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Refrigerated Storage of the Seeded Breadfruit (Breadnut) or "Chataigne"

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Breadnut or chataigne, the seeded type of breadfruit (Artocarpus altilis), harvested at the partially immature, firm, green stage was stored for 25 days at 10°C and 16°C and 9 days at 28°C (ambient conditions). Fruits were previously treated by packaging in sealed polyethylene bags or by waxing. Untreated (unpackaged) fruits served as the control. Fruits in refrigerated storage showed reduced weight losses compared to ambient (28°C) stored fruits. Fruit firmness was further enhanced when low temperature storage was combined with polyethylene packaging. Irrespective of storage temperature and treatment, there were no significant moisture content changes in the fruit's pulp or seeds. Unpackaged and waxed fruits stored at refrigerated temperatures (16°C and 10°C) showed peel colour variations from green to brown-green which were more pronounced at 10°C. These symptoms are consistent with chilling injury. Fruits in polyethylene bags at 16°C showed a reduction in brown colour development of the peel for up to 25 days. Waxed fruits, particularly at 10°C and 16°C, underwent deteriorative changes in internal seed and pulp colour. Storage at 16°C for 25 days in polyethylene packaging appears best for retaining fruit colour, firmness and appearance, and the pulp of these fruits was the most suitable for traditional cooking.

Keywords: Breadnut, Seeded breadfruit, Chilling injury, Polyethylene packaging, Waxing

1. Introduction

Distinguished primarily by the presence or absence of seeds in the fruit, two types of breadfruit (*Artocarpus altilis* (Park) Fosberg) have been recognised. The seedless variety is known as breadfruit in English-speaking countries and the seeded type as breadnut. The seeded breadfruit is commonly referred to as "chataigne" in Trinidad and Tobago, Grenada and St. Lucia, and "katahar" in Guyana. The other common names of the seeded type when translated into French are "chataignier" (with seeds), in Guatemala and Honduras as "castana" (with seeds), in Yucatan, "castano de Malabar" (with seeds) and in Puerto Rico, "pana de pepitas" (with seeds). In Malaya and Java, it is "kulor" (with seeds) (**Morton, 1987**). In contrast to the seedless type, the rind of the seeded fruit is covered with fleshy spines and seeds are embedded in a fibrous core. In the Caribbean and especially in Trinidad and Tobago and Guyana, both the seeds and pulp of the seeded breadfruit are consumed in the green, partially immature stage as a vegetable. In the ripened stage, the seeds are roasted or boiled and consumed as a snack. The seeds constitute a higher source of protein 5.25 - 13.3g and 13.8 - 19.9g per 100g of edible portion in the fresh and dried states respectively. When compared to the seedless breadfruit, the seeded breadfruit is actually of more value as a food (**Morton, 1987**). In addition, researchers have shown that the seeds are a good source of calcium, phosphorus and niacin (**Kennard** and **Winters, 1960; Bravo *et al.*, 1983**).

There has been a substantial increase in the export demand for tropical crops from ethnic markets; one such crop being the seeded breadfruit to be utilised in the fresh green form as a vegetable. However, the main problem with the use of the seeded breadfruit is

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its high perishability, which results in high postharvest losses. Some research has been conducted on the seedless breadfruit, but work on the seeded breadfruit is almost non-existent. **Thompson *et al.* (1974)** showed that the storage period of the seedless breadfruit could be extended by refrigeration at temperatures above 12°C and by packing in sealed polyethylene bags. Similar findings have also been shown by **Sankat** and **Maharaj (1990)**. The present study was carried out to investigate the effect of storage temperature, packaging and waxing on the shelf life and marketability of the seeded breadfruit.

2. Materials and Methods

Partially immature seeded breadfruits were harvested by hand from trees in El Dorado, East Trinidad, W.I. At the time of harvest, fruit maturity was determined by size, colour and how closely the fruit segments were packed. The partially immature fruits were medium to large with large fruit segments and green in colour. Fruits averaged 1kg in weight and 14-18cm in diameter. Fruits were harvested with their stems intact, caught at the bottom of the tree with the aid of a bag and laid down for the latex to drain away. In the laboratory, the fruits were washed under running water, placed in a fungicidal dip (0.05% benomyl, 2 mins.) at ambient room temperature (28°C) and air-dried using an electric blower.

A total of 135 fruits were divided into three (3) groups as follows:

(i) **Control**
Untreated, unpackaged fruits,

(ii) **Packaged**
Individual fruits packaged in heat-sealed polyethylene bags (30.5cm x 40.6cm, 0.75ml gauge thickness), and

(iii) **Waxed**
Individual fruits hand-brushed with undiluted liquid paraffin-based wax "Fresh Wax 5IV".

The treated fruits were placed in ventilated, covered cardboard boxes lined with shredded paper. To investigate the effect of storage temperature, fruits from each of the above treatments (Control, Packaged, Waxed) were further divided into three (3) groups and stored at ambient temperature (28°C) as well as in "Walk-In" refrigerated chambers set at 16°C and 10°C respectively. A relative humidity of 85-95% was maintained in the refrigerated chambers.

The trial lasted 25 days for refrigerated fruits (16°C and 10°C) and nine (9) days for fruits stored at ambient temperature (28°C). Refrigerated fruits were sampled at 5-day intervals and ambient-stored fruits at 3-day intervals. At each sampling interval, 3 fruits at each storage temperature (28°C, 16°C and 10°C respectively) and storage treatment (control, packaged and waxed) were removed from storage and subjected to physical and sensory analyses. Three (3) fruits were also analysed at the beginning of the storage trial.

For the non-destructive weight change measurements, the changes in weight of the same two (2) fruits were used throughout the experimental period, at each storage temperature and treatment. These fruits were weighed at each sampling day and returned to storage. Fruit firmness was measured with a Penetrometer (Stanhope-seta, Model No. 1700/1719) and reported as the distance travelled (mm) by a 50g cone after 5 secs. Whole seed firmness was measured using a Compten compression tester (**Compten Industries of Florida, 1991**) and reported in KPa. Moisture contents reported on a percentage wet basis were determined of the fruit's pulp and seeds by drying such samples to constant weight at 70°C.

For sensory evaluation, acceptability was rated on a scale of 1-5 as follows:

1: Very hard (acceptable);

2: Medium hard (acceptable);

3: Slightly soft (unacceptable for vegetable use);

4: Medium soft (unacceptable for vegetable use);

5: Very soft (unacceptable for vegetable use).

Subjective fruit skin colour was rated on a scale 1-6 as follows:

1: Deep green (90 - 100% green);

2: Light green (70 - 90% green);

3: Yellowish-brown (50 - 70% green);

4: Greenish-brown (25 - 50% green);

5: Brown with a tinge of green (< 25% green);

6: Predominantly brown (< 5% green).

Pulp colour was rated on a scale 1-5 as follows:

1: Whitish-green;

2: Cream with a tinge of green;

3: Yellowish-green;

4: Yellowish-brown;

5: Reddish-brown.

Internal seed colour was based on a cross-sectional view and rated on a scale of 1 - 6 as follows:

1: Off-white;

2: Creamy/white;

3: Yellow/white;

4: Reddish-brown with specks of white;

5: Light brown, and

6: Brown.

The data obtained from this study were analysed by the Analysis of Variance method (ANOVA) using the computer software programme GENSTAT 5 (**Release 2.2, Lawes Agricultural Trust, 1990**).

3. Results and Discussion

3.1 Weight Changes

Weight loss of the seeded breadfruit in storage was significantly affected ($p<0.001$) by storage time, temperature, treatments and their interactions. Generally, weight loss increased with time over the 25-day storage period (**Figure 1**). Fruits stored under ambient conditions (28°C) showed the highest weight loss while low temperature storage (16°C and 10°C) resulted in considerable reduction in weight loss especially when combined with polyethylene packaging. Weight loss of ambient stored fruits (28°C) averaged 3.03%/day (R^2=0.98), 0.27%/day (R^2=0.98) and 1.34%/day (R^2=0.98) for the control (unpackaged), packaged and waxed treated fruits respectively. For fruits stored at 16°C however, average weight losses were 1.21%/day (R^2=0.97) for unpackaged, 0.10%/day (R^2=0.99) for packaged and 0.40%/day (R^2=0.98) for waxed treated fruits, while for fruits stored at 10°C, weight losses were reduced to 0.78%/day (R^2=0.97), 0.06%/day (R^2=0.98) and 0.28%/day (R^2=0.99) for the control, packaged and waxed treated fruits, respectively.

Storage of perishables at low temperature is one of the most common methods used, as low temperature reduces the rate of respiration, transpiration, enzymatic activity and growth of microorganisms. Waxing and polyethylene packaging are also used to extend the life of fruits and vegetables by reducing moisture loss and creating a modified atmosphere around the fruit (**Kays, 1991**). The results suggest that weight changes in the seeded breadfruit may be primarily due to water loss.

3.2 Moisture Content

The initial moisture content of the seeds and pulp were approximately 85% and 88% (wet basis) respectively. Moisture content of both seeds and pulp generally decreased but at varying rates and was not significantly affected by treatment, temperature or storage time. The loss in weight of the whole fruit therefore does not directly correspond to the loss in moisture of the seeds and pulp. This may suggest that weight loss is due to moisture loss on or just below the fruit's surface (skin or peel). This is supported by the observation that slight shrivelling of the fruit's surface accompanied weight loss.

3.3 Firmness

Firmness or texture of the whole fruit (expressed as penetration depth, mm) was significantly affected by storage treatment ($p < 0.05$). These results are shown in **Figure 2**. An increase in penetration depth of

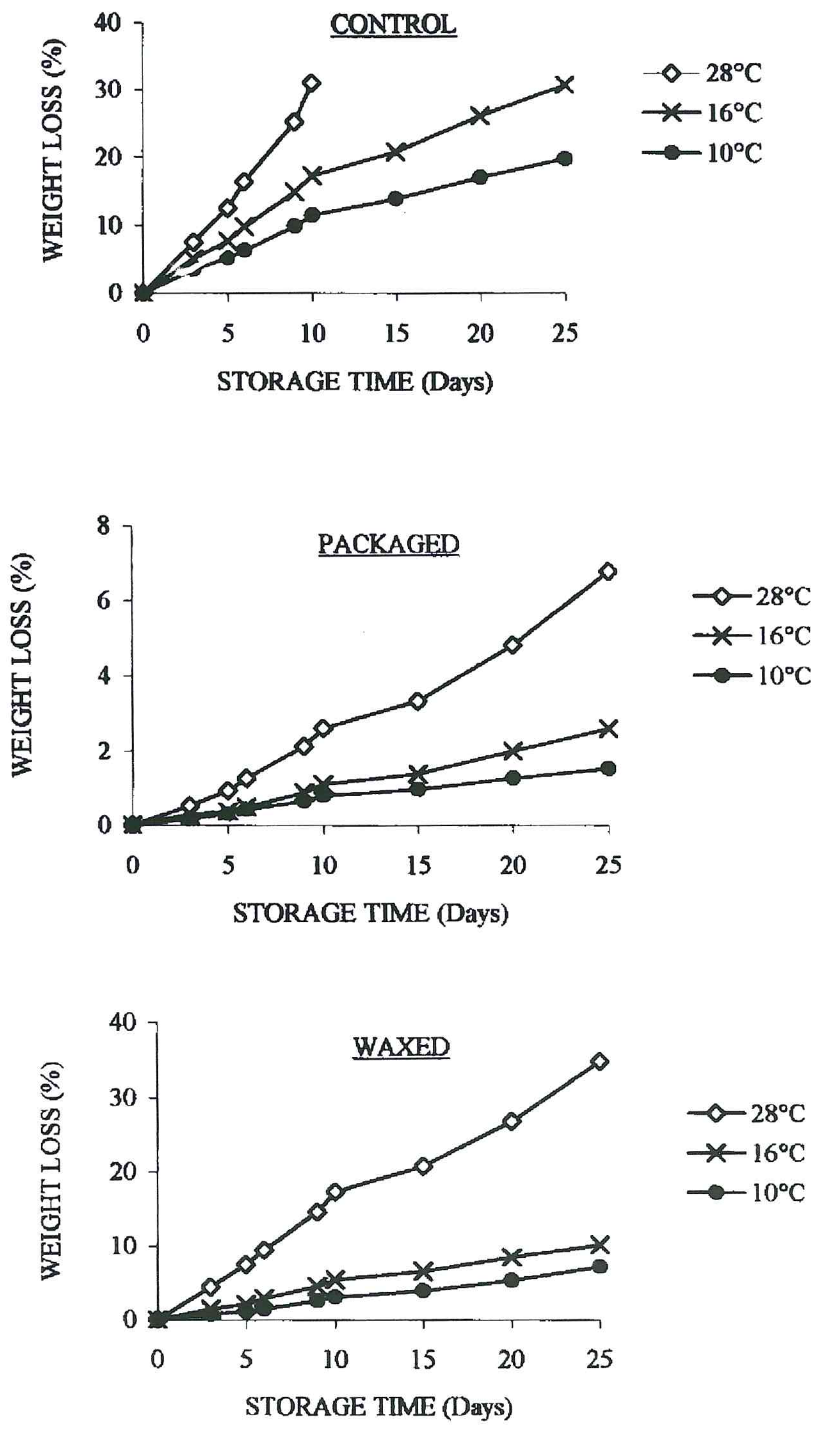

FIGURE 1: *The Effect of Temperature and Storage Treatment on Weight Loss in Control, Packaged and Waxed Breadnuts stored under Ambient and Refrigerated Conditions*

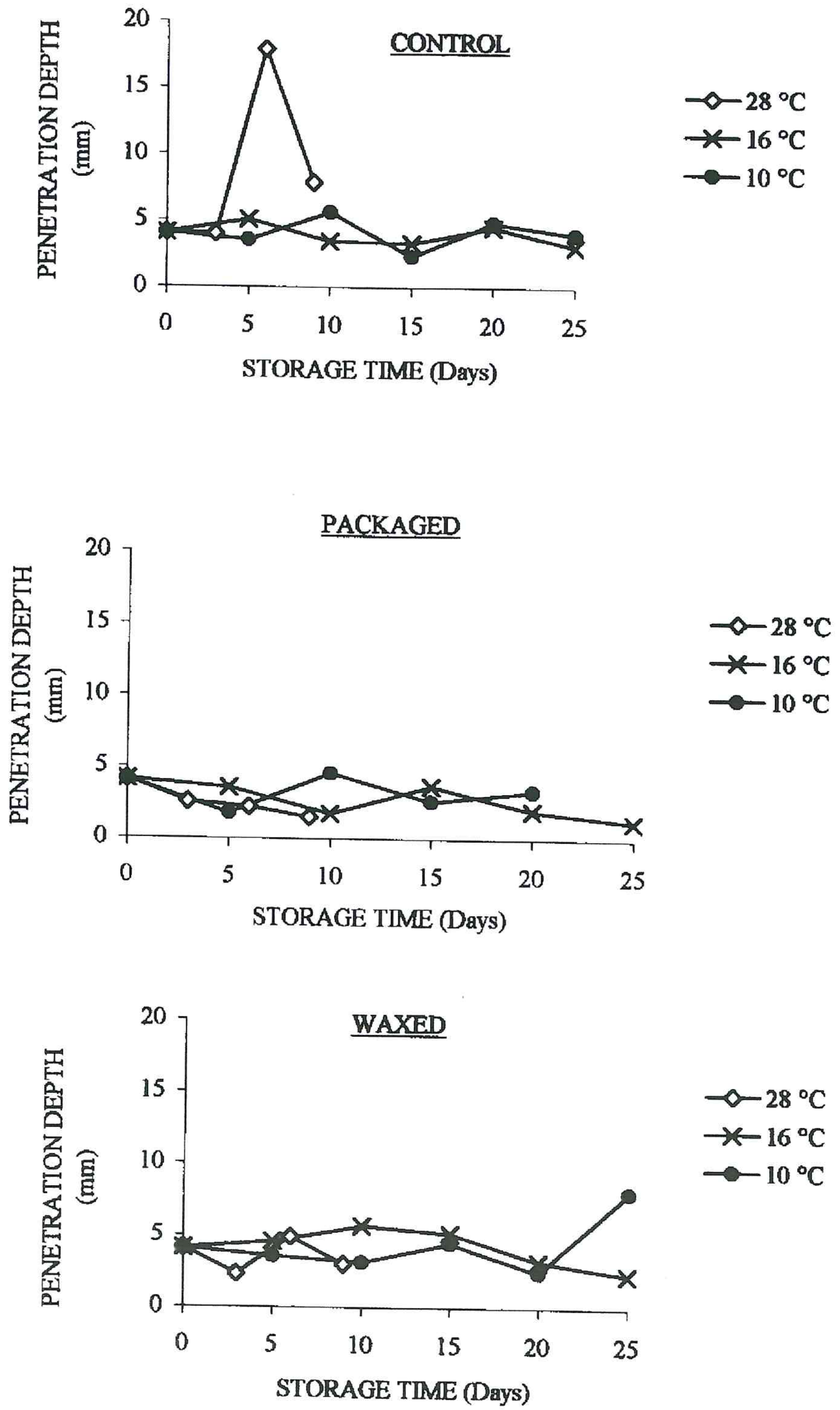

FIGURE 2: *The Effect of Temperature and Storage Treatment on Firmness (Peneratration Depth) of Control, Packaged and Waxed Breadnuts stored under Ambient and Refrigerated Conditions*

untreated, ambient stored fruits represents softening of the fruit which is associated with the ripening process. With one exception, refrigerated, packaged and waxed fruits showed lower penetration values and these fruits remained firm for the duration of the storage trial (25 days).

Firmness (Young's modulus-E) of the whole seeds as determined from compression testing was significantly affected by storage time, temperature ($p<0.001$) and treatment ($p<0.05$). An increase in Young's modulus represents an increase in seed firmness. Young's modulus was highest for all ambient (28°C) stored fruits, averaging between 5000-8000 KPa for unpackaged, packaged and waxed fruits (**Figure 3**). For such fruits, an initial increase in E values was detected for short periods, probably due to maturation of the seeds. Normally, as seeds mature, they become firmer due to moisture loss.

Refrigerated fruits at 10°C and 16°C mainly exhibited a decrease from its initial E value, suggesting textural alterations resulting from chilling injury of the seeds from the partially immature fruits. Young's modulus values of unpackaged and waxed fruits at 10°C were lower than those of packaged fruits. Packaged fruits would have had a modified atmosphere (MA) created around them and modified atmospheres are known to reduce fruit softening (**Kays, 1991**). At 10°C, waxed and unpackaged (control) fruits were also more susceptible to chilling injury. There were no appreciable differences in E values in unpackaged and packaged fruits stored at 16°C, while E values were the lowest for waxed fruits. Waxing appears to enhance chilling injury as there were marginal differences in E values of seeds from waxed treated fruits at 10°C and 16°C.

Thompson *et al.* (1974) showed that fruit-softening occurs after prolonged low temperature storage followed by removal to ambient temperature, suggesting that some form of chilling damage occurs to the fruits at the lower temperature. Furthermore, **Kays (1991)** explained that exposure of some products to chilling temperatures, even for short periods, may result in textural alterations and cited sweet potatoes as an example where the centre of the root becomes woody and inedible when held at temperatures below 10°C. **Lyons (1973)** concluded that in general, the severity of injury of sensitive plant tissues increases as temperature is lowered or as exposure is extended at any chilling temperature. **Ryall and Lipton (1979)** indicated that immature fruits are generally more susceptible to chilling injury than mature fruits.

3.4 Peel Colour

Peel colour of fruits in storage was significantly affected by storage time, temperature, treatment ($p<0.001$) and their interactions (**Figure 4**). As time progressed, fruit peel colour changed from deep green to predominantly brown, as during storage the green pigment, chlorophyll, underwent considerable changes. Ambient stored (28°C) unpackaged fruits changed colour from green to yellowish-brown after nine (9) days, indicative of ripening due to physiological maturity. Under ambient conditions (28°C), waxed and packaged fruits however, were predominantly green after day 6 and 9 respectively. Under low/reduced temperature storage (10°C and 16°C), unpackaged and waxed treated fruits rapidly underwent a deteriorative colour change from green to brown, with no signs of yellowing and thus symptomatic of a chilling disorder. These results agree with the findings of **Thompson *et al.* (1974)** who reported that the seedless breadfruit changed colour from green to dull brown due to chilling injury. Brown colour development was much less severe for packaged fruits stored at 16°C compared to their unpackaged and waxed counterparts. After 25 days, packaged fruits at 16°C remained predominantly green (rating of 2.33) while unpackaged and waxed fruits were predominantly brown i.e., rating of 5.3 and 4.7 respectively. Browning for packaged fruits was more apparent at 10°C compared to 16°C (**Figure 4**).

3.5 Pulp Colour

Pulp colour was significantly affected by storage time, temperature ($p<0.001$), treatment ($p<0.01$) and time/treatment interaction ($p<0.001$). At all storage temperatures, packaged fruits showed a more gradual change in pulp colour from the initial whitish green. After 25 days at 16°C, the pulp of packaged fruits appeared cream with a tinge of green, while the pulp of unpackaged (control) fruits appeared yellowish-green in colour. Waxing was found to promote colour deterioration of the pulp, as these fruits showed abnormal color changes from whitish-green to reddish-brown by the 15th day under refrigerated storage conditions.

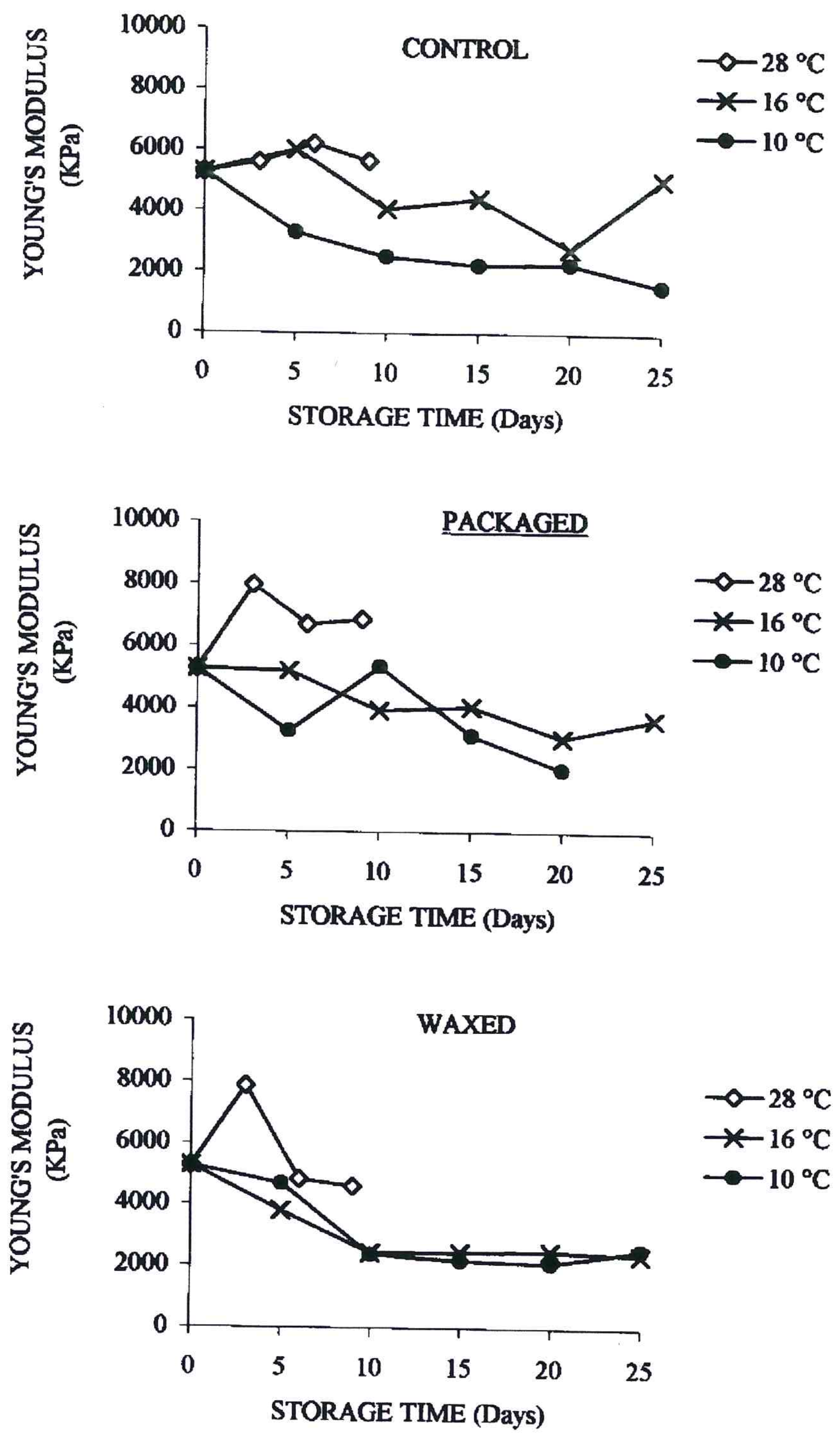

FIGURE 3: *The Effect of Temperature and Storage Treatment on the Firmness (Young's Modulus, E) of Whole Seeds of Control, Packaged and Waxed Breadnuts stored under Ambient and Refrigerated Conditions*

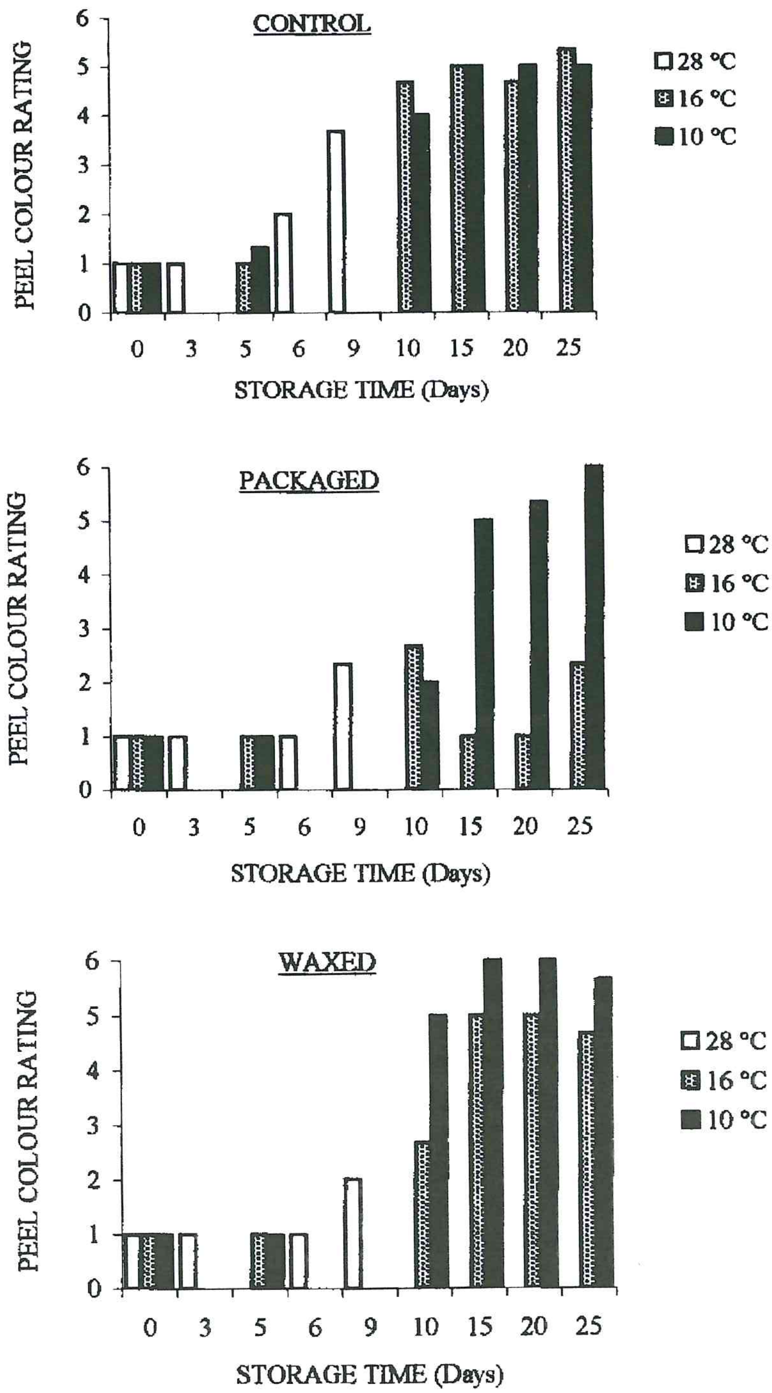

FIGURE 4: *The Effect of Temperature and Storage Treatment on Peel Colour Rating of Control, Packaged and Waxed Breadnuts stored under Ambient and Refrigerated Conditions*

3.6 Internal Seed Colour

Internal colour of the seeds of the fruit was significantly affected by storage time ($p<0.001$) and treatment ($p<0.05$). Internal seed colour changed from an initial off-white to a reddish-brown with specks of white in fruits stored at 10°C and to a lesser extent in fruits at 16°C, suggesting that these fruits suffered chilling injury at the low temperatures. Colour ratings increased with storage time. The seeds of waxed fruits showed more internal browning as compared to packaged and unpackaged fruits, suggesting that waxing enhanced chilling injury.

3.7 Acceptability

Acceptability based upon thumb test was significantly affected by storage time, temperature, treatment, time/temperature and time/treatment interactions ($p<0.001$). Fruits were harvested at a partially immature stage and were very firm when subjected to the thumb test. Unpackaged (control) fruits began to soften after 3 days at 28°C, whereas unpackaged fruits stored under refrigerated conditions (16°C and 10°C) softened only slightly by the 10th day. Beyond this time, softening increased with storage time particularly at 16°C. Irregular increases in acceptability ratings for all fruits were observed due to the compound nature of the fruit. This caused uneven ripening within the same fruit leading to variability in acceptability ratings. Polyethylene packaged fruits at 16°C and 10°C remained hard and firm for the duration of the storage period (25 days) whereas waxing did not delay the softening process for any extended period when compared with polyethylene packaging.

4 Conclusions

Prolonged storage of the freshly harvested seeded breadfruit in the partially immature stage is not possible beyond 3-4 days under tropical, ambient conditions (28°C). However, when such fruits are placed in sealed polyethylene bags, storage life under ambient conditions can be extended up to nine (9) days. Refrigerated storage can also extend the storage life of these fruits but there is the risk of chilling injury. This is more apparent in waxed fruits. Fruits stored at 16°C in sealed polyethylene packaging are acceptable after 25 days without any symptoms of chilling injury of the peel and pulp, but the seeds become discoloured. Polyethylene packaging has a beneficial effect on reducing weight loss and shrivelling while maintaining fruit firmness and enhancing green colour retention.

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