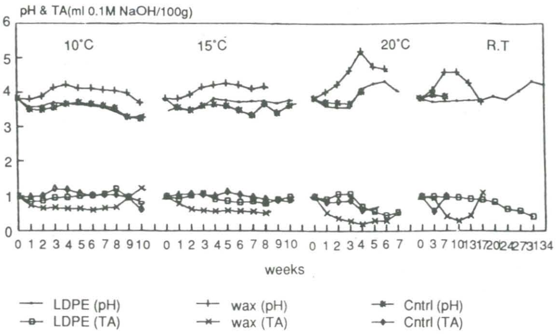

Fig. 4: pH and titratable acidity of pineapples at 10ºC, 15ºC, 20ºC and room temperature.

under the different treatments are listed in Table 1. The appearance of black heart was delayed by waxing and shrinkwrapping.

TABLE 1
The approximate time (weeks) for pineapples to develop internal browning

Temperature	Control	Shrink-wrapped	Paraffin wax
10°C	6	7	11
15°C	3	5	10
20°C	1	3	7

Ambient fruits did not show IB but were unacceptable by the 3rd-4th week

Unlike the control fruits the pineapple skin colour of paraffin-treated fruits remained green and the flesh remained pale yellow showing that ripening was retarded with the paraffin treatment.

pH and Titratable Acidity

Paraffin waxing significantly reduced the acidity of the pineapples on storage for all the temperatures studied. Even shrinkwrapped fruits appeared to have a reduced acidity compared to control fruits but it was not as pronounced as in paraffin-waxed fruits. The degree of acidity developed in the fruit could be related to the availability of oxygen to the fruit. pH was found to be correlated to titratable acidity for pineapples stored at 20°C and room temperature but not for pineapples stored at 10°C and 15°C. pH was also found to be correlated to ripeness or orange colour (a+b values) for paraffin-waxed fruits.

Soluble Solids Content (SSC)

There was a general decrease in SSC content of pineapples on storage except in paraffin-treated and control fruits stored at 10°C and 15°C *(Fig. 5)*. SSC was found to be correlated to ripeness or orange colour (a+b values) for control fruits stored at 15°C and 20°C.

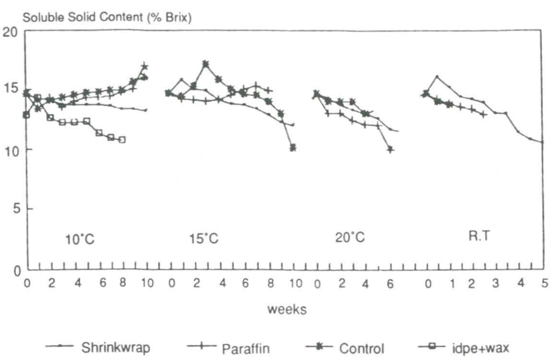

Fig. 5: Total soluble solids in pineapples stored at 10ºC, 15ºC, 20ºC and room temperature.

Ascorbic Acid

There was an initial increase followed by a gradual decrease in ascorbic acid content of pineapples on storage indicating ripening and senescence *(Fig.6)*. Ascorbic acid has been repeatedly shown in various fruits, to increase during ripening and decrease during senescence even on storage (Khin 1991; Ku-Natrah 1992). At the lower temperatures of storage, the paraffin waxed fruits had the highest ascorbic acid content followed by shrinkwrapped fruits showing that paraffin waxing increased the vitamin C content of pineapples especially those stored at low temperatures. This was probably because paraffin acted as a gas barrier, inhibiting oxygen from entering the fruit, thus reducing the oxidation of ascorbic acid.

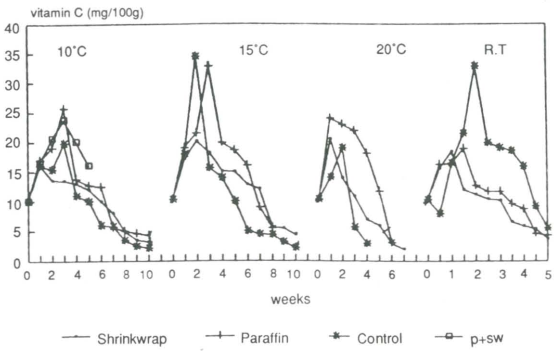

Fig. 6: Vitamin C content in pineapples stored at 10⁰C, 15⁰C, 20⁰C and room temperature.

Sensory Evaluation

Results of the sensory evaluation for control, 5% paraffin and 10% paraffin-treated fruits stored at 10⁰C are shown in Table 2. Because of the variability of the fruit, statistical analysis showed no significant difference between the treatments. However, 10% paraffin-treated fruits had a higher mean score after 8 weeks storage for appearance, flavour, taste, texture and colour than untreated fruits (Table 2).

TABLE 2
Sensory evaluation of control and paraffin-treated pineapples stored at 10⁰C

	Week	Control	5% paraffin	10% paraffin
appearance				
	4	a 6.20 A	a 6.80 A	a 5.01 A
	8	b 3.45 A	b 4.00 A	a 4.30 A
flavour				
	4	a 5.45 A	a 5.40 A	a 5.35 A
	8	a 4.35 A	a 5.55 A	a 4.80 A
taste				
	4	a 6.00 A	a 5.55 A	a 5.85 A
	8	a 5.00 A	b 3.00 B	a 6.15 A
texture				
	4	a 6.35 A	a 6.25 A	a 6.15 A
	8	a 5.70 A	b 3.35 B	a 5.75 A
colour				
	4	a 5.80 A	a 6.10 A	a 6.15 A
	8	a 5.50 A	b 4.25 B	a 5.65 A

Values followed by different letters differ significantly
Capital letters show significant difference between treatments
Small letters show significant difference between weeks

DISCUSSION

Paraffin waxes restrict both gas exchange and water loss (Chace and Pantastico 1975). Weight loss by shrinkwrapped pineapples was least, because LDPE packaging is least permeable to moisture and will provide an environment of high relative humidity to the pineapples. Shrinkwrapping may also cause an accumulation of CO_2 and reduction of oxygen in the package which will further reduce both respiration and transpiration of the fruit. Shrinkwrapping does not provide a gas-tight seal but will restrict gas exchange to a certain extent, the amount of which needs to be measured in each situation. This study was not done due to the lack of facilities here. Undoubtedly the main effect is the prevention of water loss.

The pulp firmness of pineapples was found to be correlated with weight/moisture loss (Table 3), accounting for the good firmness reading of shrinkwrapped fruits. As explained previously, high CO_2 atmosphere which is present within the shrinkwrap packaging also inhibits breakdown of pectic substances in other fruits so that a firmer texture is retained for a longer period (Wills *et al.* 1981). It was found that for paraffin waxing the concentration of paraffin used caused lesions to the surface of the pineapples and was detrimental to the surface texture. Work will be carried out to find out the optimum concentration of paraffin to be used for waxing of pineapples in the near future. It was also found that pineapple texture was positively correlated to ascorbic acid content (Table 3).

Paraffin treatment significantly retarded the ripening of pineapples since the skin remained green and the flesh remained pale yellow during storage at 10⁰C. Paraffin treatment also retarded the development of physiological internal browning symptoms known as 'black heart' which occurs in cold-stored pineapples. This is in agreement with the report by Paull and Rohrbach (1985), on pineapples stored below 21⁰C. Other surface coatings have been reported to reduce the susceptibility of bananas to chill damage (Lowings and Cutts 1982). Surface coatings have been reported to reduce carotenogenesis in mangoes (Dhalla and Hanson 1988), reduce the rate of chlorophyll breakdown in banana skin (Banks 1984); retard yellowing in plantains (Olorunda and Aworth 1984), and to be more effective and cheaper than gibberellic acid in delaying the degreening of limes (Motlagh and Quantick 1988).

Waxing of fruits and exposing fruit to high temperatures (> 32⁰C) for a short period (24 h)

TABLE 3
Correlation coefficients (r squared values) of various parameters under different conditions

pH vs	TA	Texskn	Texplp	TSS	Vit C	Wt loss	Lvalue	(a+b)
10^{0}C LDPE	0.125	0.66	0.08	0.43	0.72	0.82	0.07	0.18
WAX	0.03	0.0005	0.02	0.48	0.04	0.028	0.15	0.49
CNTRL	0.03	0.03	0.09	0.26	0.12	0.2	0.09	0.0004
15^{0}C LDPE	0.16	0.31	0.43	0.52	0.39	0.37	0.002	0.07
WAX	0.67	0.29	0.62	0.105	0.012	0.65	0.56	0.5
CNTRL	0.005	0.003	0.008	0.001	0.0009	0.008	0.54	0.16
20^{0}C LDPE	0.92	0.44	0.6	0.62	0.67	0.92	0.01	0.03
WAX	0.88	0.19	0.72	0.21	0.19	0.37	0.36	0.77
CNTRI	0.999	0.15	0.36	0.986	0.37	0.35	0.51	0.6
R.T LDPE	0.777	0.51	0.78	0.84	0.6	0.67	0.58	0.008
WAX	0.9	0.05	0.05	0.15	0.66	0.23	0.89	0.75
CNTRL	0.776	0.54	0.53	0.39	0.1	0.28		

Lvalue vs	Texskn	Texplp	TSS	Vit C	Wtloss	[Asc acid vs	]	Wtloss
10^{0}C LDPE	0.005	0.26	0.0088	0.1	0.04	[10^{0}C	LDPE]	0.92
WAX	0.25	0.18	0.09	0.05	0.27	[	WAX]	0.71
CNTRL	0.28	0.26	0.59	0.76	0.65	[	CNTRL]	0.78
15^{0}C LDPE	0.025	0.0001	0.0008	0.016	0.03	[15^{0}C	LDPE]	0.76
WAX	0.03	0.26	0.03	0.014	0.35	[	WAX]	0.33
CNTRL	0.08		0.35	0.15	0.012	[	CNTRL]	0.57
20^{0}C LDPE	0.039	0.163	0.02	0.003	0.0025	[20^{0}C	LDPE]	0.82
WAX	0.22	0.04	0.61	0.02	0.35	[	WAX]	0.91
CNTRL	0.9		0.47	0.63	0.997	[	CNTRL]	0.68
R.T LDPE	0.07	0.13	0.61	0.38	0.016	[R.T	LDPE]	0.17
WAX	0.34	0.14	0.19	0.11	0.057	[	WAX]	0.002

(a+b) vs	Texskn	Texplp	TSS	Vit C	Wtloss	[TSS vs	]	Vit C	Wtloss
10^{0}C LDPE	0.096	0.3	0.003	0.09	0.0000	[10^{0}C	LDPE]	0.21	0.16
WAX	0.26	0.35	0.09	0.03	0.22	[	WAX]	0.03	0.07
CNTRL	0.02	0.08	0.0009	0.53	0.0036	[	CNTRL]	0.21	0.4
15^{0}C LDPE	0.015	0.02	0.107	0.18	0.013	[15^{0}C	LDPE]	0.51	0.43
WAX	0.12	0.02	0.11	0.07	0.44	[	WAX]	0.0058	0.001
CNTRL	0.14	0.4	0.86	0.0005	0.068	[	CNTRL]	0.02	0.11
20^{0}C LDPE	0.45	0.24	0.18	0.59	0.39	[20^{0}C	LDPE]	0.72	0.69
WAX	0.019	0.04	0.33	0.37	0.0041	[	WAX]	0.6	0.4
CNTRL	0.52	0.15	0.87	0.63	0.82	[	CNTRL]	0.45	0.47
R.T LDPE	0.32		0.0000	0.09	0.15	[R.T	LDPE]	0.48	0.37
WAX	0.34		0.12	0.1	0.004	[	WAX]	0.03	0.64

Texskn vs	Texplp	TSS	Vit C	Wtloss	[Pulp texture vs	]	TSS	Vit C	Wtloss
10^{0}C LDPE	0.04	0.02	0.21	0.29	[10^{0}C	LDPE]	0.02	0.3	0.21
WAX	0.08	0.07	0.79	0.38	[	WAX]	0.07	0.53	0.006
CNTRL	0.002	0.31	0.67	0.27	[	CNTRL]	0.31	0.58	0.61
15^{0}C LDPE	0.62	0.24	0.65	0.89	[15^{0}C	LDPE]	0.24	0.84	0.76
WAX	0.2	0.05	0.75	0.06	[	WAX]	0.05	0.0000	0.82
CNTRL	0.67	0.22	0.49	0.44	[	CNTRL]	0.22	0.06	0.87
20^{0}C LDPE	0.13	0.51	0.77	0.05	[20^{0}C	LDPE]	0.51	0.32	0.57
WAX	0.14	0.03	0.71	0.67	[	WAX]	0.03	0.996	0.4
CNTRL	0.5	0.18	0.43	0.0008	[	CNTRL]	0.18	0.039	0.89
R.T LDPE	0.19	0.04	0.31	0.76	[R.T	LDPE]	0.04	0.0000	0.16
WAX	0.19	0.86		0.49	[	WAX]	0.86		0.91

before or after chilling stress can control storage-induced black heart (Akamine *et al.* 1975). Prolonged storage periods at temperatures less than 12^{0}C have been reported to reduce IB symptom development and the number of affected fruit (Paull and Rohrbach 1985). This was ascribed to damage to the metabolic pathway leading to browning involving monophenols which are ortho-hydroxylated and then oxydised to the resultant catechol derivative, or brown pigments (Singleton 1972). The enzyme tyrosine ammonium lyase responsible in pineapples (Sun 1971) is not hindered by low oxygen concentration. However, the browning reaction was found to require more than 5% oxygen concentration for linking of oxygen with the polyphenol oxidase cuprous ion, and at the same time binding with the aromatic ring converting phenol to phenolate (Bright *et al.* 1963; Singleton 1972). Van Lelyveld and De Bruyn (1977) identified the phenolic compounds as p-coumaric acid, ferulic acid,· cafeic acid and sinapic acid. Polyphenol oxidase activity has been shown to increase 30 times in pineapple fruit in response to chilling (Walker 1975). Increased phenolic cinnamic acids have been identified in pineapples with black heart symptoms (Van Lelyveld and De Bruyn 1977). Teisson *et al.* (1979) reported that although a larger volume of fruit was affected at 5^{0}C, the browning was less intense. Rohrbach and Paull (1982) explained the effectiveness of fruit waxing and polyethylene shrinkwrapping by the low oxygen levels after chilling which perhaps reduced black heart development.

Pineapples treated with paraffin seemed to have significantly lower titratable acid values compared to the control. Surface coatings have been reported to differentially alter the permeability of banana skin to CO_2 and O_2, reducing the internal O_2 content without a concomitant rise in CO_2 levels (Banks 1984), and retard pH depression in plantains (Olorunda and Aworth 1984).

The two main factors which affect the soluble solids content of a fruit are:

(a) enzymic breakdown of insoluble polysaccharide (in this case most probably pectic substances) to soluble solids which increase the soluble solids content of the fruit. In some plant products this enzymic reaction is reversible and the direction of reaction is dependent on temperature.

(b) utilisation of the soluble solids (sugars, etc.) for respiration by the fruit which will decrease the TSS content of the fruit.

It appears that at 10^{0}C the respiration of the fruit is considerably lowered; therefore there is very slow reduction is soluble solids. For the control and waxed fruits, the breakdown of insoluble polysaccharide (most likely pectic substances) resulted in a net increase in TSS. For shrinkwrapped fruits the breakdown of polysaccharide was probably also reduced (as verified by the good maintenance of texture of shrinkwrapped fruits at 10^{0}C *(Fig. 2)* contributing to a net reduction of TSS content at that low temperature.

Correlation Studies

The ascorbic acid contents were correlated to the pineapple pulp colour (L and a+b values) and soluble solids content (SSC) only in the control samples (Table 3). Ascorbic acid levels have been associated with the degree of blackheart symptoms caused by chilling (Sun 1971; Van Lelyveld and De Bruyn 1977). Ascorbic acid may be oxidised before the phenols are oxidised by polyphenol oxidase which would then cause browning to occur. The highest levels of ascorbic acid are found in the periphery and the top of the fruit. This gradient was thought to explain in part the occurrence of black heart symptoms initially around the core (Hammer and Nightingale 1946; Miller and Hall 1953).

Ascorbic acid was corelated to pH and TA only in shrinkwrapped fruits. Hammer and Nightingale (1946) and Miller and Hall (1953) found an identical gradient of ascorbic acid to titratable acidity within the pineapples. Ascorbic acid was correlated to the soluble solids content (SSC) only in the waxed and shrinkwrapped samples. Ascorbic acid also negatively correlated to the fruit texture for most treatments.

L and (a+b) values were also correlated to pH only in waxed and control samples stored at 15^{0}C, 20^{0}C and ambient temperature but not for samples stored at 10^{0}C. Van Lelyveld and De Bruyn (1976) found IB-affected fruits had lower citric and malic acids; this was thought to be due to assimilation in the biogenesis of ascorbic acid through citric acid cycle and glucuronate and gulonate pathways. Colour was also found to be correlated to TSS, especially in the control fruits. Various researchers (Van Lelyveld and De Bruyn 1976; Abdullah and Rohaya 1983) found IB to lower the TSS values (mainly sucrose and fructose) in pineapples but found no correlationship of IB with pH or TA.

Weight loss was found to be negatively correlated to pulp texture and ascorbic acid contents for the pineapples under most conditions (Table 3) and may relate to the gas/moisture permeability of the surface coating or packaging used.

CONCLUSION

The weight loss of pineapples was effectively controlled by LDPE shrinkwrapping, and to a lesser extent by paraffin waxing. Fruit firmness was effectively retained by shrinkwrapping. Paraffin waxing at the concentration used caused lesions on the skin and was thus detrimental to the fruit quality. Paraffin was most effective in preventing IB and retaining the colour of pineapple pulp. The ascorbic acid content of paraffin-waxed fruits was generally higher than that in untreated fruits except for pineapples stored at room temperature. This is thought to be due to the reduced destruction of ascorbic acid with reduced oxygen content in the tissues of the paraffin-treated pineapples. Paraffin waxing and shrinkwrapping also reduced the acidity of the pineapples substantially in comparison to the untreated fruits.

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