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Effect of Polymeric Coating on the Post-Harvest Quality Characteristics of Pineapple cv. 'Smooth Cayenne' Fruits

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ABSTRACT

Investigations were conducted to determine the effect of polymeric coating on the post-harvest quality characteristics of pineapple (*Ananas comosus*) cv. 'Smooth Cayenne' fruits. A 4 × 2 × 4 factorial experimental design with polymeric coating concentration (0, 5, 7.5 and 10%), storage temperature (8 and 28°C) and storage period (0, 4, 7 and 10 days) was performed. Vitamin C, total sugars, titratable acidity, astringency index, pH, translucency and fruit texture were determined using standard analytical methods. Storage significantly ($P \leq 0.05$) decreased vitamin C and total sugar content with a concomitant increase in acidity, astringency, translucency and fruit texture. Low temperature storage however minimized the effect of the observed differences. Polymeric coating influenced the physical and chemical qualities of the fruits with 5 and 7.5% polymeric coatings being the most effective preservative levels. Polymeric coating can therefore be applied to pineapple cv. 'Smooth Cayenne' fruits prior to storage to effectively prolong the chemical and physical quality characteristics of the fruits.

Keywords: acidity, *Ananas comosus*, astringency, fruit texture, storage quality, translucency

INTRODUCTION

Pineapple (*Ananas comosus*) is the world's most popular non-citrus tropical and subtropical fruit. It is a xerophytic, succulent, herbaceous perennial, monocotyledonous plant with its leaves arranged in a dense rosette pattern (Ekern 1985; Essuman 2003; Montero-Calderón *et al*. 2008). The fruit is a compound of several parthenocarpic fruitlets fused together with the bracts and central axis of inflorescence, and terminates in a vegetative shoot commonly referred to as the crown (Salunkhe and Dasai 1984; Bartholomew and Malezieux 1994). It is best suited for mild tropical climates with temperatures ranging between 16–32°C with minimal shading and mild sunshine (Knight 1980; Hassan *et al*. 2010). Over the past 100 years, pineapple has become one of the leading commercial fruits crops of the tropics and large-scale cultivation is generally located at some distance from the equator. The pineapple is a delicious fruit and due to its high sugar content (12–18 °Brix), and it is classified as a high energy food (Py *et al*. 1987; Paull and Chen 2003; Budu and Joyce 2005; Chonhenchob *et al.* 2007). With the exception of vitamin D, the ripe pineapple fruit flesh contains all the vitamins with a very high content of vitamin C/ascorbic acid. It also serves as a good source of fibre and minerals (Gil *et al.* 2006; Montero-Calderón *et al.* 2008; Rocculi *et al.* 2009; Hassan *et al.* 2010).

The fruit is also used for a wide variety of products such as jams, wines, vinegar and syrups, making its importance as food diverse. Despite its robust appearance, the fruit is more susceptible to post-harvest losses and storage loss as a result of increased handling, temperature control and disease incidence or a combination of two of these factors or from some of the normal but inadvertently reactions of pineapple fruit. In West Africa, the volume of exports of the crop increased from about 33,000 tonnes in 2000 to 65,500 tonnes in 2008 (GEPC 2010). Although the pineapple industry is growing at a very fast rate, it is saddled with many problems, which result in low yields on farmers' plot. Losses in quality and quantity affect horticultural crops between harvest and consumption. In developing countries such as Ghana, post-harvest losses are estimated at 20-50%, thus according to Essuman (2003), post-harvest loss is a major factor contributing towards food scarcity and it is unlikely that food production alone can solve the deficit problem.

To successfully reduce post-harvest losses in pineapples, the use of surface or polymeric coating has been identified as a chemical treatment capable of reducing or delaying senescence in fruits. Banks (1984) and Santerre *et al.* (1989) reported that several types of surface coatings have been applied successfully for the preservation of fresh products. Mixtures of sucrose, fatty acids and esters have been used for coating fresh fruits and vegetables to extend their shelf-life and minimize quality changes. Fruit coating with waxes 'Pro-long' and carboxymethylchitosan have been reported to be beneficial (Smith and Stow 1984; El Ghaouth *et al.* 1992). Wills *et al.* (1989) also reported that the use of post-harvest waxes and coating materials reduce moisture loss and subsequent loss of appearance and marketability due to shriveling and wilting.

As the global pineapple market develops, it is important to find out how surface or polymeric coating could be effectively used as a quality management tool to increase their shelf-life thereby reducing post-harvest losses and market value of the fruits. This work therefore aimed to investigate the effect of polymeric coating on the post-harvest quality characteristics of pineapple (*Ananas comosus*) cv. 'Smooth Cayenne' fruits.

MATERIALS AND METHODS

Procurement and preparation of pineapple fruit

The pineapple cv. 'Smooth Cayenne' fruits with a known crop history were freshly harvested early in the morning (6–8 am) as intended for export from a major pineapple exporter (Jei River Farms in Kasoa, Ghana) and used for the study. They were sorted and graded into size, weight, shell colour and crown conditions.

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Preparation of polymeric coating

The coating material (Stafresh 7055, a wettable emulsion) was purchased from a local representative of Chemico Ltd., Accra, Ghana. Different concentrations (0, 5, 7.5 and 10%, v/v) were prepared using de-ionised water. The mixture was manually stirred for about 15 min to ensure uniform dispersal of coating material in solution.

Pre-storage operations - Field operations

Freshly harvested fruits were sorted to remove defected fruits, graded according to sizes and manually dipped and swirled in a plastic container containing the coating medium for about 45 sec. Each of the fruits were placed in ventilated plastic containers (~200 cm^3) and allowed to air dry for about 30 min before pre-cooling. Treated fruits were precooled on-farm in an air-conditioned room (temperature 21 ± 2.0°C and RH = 82 ± 2.6) for up to 6 hrs to reduce field and respiratory heat before fruits were weighed and placed in experimental treatment.

Storage studies

Weighed fruits were placed in cardboard boxes (6 fruits per box as used for export) and subjected to ambient temperature (28.0 ± 1.2°C) and cold storage (8°C) for a period of 10 days and samples were taken after 4, 7 and 10 days for analysis. Relative humidity was monitored daily and recorded as being between 82-85%.

Experimental design

The study was conducted using a 4 × 2 × 4 factorial design. The factors investigated were as follows:

i. Polymeric coating (0, 5, 7.5 and 10%)
ii. Storage temperature (8°C and ambient [28°C])
iii. Storage period (0, 4, 7 and 10 days).

Dependent variables measured were Vitamin C content, sugar content, titratable acidity, pH, astringency, translucency and fruit texture. All the samples were analysed in triplicate and the mean values were reported.

Chemical analysis

Chemical analysis was performed on the juice extract. Fruits were manually chopped into small sizes (2-5 g) and blended at high speed for about 45 sec with a Hobart warring blender and filtered through a cheese cloth into a clean 600-ml beaker. Portions of the juice extracted were drawn and used for the various analyses.

Vitamin C content of the fruits was measured using the procedure outlined by AOAC method 43.051-55 (AOAC 1990).

Analysis on the sugar content was performed on the juice extract using a Deltare refractometer (Range 0–50% sugar w/w) (Bellingham Stanley Ltd., Chelmsford, England) and data was expressed as percentage of sugar content.

The pH of the juice extracted was measured with a pH meter (TOA Electronics, Tokyo, Japan). For titratable acidity, 10-ml aliquots of juice were pipetted into a conical flask containing 100 ml of distilled water. The aliquots were titrated against 0.1 N NaOH to a phenolphthalein (1%) end point. The acidity was calculated as g citric acid/100 g fruit.

Astringency index was quantified as the ratio of the titratable acidity and the sugar content of the pineapple.

$$AI = \frac{[\text{Titratable acidity (g citric acid /100 g fruit}]}{\text{sugar content (\%)}}$$

Physical determinations

Texture (pulp firmness) of the fruits was determined using a penetrometer (Gullimex model FT 327, Haslemere, Surrey, England) with a 0.8 mm plunger tip. Three determinations at the mid section of the fruit were taken equidistantly with three replications. About 1.3 cm – 1.9 cm diameter disc of peel using a fruit peeler (Gullimex fruit peeler, Haslemere, Surrey, England) was made at three equidistant points on the mid section of the fruit. Fruits were held firmly in one hand and the penetrometer held between the thumb and forefinger against the fruit and pressed with increasing pressure slowly till the plunger tip penetrated into a depth of about 0.8 mm. The reading on the dial in kg was measured as firmness of the fruit.

Translucency was determined by making a transverse section of the fruit at the mid section. The total length of the translucid portion of the fruit was measured with a ruler and expressed as a percentage of the diameter. Triplicate readings were made and the mean value was used as the extent of translucency. The following scale was used: 1 = none (no sign of translucency); 2 = < 10% translucency; 3 = 10–30% translucency; 4 = 30-50% translucency; 5 = > 50% translucency.

Data analysis

The data collected was analyzed using multi-factorial analysis of variance (ANOVA). Significant differences between treatments means were tested using Duncan's multiple range test (DMRT) with the least significant difference (LSD) procedure to estimate and test the degree of association between any two dependent variables investigated. All statistical analysis were conducted using Statgraphics software Ver. 4.2 (Statistical Graphics Corp. STSC Inc., Rockville, MD, USA).

RESULTS AND DISCUSSION

Vitamin C (ascorbic acid) content

Vitamin C is an important vitamin because apart from the nutritional benefits (especially for the prevention of the disease scurvy) it cannot be synthesized by the body (Wills *et al*. 1989). Pimpimpol and Siriphanich (1993) have reported that the susceptibility of pineapple to chilling injury and the black heart disorder is dependent on the concentration of vitamin C in the fruit.

The ANOVA summary table (**Table 1**) shows that the vitamin C content of the fruit was significantly ($P \leq 0.05$) influenced by the storage temperature, the polymeric coating and the storage interval. Means separation using MRT revealed that low temperature storage (8.0°C) had a higher mean vitamin C content (10.59 mg/100 g fruit) than the value for ambient (28°C) storage (8.42 mg/100 g fruit) (**Table 2**). Abdullah and Rohaya (1996) reported that chemical quality characteristics like ascorbic acid in pineapple have a better retention under low temperature than ambient storage.

Means separation for the effect of polymeric coating on the vitamin C content showed that 7.5% coating gave higher mean vitamin C content (10.05 mg/100 g fruit) after 10 days' storage. However, this was not significantly ($P > 0.05$) different from coating at 5 or 10%. The least vitamin C content (8.75 mg/100 g fruit) was observed in the non-coated fruits which was also not significantly different from coating at 5% (**Table 2**).

The degradation of ascorbic acid is known to occur by both oxidative and non-oxidative mechanisms (Saguy *et al.* 1978a; Robertson and Samaniego 1986). Although the rate of oxidative degradation has been determined to be 10-1000 times faster than non-oxidative degradation (Heulin 1953; Kefford *et al.* 1958). Surface coating of fruits form a semi-permeable barrier which restricts the rate of oxygen intake across the pineapple shell into the interior. The reduced oxygen level within the fruit would slow metabolic processes and thus the rate of ascorbic acid degradation would be slower for coated than for non-coated fruits.

DMRT conducted to evaluate the effect of storage interval on the vitamin C content revealed a decreasing trend from a mean value of (11.66 mg/100 g fruit) on day 0 of storage (harvest day) to a mean value of 7.38 mg/100 g after 10 days of storage (**Table 2**). This represents a 36.7% reduction of fresh juice vitamin C content. Achinewhu (1995) concluded that after storing pineapple at room temperature (30-32°C) for 2 weeks that ascorbic acid content was reduced to between 59 to 65% of the fresh juice. The

Table 1 ANOVA summary table (showing only F-values of quality characteristics studied).

Sources of variation	Astringency index	Vitamin C	Sugar content	Titratable acidity	Pulp firmness	pH	Pulp temperature	Translucency
Storage temperature (ST)	0.3386	52.396 *	27.74 *	4.885	1000.0 *	2.345	1000.0 *	28.17 *
Polymeric coating (PC)	14.773 *	4.348 *	0.154	7.211 *	4.952 *	1.006	2.325	2.041
Storage interval (SI)	185.022 *	39.607 *	172.19 *	19.073 *	889.78 *	4.250 *	1000.0 *	14.25 *
ST × PC	1.693	0.930	1.317	1.386	3.936 *	1.968	2.82	2.041
ST × SI	18 888 *	2.318	10.78 *	3.080	450.11 *	1.816	1000.0 *	3.462
PC × SI	3.759 *	1.64	0.789	1.707	2.756	0.909	1.334	1.000

* means significant at $P \leq 0.05$; Value without (*) means effect was insignificant at $P \leq 0.05$

difference in Achinewhu's observation could be due to the elevated temperatures under which he conducted his study and the longer storage period. Results of ANOVA reported in **Table 1** showed that temperature and the duration of storage have significant ($P \leq 0.05$) effects on the vitamin C content.

Sugar content

The sugar content of pineapple is an indispensable requirement for the organoleptic quality of the fruit. The results from the analysis of the study (**Table 1**) showed that the sugar content of the fruit was significantly ($P \leq 0.05$) influenced by the temperature of storage, the interval of storage and the interaction between storage temperature and storage interval. This suggests that the effect of storage temperature on the sugar content of fruit did not act independently but was dependent on storage duration.

DMRT conducted to establish the effect of storage temperature on the sugar content of the fruit showed that low temperature storage had a significantly ($P \leq 0.05$) higher mean value (11.92%) than the value (11.35%) representing ambient storage (**Table 2**). Pineapple contains fermentable sugars such as glucose and sucrose that are easily metabolized. The metabolic pathway involved in respiration in plants results in sugar conversion which is dependent on temperature (Dull 1971). Probably, the lower rate of respiration as encountered in low-temperature storage might have accounted for the difference in sugar content after 10 days of storage.

Means separation using DMRT to investigate the effect of storage interval on the sugar content of pineapple indicates that the interval of storage has a reducing effect on the sugar content (**Table 2**). Harvest day (day 0 of storage) sugar content showed a higher mean value (13.69%) than the rest of the storage intervals. The lowest mean value (10.64%) was recorded on the 10^{th} day of storage (**Table 2**). The value was not significantly ($P > 0.05$) different from the value observed (10.67%) on day 7 of storage. There are conflicting observations reported by two investigators as to the behaviour of pineapple sugar under low and ambient storage temperatures.

Mohammed and Wickham (1995) reported an accelerated ripening of fruit accompanied by an increase in sugar after four days of storage under ambient temperatures, although under low temperature storage (10ºC) there was no significant change in the fruit sugars up to 12 days of storage. Abdullah and Rohaya (1995) however, observed deterioration in sugar content after a week under ambient temperature with no consistent pattern in the sugar levels under low-temperature storage. Plant nutrition and climatic conditions just before harvest are known to have a marked influence on sugar levels of harvested pineapple.

Titratable acidity

Titratable acidity was influenced by the level of fruit coating and the duration of storage. ANOVA on the data (**Table 1**) showed that polymeric coating and storage interval had a significant ($P \leq 0.05$) effect on titratable acidity. Mean separation further revealed that the effect of the polymeric coating on the level of acidity was highest (0.905 g/100 g) in the non-coated fruit and lowest (0.799 g/100 g) in 7.5% coating. There was no significant difference between 0 and 5% coating, 5 and 10% and 10 and 7.5% coating (**Table 2**). Means separation using DMRT to evaluate the effect of storage interval on the titratable acidity showed an increasing titratable acidity levels with increasing storage interval. Acidity was lowest (0.749 g/100 g) on 0 day of storage and highest (0.923 g/100 g) after 10 days of storage (**Table 2**). The acidity level after 4 days of storage was not significantly ($P > 0.05$) different from 7 days of storage which was also not significantly different after 10 days of storage (**Table 1**).

Acidification of pineapple is a well known phenomenon under low temperature storage (Teisson 1979; Py *et al.* 1987). However, the results of this study indicated that phenomenal acidification occurs under both ambient and low storage temperatures. Although acid levels were slightly higher in low-temperature storage, there was no significant difference between that and ambient storage (**Table 2**).

Astringency index

Astringency is an important parameter in the sensorial and organoleptic properties of pineapple fruit. The characteristic sweet pineapple flavour and aroma is dependent on the level of acids and sugars present in the fruit (Py *et al.* 1987). In this study a novel attempt was made to quantify astringency as "astringency index". This factor was influenced by the polymeric coating, storage interval and the interaction between the storage interval and the polymeric coating and also the storage interval and storage temperature. ANOVA of the data showed that the polymeric coating and storage interval had a significant effect on the index of astringency (**Table 1**). The ANOVA also showed that the interaction between the storage interval and the storage temperature and the storage interval and the polymeric coating were also significant (**Table 1**). This suggests that the storage interval did not act independently on the astringency but was affected by the level of coating and the temperature of storage.

Mean separation of treatment using DMRT further revealed that coating at 7.5% had the least astringency (0.067) while 0% coating had the highest index of astringency (0.079) (**Table 2**). A high astringency suggests either a high acidity or low sugar content. The effect of the polymeric coating on the sugar content of the fruit was not significant therefore the high astringency in the non-coated fruit could be attributed to the high mean acid levels (**Table 2**). Means separation for the effect of the storage interval on astringency showed an increasing astringency with increasing storage days. Fruits on the harvest day (day 0) were least astringent (0.0550 and 10 days if storage gave the highest astringent fruit (0.0787) (**Table 2**).

pH

Inference from the ANOVA table (**Table 1**) indicates that the pH of the fruit juice was influenced by the interval of storage. Means separation revealed that the mean value of the juice was highest (4.00) on the harvest day (0 day storage) and lowest (3.86) after one week of storage (**Table 2**). The pH value did not follow any consistent trend under ambient storage but there was an observed drop in pH up to the 7^{th} day of storage under low temperature storage and a significant increase in by the 10^{th} day of storage (**Table 2**).

Table 2 Summary of means of (DMRT (LSD))* for factors + significantly affected by treatments.

Treatment	Level	Astringency index	Vitamin C	Sugar content	Titratable acidity	Pulp firmness	pH	Pulp temperature	Translucency
ST (ºC)	8	-	10.590 b	11.920 b	4.467 b	18.900 a	-	3.250 a	-
	28	-	8.422 a	11.347 a	2.255 a	32.816 b	-	3.968 b	-
PC (%)	0	0.079 c	8.753 a	0.905 c	3.276 a	-	-	-	-
	5	0.3077 bc	9.235 ab	0.879 bc	3.308 ab	-	-	-	-
	7.5	0.067 a	10.053 b	0.799 a	3.351 ab	-	-	-	-
	10	0.074 b	9.984 b	0.838 ab	3.448 b	-	-	-	-
SI (days)	0	0.055 a	11.66 a	13.685 c	0.749 a	4.705 a	4.00 c	40.500 d	3.000 a
	4	0.075 b	10.355 b	11.538 b	0.859 b	3.321 b	3.885 ab	28.475 c	3.375 a
	7	0.083 c	8.632 c	10.675 a	0.890 bc	2.858 c	3.858 a	19.228 b	4.000 b
	10	0.087 c	7.377 d	10.636 a	0.923 c	2.560 d	3.961 bc	18.931 a	4.062 b

* means with the same letters within the columns of a treatment are not significantly different at $P \leq 0.05$
+ Values for factors shown in the table represent means of four treatments each with two duplicates
DMRT – Duncan's Multiple Range Test ; LSD – Least Significant Difference

Translucency

Translucency is an important attribute in determining the eating quality of pineapple. A highly translucid fruit is judged as over-ripe while fruit with low translucence is generally considered unripe and has low aesthetic and consumer appeal. Translucency as revealed by the ANOVA table was influenced by the temperature of storage and the interval at which the storage was done (**Table 1**).

Means separation (**Table 2**) further revealed that the effect of ambient temperature storage resulted in a higher mean translucency value (3.79) which was significantly ($P \leq 0.05$) different from the contribution of low temperature storage to translucency (3.25). Under ambient storage, mean temperature values were higher (32.8ºC) than low temperature storage (18.9ºC). Bartholomew and Malezieux (1994) reported that the fruit fresh colour and translucence are altered by temperature changes. Teisson (1979) observed that high temperature make fruit flesh highly translucid and this agrees with the findings of this study.

Means separation for the effect of storage interval on the translucency of the fruit showed that translucency increased with increasing storage interval (**Table 2**). However, the difference between 0 day and 4 day storage were not significantly ($P \leq 0.05$) different. As well, the samples stored for 7 day and 10 day were also not significant ($P > 0.05$). Therefore, the real difference in translucency can be explained by the difference in the 0 day storage and that of the 7 day storage. **Table 2** showed that under ambient temperature, four days were needed to make non-coated fruits highly translucid, while this was attained after 7 days at 10% coating. After 10 days storage, 5, 7.5 and 7.5% coating showed relatively lower translucency values. As well, **Table 2** indicates that under low temperature storage, the level of translucency was the same for all the treatments although there was a noticeable increase after 7 days of storage for all the treatments.

Pulp firmness (texture)

Fruit firmness or texture is an important quality factor in many fruits and vegetables. It has been employed as a useful index in determining fruit maturity, harvest dates and its eating quality (Kader 1983). The ANOVA summary table (**Table 1**) shows that the texture of the fruit was significantly influenced by the storage temperature, the level of coating and the interval of storage. Means separation (**Table 2**) for the effect of storage temperature on the firmness if the fruit showed that fruits were almost twice (4.47 kg) as much firmer under low temperature than under ambient temperature storage (2.25 kg). Bourne (1982) concluded, after studying the effect of temperature on the firmness of some raw fruits and vegetables, that cold storage gave a consistently higher firmness value than fruits under ambient temperature.

Means separation for the effect of the polymeric coating on the firmness of the fruits revealed that firmness increased as the level of coating was increased. Mean fruit firmness was highest (3.448 kg) at 10% coating and least (3.27 kg) at 0% coating (**Table 2**). Statistically, however, there was no significant ($P > 0.05$) difference between 0, 5 and 7.5% coating and also 5, 7.5 and 10% coating (**Table 2**). This implies that the significant difference in the effect of coating on the firmness of the fruit can be attributed to the difference in firmness for non-coated (0%) fruits and that of 10% coating which was significantly different from each other.

The separation of means for the effect of storage interval on the firmness of the fruit revealed that there was a consistent loss of firmness with increasing storage interval (**Table 2**). This observation was more noticeable under ambient temperatures than under low temperature storage (**Table 2**). Loss of firmness was delayed in coated than non-coated fruits. Park *et al.* (1993) reported that coated tomatoes showed lower respiration and O_2 consumption than non-coated tomatoes and had better firmness retention. In this study, it was probable that a reduction in the rate of respiration of coated pineapple coupled with retention of moisture created by the film of coating on the fruit surface might have accounted for the delayed loss of firmness in the coated fruits.

CONCLUDING REMARKS

Storage caused significant decreases in vitamin C and total sugars with concomitant increases in acidity, astringency, translucency and fruit texture. Low temperature storage minimized the effect of the observed differences. All the four levels of the polymeric coating concentrations influenced the physical and chemical qualities of the fruits causing only minimal changes during post-harvest storage. The 7.5% polymeric coated fruits gave the best quality attributes. However, the 5% coating was preferred because of economy and for the fact that there were no significance between the 7.5 and 5% coated fruits. Polymeric coating can therefore be applied to pineapple cv. 'Smooth Cayenne' fruits prior to storage to effectively prolong the chemical and physical quality characteristics of the fruits.

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