REFRIGERATED STORAGE OF BREADFRUIT AND THE EFFECT OF WAXING, PACKAGING AND STORAGE IN WATER

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Breadfruit (*Artocarpus altilis*) is marketed and consumed in the Caribbean Islands in the mature, green, firm and unripe state. It is a climacteric fruit of extreme perishability. In a storage trial lasting 25 days, the post-harvest behaviour was determined of the fruit in refrigerated storage at 16 (61), 12 (54) and 8°C (46°F) and under ambient (28°C or 82°F) conditions. Four treatments were used: normal air storage (control), storage of individual fruits in water, packaging in polyethylene bags and waxing. Fruits held under ambient conditions were stored for up to 8 days. During storage, physical (weight, volume, specific gravity. and firmness), chemical (total soluble solids, pH and moisture) and sensory (skin and flesh colour, acceptability based upon firmness and odour) changes were evaluated. Under ambient conditions air-stored fruits ripened rapidly showing considerable changes and were unacceptable by the fourth day. Fruits stored in water showed a slight delay in the ripening process, however they increased in weight and volume, showed a rapid decline in pH with off-odour development by the fifth day. Waxing in particular and packaging to a lesser extent extended the shelf-life of the fruit under ambient conditions to 1 week. In refrigerated storage, the ripening process was delayed as the storage temperature was lowered, however severe chilling injury occurred as browning of the fruit's skin. This was the limiting factor. Waxing in particular, and to some extent packaging and storage in water alleviated this behaviour. Waxing appears to be the treatment of choice, with the potential to extend the marketable shelf -ife to 18 days at 16°C (61°F).

The breadfruit (*Artocarpus altilis*) is a very popular fruit in the islands of the Caribbean. The mature, green fruit is used for cooking – either boiled, baked, fried or roasted. Breadfruit is well-known for its poor keeping qualities, as fruits ripen and soften within 2–3 days of harvest. In the Caribbean, such ripe, sweet fruits have no commercial value, as only mature, green fruits of a firm texture are purchased by consumers. The high perishability of the breadfruit not only results in losses during local marketing, but severely restricts its export potential to overseas markets having Caribbean and Asian communities, e.g. Toronto, New York and London.

Despite its importance, little post-harvest storage research has been carried out on this crop. Breadfruits exhibit a respiratory climacteric and Biale and Barcus (1970) reported that detached fruits show a high rate of respiration peaking to a value greater than 3ml CO_2 per kg per hr (48.04 x 10^{-6} cu ft CO_2 per lb per hr), 5 days after harvest. Matthews *et al.* (1986) noted that there is a lack of simple, suitable methods for preserving the fruit in the fresh form. A traditional method of breadfruit storage employed by small farmers in the Caribbean consists of immersing the fruit under water at ambient temperature (28–30°C or 82–86°F). Thompson *et al.* (1974) reported that storage in water prolonged the shelf-life for approximately 1 week, after which time the fruit started to split and softening was observed. They also noted that under ambient, Jamaican conditions (28°C or 82°F) fruits softened completely in 2–4 days; at 12°C (54°F) fruits softened after 8 days while at 7°C (45°F) softening was greatly delayed but the skin colour of the fruit changed from green to dull brown 2–3 days after storage. Mariott *et al.* (1979) reported that one of the principal problems associated with breadfruit storage is abnormal skin browning. The storage of breadfruits in polyethylene bags has been reported to delay the ripening and softening process (Mariott *et al.*, 1974; Passam *et al.*, 1981; Thompson *et al.*, 1974).

Objectives

The overall goal of this study was to determine the elements of an appropriate post-harvest system for handling and storage of the breadfruit so as to enhance its shelf-life and extend its marketability, particularly to export markets. Specific objectives were therefore:-

- to characterize the post-harvest behaviour at different refrigerated storage temperatures (8 [46], 12 [54], 16 [61] and 28°C [82°F]) through measurement of the physical, chemical and sensory changes which affect its marketability.

- to examine the above-mentioned behaviour of waxed and packaged fruits, as well as fruits stored in water.

Materials and methods

An experimental storage trial was designed and conducted for mature, green breadfruits of the 'Yellow-heart' variety commonly grown in the island of Trinidad. Fruits were carefully harvested by a tree climber from a single tree, approximately 20m (65ft) tall. Fruits were caught at the bottom of the tree in a large, woven polyethylene bag by a catcher. Damaged fruits were rejected. Fruit maturity was assessed by the large fruit size, large segment size and green colour, with the exudate from the cut stem also being noted and used as a criterion for fruit selection. Fruits were transported from the field to the storage laboratory in plastic field crates and chipped ice was placed over fruits to provide some pre-cooling during transport. On arrival at the laboratory fruits were assigned a number previously determined from a random number table and were labelled. Fruits were individually washed using running tap water and their individual weights measured when submerged in water and suspended from a bottom-loading electronic balance (Sartorious Model 1216 MP) and using a sinker. These data were used in calculating the fruit's initial volume and specific gravity (s.g.). Fruits were then pre-treated by dipping for 2 minutes in a fungicidal solution of 0.05 per cent benomyl, maintained at room temperature (28°C). Subsequent to this treatment, fruits were air-dried using an electrical blower to remove residual surface moisture, and then the individual fruit weight in air was measured using the electronic balance.

Seventy-two breadfruits averaging 1.2kg (2.65lb) in weight and with a standard deviation of ±0.2kg (0.44lb) were divided into four storage treatments as follows:

Treatment I – 18 fruits stored in air (control); three to be stored at 28°C (82°F; ambient), and five each at 16 (61), 12 (54) and 8°C (46°F).

Treatment II – 18 fruits stored in water; three at 28°C (82°F), and five each at 16 (61), 12 (54) and 8°C (46°F).

Treatment III – 18 fruits to be individually packaged in sealed polyethylene bags – 27cm x 40cm (10.6in x 15.7in); 100 gauge – with three stored at 28°C (82°F) and five each at 16 (61), 12 (54) and 8°C (46°F).

Treatment IV – 18 fruits brush-coated with a 'Fresh Mark FM-51V' undiluted wax; three stored at 28°C (82°F), and five each at 16 (61), 12 (54) and 8°C (46°F).

For refrigerated storage, three 'walk-in' storage rooms were used – two Forma Scientific at 8 (46) and 12°C (54°F) ±0.5°C or 0.90°F and one Bally at 16°C (61°F) ±1.5°C or 2.7°F. Fruits to be stored in water were kept individually in pails of 15 litre (0.53ft^3) capacity with the water initially pre-cooled in the 'walk-in' refrigerated rooms.

For fruits stored under ambient conditions and where the self-life was expected to be short, fruits were stored for a maximum of 8 days during which time pre-determined, previously randomly selected fruit, were sampled for the measurement of physical, chemical and sensory characteristics on Days 4, 5, and 8.

On each sampling day therefore, four fruits (one from each treatment) were analysed. Refrigerated stored fruits were held for a maximum of 25 days, and fruits were sampled from each treatment. On each sampling day therefore, an additional 12 fruits (four treatments; three temperatures) were analysed from refrigerated storage. At the beginning of the storage trial, three fruits were analysed for initital quality.

Analysis consisted of the determination of weight and volume loss in storage, calculated as a percentage from the initial and final (on removal from storage) individual fruit weight and volume. From the mass:volume ratio, s.g. was also determined. The firmness of the fruit, with the skin removed, was measured by a digital penetrometer (Koehler, model PNR10), using a cone and an added weight of 50g (0.11lb). The depth of penetration of the cone into the fruit was automatically measured after 5 seconds and reported in millimetres. Moisture content determinations of the breadfruit were made by drying a 20g (0.044lb) sample of the sliced pulp at 76°C for 48 hours. Total soluble solids (TSS) was measured using a refractometer (Atago, type T) and a 1:1 dilution of the blended breadfruit pulp. This diluted pulp was also used for pH determination using a glass electrode (Analytical Measurements, model 707).

Subjective determinations were also made of the fruit's skin and flesh colour, odour and acceptability based upon firmness to the touch of the skin.

Skin colour was rated based on changes to the initial green colour of the skin as follows: 1 – deep green; 2 – light green; 3 – green with 25-50 per cent yellow; 4 – over 50 per cent yellow and slight browning; 5 – predominantly brown.

Flesh colour was rated based on colour changes of the fruit's flesh as follows: 1 – white to cream; 2 – cream; 3 – pale yellow (25–50 per cent); 4 – yellow (> 50 per cent); 5 – brown.

Acceptability ratings based upon firmness to the touch of the fruit were: 1 – hard and very acceptable; 2 – medium hard and acceptable; 3 – initiation of softening and partially acceptable; 4 – medium soft and unacceptable; 5 – very soft and unacceptable.

Odour ratings were based upon the development of off-odours emanating from the fruit as follows: 1 – no off-odour, 2 – slight off-odour; 3 – strong off-odour; 4 – intense off-odour.

Results and discussion

The physical, chemical and sensory effects on the breadfruit of duration of storage (time), storage temperatures and storage treatments were determined from the experimental data using analysis of variance.

Weight loss in storage

The percentage loss in weight of breadfruits in storage was significantly affected by storage time ($p < 0.001$), temperature ($p < 0.001$) and treatment ($p < 0.001$).

As shown in Figure 1, the loss in fresh weight of fruits stored in air (treament 1 - control) increased almost linearly with storage time and averaged 2.64, 0.62, 1.77 and 1.16per cent per day at 28 (82), 16 (61), 12 (54) and 8°C (46°F),respectively. The comparatively low weight loss obtained at 16°C can be attributed to the design of the 'walk-in' refrigerated chamber used. This was fitted with a low velocity evaporator ideally suited to perishable crop storage and a high relative humidity environment was also obtained (> 95 per cent).

Waxing and packaging (Treatments III and IV) reduced weight losses compared to control fruits with average values of 1.43, 0.20, 0.44 and 0.32 per cent per day obtained for waxed fruits at 28 (82), 16 (61), 12 (54) and 8°C (46°F) respectively. Comparative values for packaged fruits were 0.81, 0.12, 0.10 and 0.09 per cent per day.

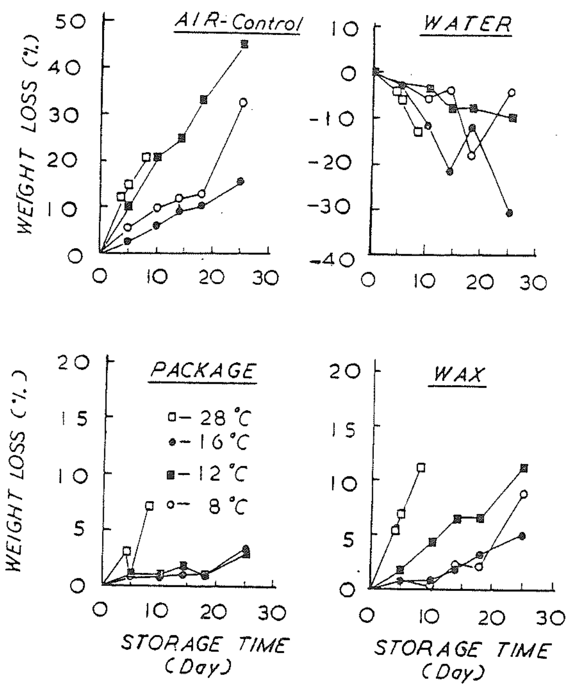

Figure 1. Weight losses of breadfruits in storage

For fruits stored in water (Treatment II) there were significant weight gains at all temperatures, particularly at the higher storage temperatures of 28 (82) and 16°C (61°F). Fruits stored in water at 28 (82), 16 (61), 12 (54) and 8°C (46°F) showed estimated weight gains of 1.57, 1.14, 0.41 and 0.35 per cent per day, respectively. These weight gains are attributed to the uptake of water by the fruit's tissue. Thompson (1974) reported that fruits stored in water at 12–13°C (54–55°F) gained weight at 0.9 per cent per day during a 15-day storage period.

Generally, as the storage temperature was lowered weight losses were reduced for Treatments I, III and IV. Storing fruits under refrigerated conditions significantly reduced weight loss compared to storage under ambient conditions.

Change in volume

Changes in volume of stored breadfruits were significantly affected by storage time ($p < 0.05$), temperature ($p < 0.001$) and treatment ($p < 0.001$).

Under ambient storage conditions there was a rapid decline in volume or shrinkage of fruits with estimated average losses per day of 3.46, 0.89 and 0.71 per cent for control, packaged and waxed fruits respectively. In refrigerated storage, waxed fruits showed higher losses in volume compared to packaged fruits (Figure 2) with average losses estimated at 0.10, 0.31 and 0.12 per cent per day at 16 (61), 12 (54) and 8°C (46°F) respectively, compared to corresponding values of 0.06, 0.05 and 0.05 per cent per day for packaged fruits. As shown in Figure 2, in the earlier period of the storage trial packaged fruits showed small increases in volume while in the later period volume losses occurred. The initial swelling action of packaged fruits was accompanied by small losses in weight as previously reported and this phenomenon may therefore be attributed to an accumulation of gas within the fruit, e.g. CO_2.

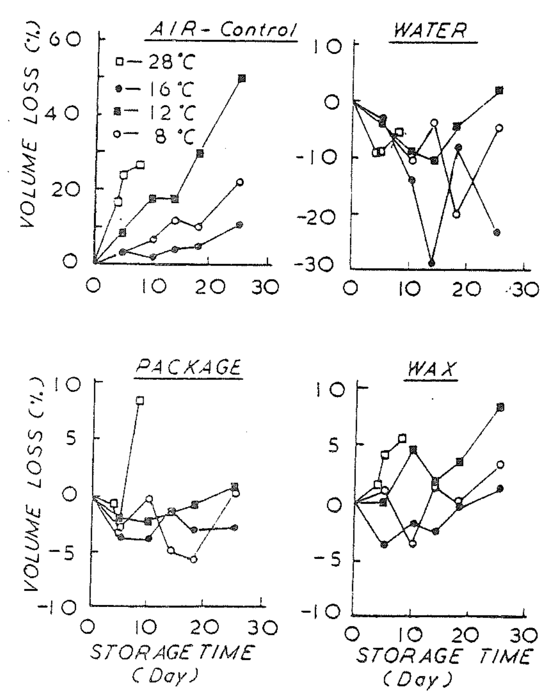

Figure 2. Volume losses of breadfruits in storage

For fruits stored in water under both ambient and refrigerated conditions there were increases in volume (swelling) as indicated by the negative values for average volume losses which were estimated at -0.74, -0.89, -0.07 and -0.35 per cent per day at 28 (82), 16 (61), 12 (54) and 8°C (46°F) respectively. This increase in volume was due to fruits absorbing water, increasing in weight as previously discussed, and increasing in size. As shown in Figure 2 while an increase in volume was shown in the first period of the storage trial, this was generally followed by shrinkage; this being noticeable after 14 days in storage. Thompson (1974) reported that storing breadfruits in water resulted in splitting of the epicarp. While this was not observed here, the behaviour is clearly related to the water uptake and swelling action of the fruit.

The s.g. of the breadfruit at harvest and prior to storage averaged 0.84. During the storage trial, only ambient stored fruits in air (control) showed any major changes in s.g. The s.g. increased to 0.94 by the fifth day of storage. This may be explained by the relatively high losses in volume (shrinkage) which accompanied the losses in weight.

Moisture content

There was a small treatment effect ($p < 0.05$) on the moisture content of stored fruits. Prior to storage the moisture content of fruits averaged 75.2 per cent (wet basis). Treatment means for the duration of the storage trial were 77.2, 76.5, 75.4 and 73.1 per cent for fruits stored in water, waxed, packaged and control fruits respectively. These results are not surprising and are consistent with the weight gains of water-stored fruits and the desiccation of air-stored fruits.

Fruit firmness

Fruit firmness was measured by the cone's penetration depth into the peeled fruit flesh and reported in millimetres. Significant differences in fruit firmness were obtained treatment ($p < 0.001$) and temperature ($p < 0.001$). Under ambient storage conditions, packaged fruits exhibited a significant delay in softening, when compared to fruits stored in air, water, or waxed fruit (Figure 3). This behaviour is attributed to the modified atmosphere conditions created by packaging and the subsequent delay in the ripening and softening rates.

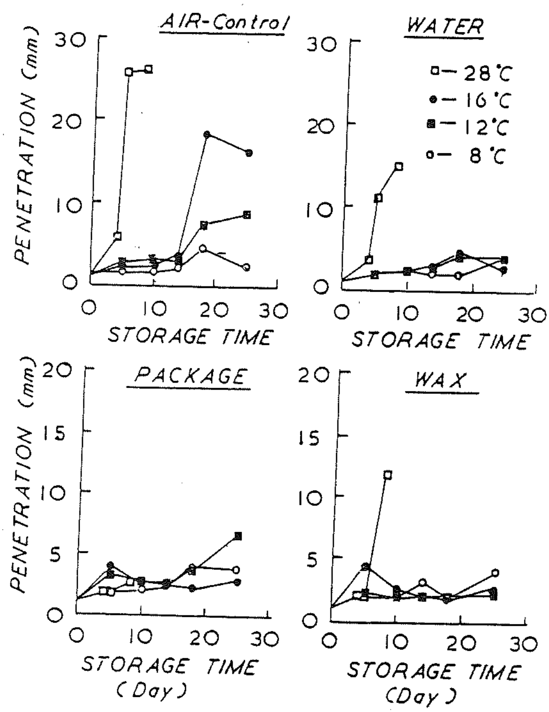

Figure 3 Fruit firmness as measured by a penetrometer, of breadfruits in storage.

Figure 3 also shows that in refrigerated storage, and for all treatments there were significant reductions in the rate of fruit softening. For fruits stored in air, as the storage temperature was lowered to 8°C (46°F) from 28°C (82°F), fruit firmness was increasingly maintained. However beyond 14 days in storage, softening increased rapidly with this being most noticeable at 16°C (61°F). These results show that breadfruits may be kept in refrigerated storage for up to 2 weeks at 16°C (61°F) beyond which time ripening and fruit softening commence. The increase in fruit softening after 14 days at this temperature may be associated with the climacteric rise in the fruit's respiration.

Packaging, waxing and storing fruits in water all maintained fruit firmness in refrigerated storage beyond the 14 days associated with control fruits. While the delay in softening of packaged breadfruits stored in refrigeration has previously been reported (Thompson *et al.*, 1974; Mariott *et al.*, 1979; Passam *et al.*, 1981), these results also show that waxing delayed the softening process. Passam *et al.* (1981) noted that waxing using a 7.5 per cent 'Sta-fresh' wax reduced weight loss of breadfruits in storage but did not affect the time for softening. In these trials waxed fruits behaved similarly to packaged fruits or fruits stored in water, i.e. fruits held under a modified atmosphere environment. The wax used and its level of application therefore appeared to have also altered the fruit's storage environment with favourable results. Despite the uptake of water by breadfruits stored in water, and the subsequent increase in moisture content, such fruits remained firm in refrigerated storage indicating a delay in the ripening process.

Soluble solids

Under ambient conditions (28°C or 82°F) fruits stored in air (control) showed rapid increases in total soluble solids (TSS) compared to fruits stored in water, packaged or waxed fruits (Figure 4). Thompson (1974) reported that fruits stored under ambient (28°C or 82°F) conditions, accumulated no soluble solids for the first 3 days after harvest, but after 4 days levels of the order of 15 per cent were found. A reduction in the rate of change of TSS accumulation was observed under refrigerated storage for all treatments when compared to ambient stored fruits. Additionally, as the storage temperature was lowered, for all treatments a decline in the accumulation was consistently observed, and at 8°C (46°F) there were very little changes in TSS from an initial value of 5 per cent. Thompson (1974) noted that at 2.5°C (36.5°F), breadfruits accumulated little soluble solids either during storage or when removed to ambient conditons. From linear regression analysis, average changes in TSS per day for fruits at 16 (61), 12 (54) and 8°C (46°F) were 0.25, 0.19 and 0.01 per cent per day respectively when stored in air; 0.23, 0.04 and 0.01 per cent per day respectively for fruits stored in water; 0.28, 0.16 and 0.06 per cent per day for packaged fruits and 0.04, 0.04 and 0.00 per cent per day respectively for waxed fruits. Again the wax coating appeared desirable as it inhibited the ripening rate of fruits and the subsequent development of sugars to a greater extent than packaging or storing fruits in water.

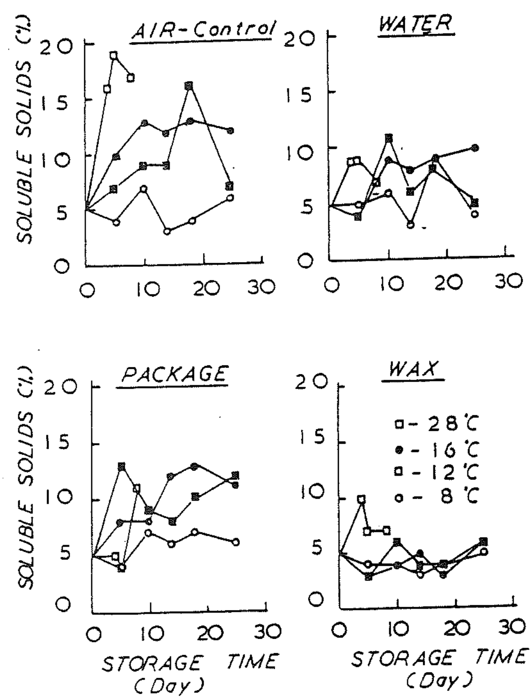

Figure 4 Total soluble solids levels of breadfruits in storage.

pH

The pH level of breadfruits prior to storage averaged 6.1, and during storage this was significantly affected by storage time ($p < 0.001$), temperature ($p < 0.001$) and treatment ($p < 0.001$). Figure 5 shows that there was a general decline in pH values with storage time for all fruits, under both ambient and refrigerated conditions. pH is inversely related to the acid content of fruits and is of importance as a measurement of the active acidity in fruits, influencing flavour and palatability (Raganna, 1977). Unlike most other fruits on ripening, breadfruits exhibit decreases in pH, a behaviour observed for bananas

(Agillon *et al.*, 1987). Wills *et al.*, (1981) noted that bananas attained the highest levels of acids on ripening implying a decrease in the pH. Fruits stored in water under ambient conditions exhibited a drastic fall in pH when compared to the other treatments. This behaviour possibly implies that there was anaerobic fermentation occuring at this temperature for fruits stored in water, with an increase in acid production. In refrigerated storage, fruits held in air and water exhibited faster rates of pH decline when compared to the other two storage treatments, with this effect being most noticeable after 14 days in storage, particularly at 12 (54) and 16°C (61°F) (Figure 5). This is probably an indication of the onset of ripening. The average declines in pH per day for these fruits were 0.06, 0.06 and 0.02 for air storage and 0.08, 0.06 and 0.02 for water storage at 16 (61), 12 (54) and 8°C (46°F) respectively.

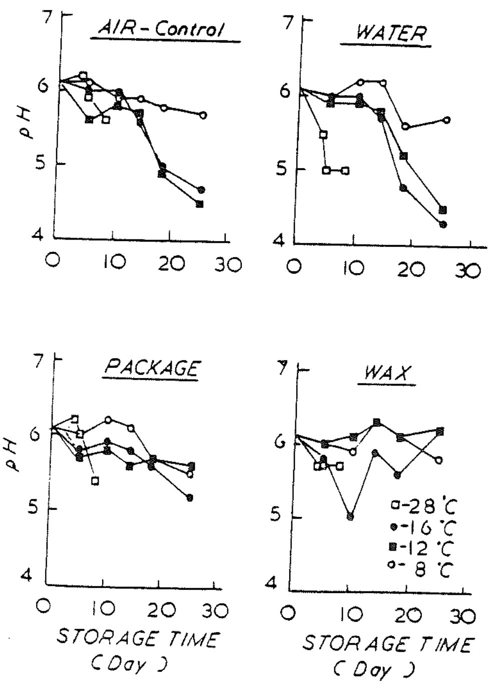

Figure 5 pH changes in stored breadfruits.

Waxed fruits exhibited smaller changes in pH values throughout the storage trial when compared to packaged fruits. Average pH decline per day for packaged fruits were 0.03, 0.02 and 0.02 at 16 (61), 12 (54) and 8°C (46°F) respectively while the corresponding values for waxed fruits were 0.01, 0.01 and 0.01 respectively. Waxed fruits particularly those at 12 (54) and 8°C (46°F) therefore showed little tendency for ripening during refrigerated storage (Figure 5).

Skin colour

The colour of the skin of the breadfruit in storage was significantly affected by storage time ($p < 0.001$), temperature ($p < 0.001$) and treatment ($p < 0.001$). The colour rating values of the breadfruit skin increased with storage time for all fruits under ambient and refrigerated conditions showing a change in the colour of the skin from green (rating of 1) to brown (rating of 5).

As with most climacteric fruits, the obvious, visible sign of ripening is loss of the green colour and an increase in the yellow pigment of the skin. Under ambient (28°C or 82°F) conditions, fruits stored in air and water rapidly changed in skin colour, showing a score of 4 after 5 days in storage. This change can be associated with normal ripening of the fruit. Packaging and particularly waxing delayed ripening under ambient conditions as the green skin colour was largely maintained during the 8-day storage period.

Under refrigeration, fruits stored in air and water at 8°C (46°F) showed abnormal, rapid browning within 5 days of storage when compared to the rest of the storage treatments (Figure 6). As the storage temperature was increased to 16°C (61°F), skin browning appeared less severe, but nevertheless there appeared to be a clear relationship between fruit exposure time for browning to occur and storage temperature, i.e. the higher the storage temperature, longer exposure times were permissible. For fruits stored in air (control), the colour score peaked to a value

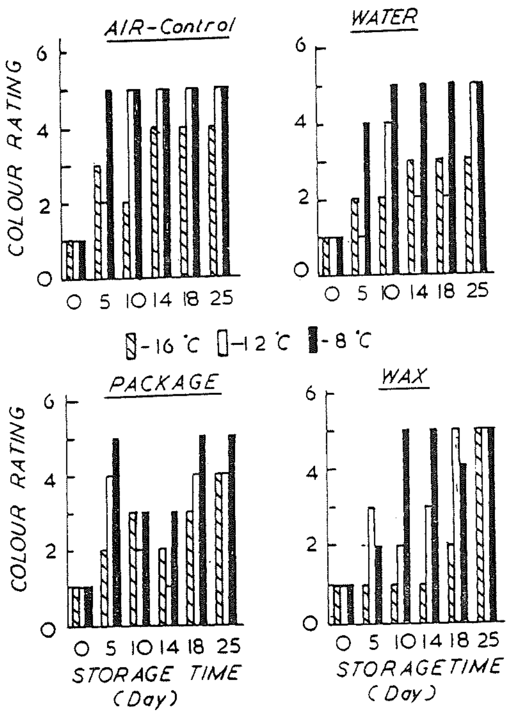

Figure 6 Colour changes of breadfruits in storage

of 5 after 5 days in storage at 8°C (46°F), while at 12°C (54°F), this occurred after 10 days. At 16°C, a colour score of 4 was found after 14 days in storage. Skin browning therefore appears to be a symptom of chilling injury, and Thomson (1974) reported that breadfruits stored below 12°C (54°F) showed symptoms consistent with chilling injury described for other tropical fruits.

Fruits stored in water showed similar trends as for fruits stored in air, however colour development was comparatively delayed.

Packaging and waxing of breadfruits in refrigerated storage resulted in impairment of skin colour development and browning when compared to control (air) and water-stored fruits. However, the exposure time/storage temperature relationship still prevailed. The browning symptom of chilling injury was therefore reduced by these treatments since waxed and packaged fruits stored at 16°C (61°F) maintained their green colour for at least 14 days in storage. Packaging and waxing limit the fruit's supply of O_2 and increase the CO_2 content surrounding the fruits and these modifications affected the fruit's susceptibility to skin browning. Modified atmosphere storage has previously been reported to reduce chilling injury, for example the general grey discolouration of the mesocarp of avocadoes (Scott and Chaplin, 1978). Grierson (1971) reported that waxing alleviated chilling injury of grapefruits but not of limes. Control of moisture loss in fruits has also been reported to alleviate the symptoms of chilling injury (Couey, 1982), although this cannot explain the behaviour of breadfruits stored in water.

Flesh colour

Under ambient conditions waxed fruits showed no increase in flesh colour rating, from an initial value of 1 (white/cream) just prior to storage. When compared to the other storage treatments at 28°C (82°F), fruits stored in air (control) showed a greater development in internal colour (yellowing), as mean scores over the 8-day storage period were 3.0, 2.8, 2.3 and 1.0 for fruits stored in air and water, and packaged and waxed fruits respectively. These scores are representative of the rate of ripening of fruits in ambient storage, as the development of the yellow flesh colour is normally associated with ripening fruits.

In refrigerated storage and over the 25-day storage period, waxed and packaged fruits showed little development of flesh colour as mean scores of 1.7 and 2.2 were obtained respectively, when compared to fruits stored in air and water with mean scores of 4 and 2.5 respectively. Waxing and packaging effectively delayed ripening. Storage temperatures between 8 and 16°C (46 and 61°F) did not appear to have any significant influence on flesh colour development.

Odour

Under ambient storage conditions a slight development of off-odours was detected for waxed and packaged fruits on the eighth day of storage. However by the fourh day of storage, fruits stored in air and water had already exhibited such signs. Fruits stored in water developed a strong off-odour by the eighth day of storage, and this may have resulted from fermentation of such fruits, as previously noted.

Under refrigerated storage conditions water-stored fruits consistently developed off-odours by the 10th day, at all-temperatures. This development was slightly more intense compared to fruits stored in refrigerated air (control) or packaged fruits. Odour formation is a result of volatiles liberated on ripening of fruits and is influenced by fruit maturity.

Acceptability

Under ambient storage conditions, fruits stored in air and water softened rapidly, and were unacceptable by the fifth day of storage, as acceptability ratings, based upon firmness to the touch, peaked to 5 and 4 respectively. These results are consistent with those of the penetrometer readings given in Figure 3.

For fruits held in refrigerated storage, Figure 7 shows that packaged and waxed fruits remained hard and very acceptable for the duration of the storage trial, i.e. 25 days. These results again demonstrate the delay in the ripening process with such treatments under refrigerated storage. Fruits stored in refrigerated air (control) and water began to show signs of softening and unacceptability by the 14th day of storage.

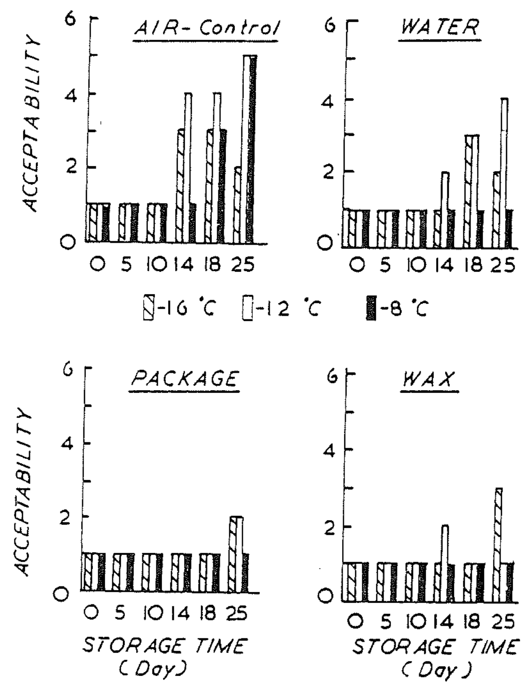

Figure 7 Acceptability of breadfruits based upon fruit firmness in refrigerated storage.

Conclusions

Breadfruit, unlike many other fruits, is consumed in the Caribbean in the unripe stage, i.e. mature green, firm and unsweet. Storage of breadfruits under ambient, tropical conditions is problematic as ripening proceeds immediately and rapidly rendering such fruits unacceptable within 4 days of harvest.

Ripening of naturally (ambient air) stored fruits manifests itself in terms of weight and volume losses (shrinkage) averaging 2.64 and 3.46 per cent per day respectively, an increase in s.g. from 0.84 to 0.94 and a rapid decline in fruit firmness with fruits becoming medium soft and unacceptable by the fourth day after harvest. It is also characterized by a marked increase in soluble solids content, from 5 to 16 per cent by the fourth day, rendering such fruits sweet and unacceptable. Storage of fruits in water under ambient conditions – a traditional method of fruit preservation – marginally reduces the rate of ripening.

However such fruits show a marked decline in pH by the fifth day of storage – from 6.1 to 5.0 with the development of off-odours. Its acceptability as a storage method by small farmers is probably due principally to the economic benefit of increases in weight (and volume) of fruits when stored under such conditions. On the other hand, waxing in particular, and packaging to a lesser extent, delay ripening under ambient (28°C or 82°F) conditions and fruits can remain marketable through such treatments for 1 week.

Refrigerated storage of breadfruits delays the ripening process and reduces weight and volume losses. At 16°C (61°F) and by the 14th day in storage however, untreated fruits stored in air show all signs of accelerated ripening, viz. increases in fruit softness, decreases in pH and increases in soluble solids content. Refrigerated storage of breadfruits in water is again limited by off-odour development after 10 days in storage. However even at 16°C (61°F) and more dramatically at 8 (46) and 12°C (54°F), breadfruits stored in air show chilling injury manifesting itself as browning of the fruits' skin. This is the limiting factor in refrigerated storage. At 8 (46), 12 (54) and 16°C (61°F) browning is practically complete after 5, 10 and 14 days respectively. As with many other fruits which show chilling injury, the air exposure time/storage temperature relationship is therefore apparent.

At the three refrigerated storage temperatures waxing in particular, and packaging to a lesser extent, delayed the ripening process through maintenance of fruit firmness, soluble solids content and pH for at least 18 days in storage. More importantly however waxing delayed the symptoms of chilling injury compared to untreated fruits which when stored at 8 (46), 12 (54) and 16°C (61°F) showed complete browning after 10, 18 and 25 days respectively.

Packaging and storage of fruits in water also alleviated the signs of chilling injury, though to a lesser extent than waxing, with these results suggesting that storage of breadfruits in a modified atmosphere environment can retard chilling injury. There is therefore potential for controlled atmosphere storage. In terms of refrigerated storage, waxing appears to be the treatment of choice and noting the chilling injury behaviour, such fruits should still be in a marketable condition after 18 days in storage at 16°C (61°F). Little evidence was seen in these storage trials of any major post-harvest decay due to fungal infections.

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