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Development of Elephant Apple Fruit Quality as Affected by Postharvest Ethanol Application and Temperature

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Abstract: Experiments were conducted to study the effects of temperature and ethanol application on the development and quality of the elephant apple fruit. Various treatments were carried out, viz., at room temperature (RT, 28°C), in exposed sunlight (ES, 35°C), in 70% ethanol (ET, 28°C), under plastic covering (PC, 28°C), under plastic covering plus 70% ethanol (PCET, 28°C), at low temperatures (LT, 12°C) and at freezing temperature (FT, -1°C). The longest preservation time was observed in fruits preserved in FT (-1°C) and shortest in fruits preserved in ES (35°C) whilst the maturity index was highest in ES (35°C) treatments and lowest in FT (-1°C) compared to the other treatments at the end of the experiments. However, fruits kept at FT (-1°C) exhibited chilling injury symptoms. Total Soluble Solids (TSS) was highest in ES (35°C) and PCET (28°C) from the 1st to the 7th harvest compared to other treatments. A similar increasing trend in TSS was observed in all the treatments. On the contrary, Titratable Acidity (TA) was highest in FT (-1°C) and LT (12°C) from the 1st till the 7th harvest. Similarly a declining trend of TA was found in all the other treatments. TSS was found to be higher in pulp than in peel in the ethanol treatment at 6, 12, 24, 48 and 72 h. However, TA was higher in peel than pulp. The results showed that low temperatures (LT and FT) and plastic covering with 70% ethanol (PCET) delayed ripening in elephant apple fruits and were the best preservation techniques.

Key words: Total soluble solids, titratable acidity, exposed sunlight, ethanol, temperature

INTRODUCTION

Temperature and preservation techniques play an important role in fruit quality and development after harvesting (Barbosa-Cánovas, 2003). For a long time, fruit preservation has posed a problem to fruit growers but now they have at their disposal different improved methods of preservation after harvest. However, little has been done and is known about the preservation of the elephant apple fruit, an increasingly popular fruit in this region. The elephant apple is a tropical fruit native to Southeast Asia. It is served and eaten in both ripe and unripe stages and it is common in chutneys and other pickled dishes. While it was originally thought of as a source of food for the poor, recent years and more mechanized harvest techniques have popularized it in Southeast Asia. It is relatively unknown in Europe or the United States, like many Asian fruits. New preservation techniques other than those traditionally employed need to be tested and developed to improve the elephant apple fruit quality and prospects.

Many events are associated with fruit ripening, depending on whether it is climacteric or non-climacteric, such as a significant change in colour, texture, flavour, sugar and ethanol content amongst other things. When a fruit ripens it passes through a series of changes in its physico-chemical characteristics. In banana, there is a significant conversion of starch to sugars in the pulp, during which enzymes responsible for starch degradation increases rapidly while those responsible for its synthesis decreases (Hill and Rees, 1995). This is usually concomitantly accompanied by an increase in Total Soluble Solids (TSS) and a decrease in Titratable Acidity (TA). It has also been reported that fruits from a shaded position has a lower storage life, but a higher TA value than fruits placed in an exposed position (Tombesi *et al*., 1993). They also observed skin colour was significantly more ripened in the exposed fruit than in the internal and shaded fruit. Recently, it has been observed that ethanol and acetaldehyde were found in increasing concentration during fruit ripening and the application of either ethanol or acetaldehyde can promote the ripening process (Podd and Staden, 2004). Ethanol is a naturally occurring substance resulting from the fermentation by yeast of fruit sugars (Dudley, 2004). Dudley also observed that ripened and over-ripen palmed contained ethanol within the pulp at varying concentrations.

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It is well documented that several factors affect the postharvest quality of fruits and flowers and these have influenced the development of several techniques for the preservation of postharvest quality of fruits. One of these factors is temperature. Generally, low temperature lengthens the storage life of fruits and flowers as their metabolic rate will be lowered. For example, the findings of on carambola fruits have shown that fruits kept at 5°C lasted longer than those held at 20°C. Furthermore studies with golden delicious apples have also shown that a delay in ethylene production was observed at temperatures below 12°C compared to those kept at 20°C (Knee, 2005).

There is no literature yet available on studies with elephant apple fruit. This study was undertaken to develop suitable postharvest techniques for the preservation of elephant apple fruits by using ethanol and varying temperature.

MATERIALS AND METHODS

The plant and experimental site were selected in the botanical garden on 15 November 2007, under the Institute of Biological Sciences, University of Malaya, Kuala Lumpur, Malaysia.

Plant material: For the experiments a 12-year-old elephant apple tree was used. The tree was approximately 8 m in height with a canopy size of about 6 m. The tree consisted of 5 branches and 30 sub-branches. Three fruits were harvested from each branch per date of harvest. Branch spacing was approximately 1-1.5 m. The weeding, irrigation and pesticide application were done as needed.

Fruit harvesting and weight measurement: The 1st harvest was done on 15th January, 2007. Harvesting continued until 16th April at 15 days interval (15th January, 30th January, 14th February, 1st March, 16th March, 31th March and 15th April 2007). Fruits were weighed immediately after harvest.

Treatment settings for harvested fruits: The treatments for the experiments were set in mid January 2007. Treatments were set following a completely randomized design repeated in different branches of the tree. For each treatment, 3 branches (replications) were selected. A total of 3 fruits from 3 branches (1 fruit/1 branch) were collected for each treatment. The treatments carried out were as follows:

- Fruits were kept at room temperature (RT, 28°C) for 4 weeks after harvest
- Fruits were kept in exposed sunlight (ES, 35°C) for 1 week after harvest, (4 h day^{-1}) and kept in room temperature for 4 weeks
- Fruits were soaked in 70% ethanol (ET, 28°C) for 1 min and kept in room temperature for 4 weeks
- Fruits were covered by a transparent plastic sheet (PC, 28°C) and kept at room temperature for 4 weeks
- Fruits were soaked in 70% ethanol (PCET, 28°C) for 1 minute and covered by a transparent plastic sheet and kept at room temperature for 4 weeks
- Fruits were kept in the refrigerator at 12°C (LT, 12°C) for 4 weeks
- Fruits were kept in the deep freezer at -1°C (FT, -1°C) for 4 weeks. Each treatment was applied to the 3 fruits harvested from 3 branches (replicates). A total 21 branches were used for the 7 treatments

Treatment settings for fruit peel and pulp: The fruits were harvested on 20th February, 2007. Treatments were set following a completely randomized design as mentioned above. Peel and pulp were separated by a small sharp knife. The peel size was 5 cm × 4 cm × 1 mm whilst the pulp size was 5×4 cm ×5 mm. The treatments were set immediately after harvest. The following treatments were carried out:

- Control treatment. The peel and pulp were kept in a refrigerator at 15°C
- The peel and pulp were submerged in 70% ethanol (ET) for 6 h in a Petri dish and kept in the refrigerator at 15°C
- The peel and pulp were submerged in 70% ethanol (ET) in a Petri dish for 12 h and kept in the refrigerator at 15°C
- The peel and pulp were submerged in 70% ethanol (ET) in a Petri dish for 24 h and kept in the refrigerator at 15°C
- The peel and pulp were kept in 70% ethanol (ET) in a Petri dish for 48 h and kept in the refrigerator at 15°C
- The peel and fruits were kept in 70% ethanol (ET) in a Petri dish for 72 h and kept in the refrigerator at 15°C

Each treatment was applied to 3 fruits from three branches (replicates). A total of 18 branches were used for the 6 treatments. Three slices were collected from each fruit (3 fruits) which meant that 9 slices were collected for each of the treatments

Juice collection: Fruit juice was collected manually using a hand thresher and cheesecloth and preserved in the freezer to determine SSC and TA.

Total soluble solids content determination (TSS): The soluble solids content was measured with a refractometer (Atago PR-1). One drop of juice was placed in the refractometer and the reading recorded.

Titratable acidity determination (TA): TA was determined by titration with 0.1 N NaOH using phenolphthalein as an indicator. Titration was carried out on 1 mL of juice diluted with 9 mL of distilled water until colour was developed and the titration reading recorded.

Statistical analysis: The experiment was set following completely randomized design. Fruit were collected randomly from the different branches. SE was represented in the table and graphs.

RESULTS AND DISCUSSION

As shown in Table 1, the treatment that gave the best preservation time was FT (-1°C) where the harvested fruits lasted more than 30 days. This was followed by those kept under LT (12°C) and ET (28°C) which were preserved for 20 and 18.5 days, respectively. The storage life for the other treatments lasted between 15 to 17 days. This finding is similar to what has been reported in many other studies on various other fruits, where low temperatures prolonged the shelf life of the fruits by reducing their metabolism (Yanuriati *et al*., 1999; Vishnu Prasanna *et al*., 2000). The initial and final weight ratios of the fruits were highest in the ES (35°C), RT (28°C) and PC (28°C) treatments ranging between 1.20 to 1.41 (Table 1). Those under the other treatments exhibited ratios between 1.08 to 1.12. Similarly, the maturity colour score was highest in the ES (35°C) treatment and lowest in FT (-1°C). It was higher in the ES (35°C), PC (28°C), PCET (28°C) and ET (28°C) treatments than in RT (28°C), LT (12°C) and FT (-1°C) treatments. These results showed that the low temperature treatment significantly slowed down ripening, weight loss and color changes.

As can be shown in Fig. 1, the total soluble solids (TSS) of the harvested fruits was highest in ES (35°C), followed by PCET (28°C) and ET, (28°C) after the 3rd harvest. The other treatments, RT (28°C), PC (28°C), LT (12°C) and FT (-1°C) showed low TSS values. There was an increasing trend in TSS values from the 1st harvest till the 7th harvest, in all the treatments, but significantly lower increases for FT(-1°C) and LT (12°C) treatments. Vishnu Prasanna *et al*. (2000) reported similar trends in studies on the effect of storage temperature on ripening in custard apples fruits. These results showed that the fruits kept at lower temperatures, in FT (-1°C) and LT (12°C) treatments ripened slowest. Similar findings were

Table 1: The effect of storage on the weight and maturity of elephant apple fruits as affected by different treatments

Treatment*	MPT** time (day)	Weight (g) Initial	Weight (g) Final	Initial: Final ratio	Maturity (bycolour)
RT (28°C)	15.0±1.8	276.1±6.5	238.7±3.5	1.20±0.2	3.5±0.25
ES (35°C)	17.0±2.0	302.3±6.4	214.3±2.3	1.41±0.1	4.5±0.20
ET (28°C)	18.5±2.2	304.4±6.1	270.7±3.0	1.12±0.1	3.7±0.23
PC (28°C)	15.5±1.5	295.2±6.6	248.5±2.9	1.20±0.2	3.8±0.22
PCET (28°C)	16.5±1.6	280.0±6.4	253.1±2.8	1.10±0.1	3.7±0.24
LT (12°C)	20.0±2.1	278.2±5.7	250.0±3.0	1.11±0.1	2.5±0.22
FT (-1°C)	>30.5±2.8	289.1±5.8	265.8±3.8	1.08±0.1	2.0±0.18

*RT: Room temperature, ES: Exposed to sunlight, ET: Ethanol, PC: Plastic covering, PCET: Plastic covering with ethanol, LT: Low temperature, FT: Freezing temperature. **MPT: Maximum preserved time. Mean±SE (n = 4)

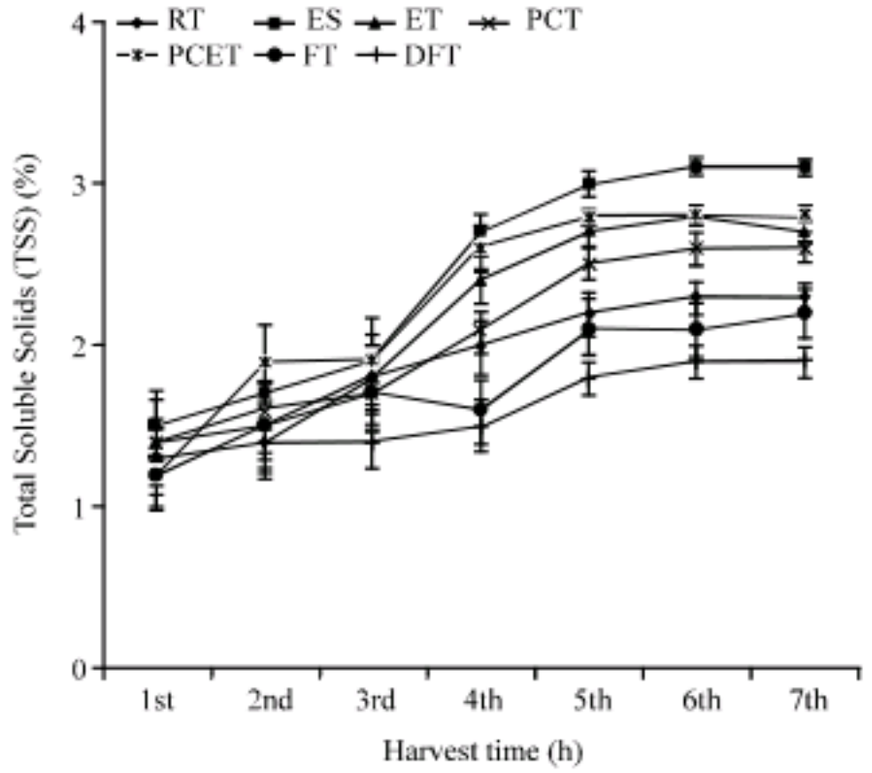

Fig. 1: Total soluble solids content at different harvest times as affected by the different treatments. Bars indicate SE (n = 4)

obtained in studies with cherimoya fruits where it was shown that TSS increased with increasing temperatures (Gutierrez *et al*., 1994).

On the contrary, Titratable Acidity (TA) was lowest in ES (35°C), PCET (28°C), ET, (28°C), RT (28°C) and PC (28°C) compared to the LT (12°C) and FT (-1°C) treatments (Fig. 2). Unlike in the case of the TSS experiments, there was a decreasing trend in all the treatments but significantly lower for the LT (12°C) and FT (-1°C) treatments from the time of the 1st harvest to the 7th harvest. Vishnu Prasanna *et al*. (2000) reported a similar trend whereby the TA (%) increased slightly as the storage temperature is lowered in custard apples.

As can be seen in the Fig. 3, after 10 days, the fruits kept under ET exhibited greatest colour change and ripened earliest whilst those kept at Room Temperature (RT) showed the least change in colour. Fruits stored under the other treatments showed a slight change in

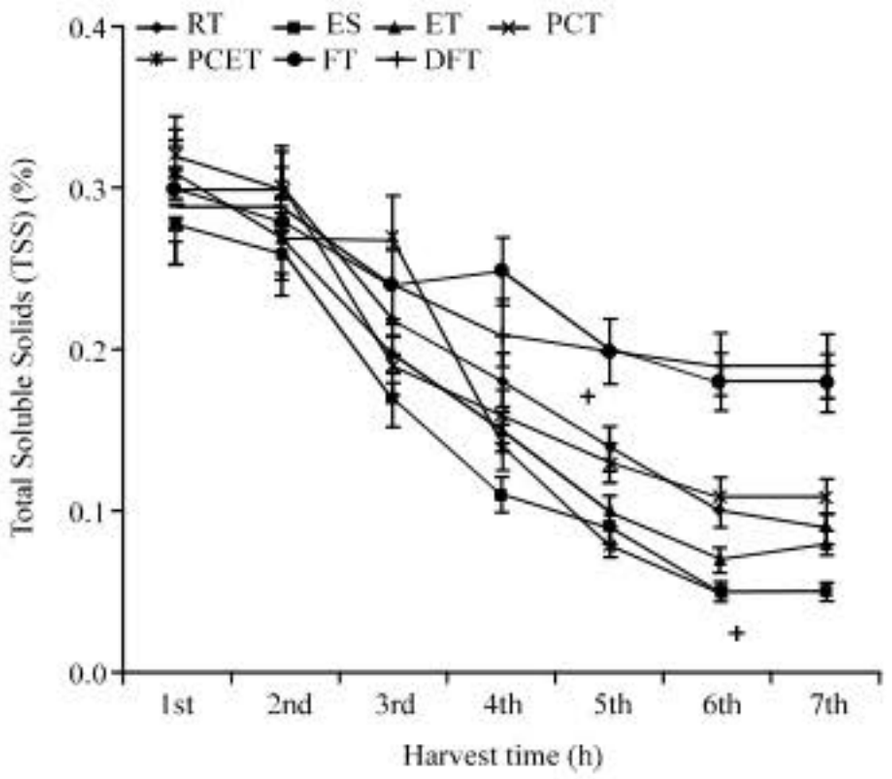

Fig. 2: Titatable acidity content at different harvesting time under the different treatments. Bars indicate SE (n= 4)

colour or intermediary ripening. However, after 25 days of storage, fruits kept under LT and PCET retained structural integrity and slight colour change whilst those kept under the other treatments exhibited severe blackening and were non-edible. These results were similar and visually supported that shown in Table 1.

Table 2 shows that the weight of the peel and pulp in fruit slices immersed in ethanol, increased slightly (6-9%) over the duration of the treatments at 6, 12, 24, 48 and 72 h. However, for control fruit slices (minus ethanol), the weight decreased significantly after 3 days (72 h) by about 60%. The Total Soluble Solids (TSS) content of the preserved slices (peel and pulp) increased with increasing time in ethanol where, it was higher in the ethanol treatments for 24, 48 and 72 h than those kept for 6, 12 h and in the control. The highest TSS content was recorded in the skin and pulp of the 72 h ethanol treatment (Table 2). On the contrary, Titratable Acidity (TA) was highest in the control fruit slices and lower in the ethanol

Fig. 3: The effect of the different treatments on fruit morphology, colour and preservation. RT: Room temperature, ES: Expose sunlight, ET: Ethanol, PC: Plastic covering, PCET: Plastic covering with ethanol, LT: Low temperature, after 10 days (a) and after 25 days (b) of preservation

Table 2: Total soluble solids, titratable acidity and weight of elephant apple fruit skin and pulp as affected by different ethanol treatments

Treatments	Total Soluble Solids (TSS)	Titratable Acidity (TA)	Slice weight (g) Initial	Slice weight (g) Final
Control				
Skin	1.5±0.20	0.45±0.03	4.8±0.45	1.7±0.2
Pulp	2.5±0.30	0.30±0.02	21.6±2.00	12.7±1.2
ET for 6 h				
Skin	2.0±0.21	0.40±0.03	4.6±0.40	5.0±0.3
Pulp	3.0±0.30	0.27±0.02	22.0 ±0.2	24.7±2.1
ET for 12 h				
Skin	2.3±0.20	0.37±0.03	4.8±0.41	5.1±0.3
Pulp	3.4±0.30	0.25±0.02	21.9±1.80	26.1±2.5
ET for 24 h				
Skin	2.5±0.25	0.35±0.03	4.7±0.35	5.1±0.2
Pulp	3.5±0.27	0.20±0.01	22.1±1.90	27.5±2.8
ET for 48 h				
Skin	2.6±0.25	0.34±0.02	5.0±0.38	5.2±0.3
Pulp	3.6±0.26	0.15±0.01	21.8±2.00	29.9±2.9
ET for 72 h				
Skin	2.8±0.20	0.30±0.02	4.9±0.31	5.2±0.2
Pulp	3.8±0.24	1.00±0.01	22.0±1.70	30.3±2.8

ET: Ethanol, h: Hour, Skin and pulp slice size: 5×4 cm, Mean±SE (n = 4)

treated slices. The TA value gradually decreased in the peel and pulp slices treated with ethanol over the 6, 12, 24, 48 and 72 h period and was lowest in the ET 72 sample. These results appear to show that a longer treatment with ethanol caused the pulp and skin slices to exhibit ripening characteristics although Thakur and Pandey (2004) reported that ethanol treatment delayed fruit ripening in tomatoes.

In this study, it can be concluded that a low temperature slowed down the ripening process in elephant apple fruits. In addition to this it was observed that plastic covered fruits treated with ethanol (PCET) lengthened the longevity of the fruits particularly at room temperature. It will be interesting to study the ripening process in elephant apple fruits after storage at low and freezing temperatures and in ethanol (PCET).

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