STORABILITY OF PAPAYAS UNDER REFRIGERATED AND CONTROLLED ATMOSPHERE

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Abstract

A storage trial was conducted on papayas of the variety Tainung No. 1 grown in Trinidad and Tobago, with a view to evaluating an appropriate post-harvest system for such fruits. Papayas were harvested at the colour break stage, washed, hot water dipped (48°C - 20 min.) treated with Benlate at 52°C for 2 minutes and air dried before storage at 16°C. Four groups of fruits were either untreated, waxed, treated with a Nutri-save film or packaged in stretch-film before being refrigerated, while two groups of waxed and untreated fruits were kept in controlled atmosphere conditions (1.5-2.0% O_2 and 5% CO_2, 16°C).

Papayas packaged in stretch-film and stored in a modified atmosphere as well as untreated fruits stored in controlled atmosphere exhibited good storage potential for up to 29 days. This can be compared to untreated fruits stored at 16°C which were unacceptable after approximately 17 days in storage.

1. Introduction

The papaya *(Carica papaya L.)* is most often consumed in the ripe stage as a fresh fruit. Papayas are harvested as soon as a trace of yellow appears on the apex or between the ridges and can be held for a few days under ambient, tropical conditions (Lee, 1970).

The papaya is very susceptible to anthracnose caused by the fungus Colletotrichum gloeosporioides. Akamine and Arisumi (1953), reduced anthracnose infection by dipping fruits in hot water at 47-48°C for 20 minutes followed by cooling with water. Fungicides have been added to the hot water to improve decay control as seen with mangoes (Spalding and Reeder, 1978). Federal quarantine regulations mandate that papayas for export to the U.S. must be disinfested for fruit flies within 18 hours of harvest usually with a heat treatment. A double hot water immersion treatment as described by Couey and Hayes (1986), can be used as a possible quarantine procedure. Fruits less than one quarter ripe are initially immersed in water for 40 minutes at 42°C and then at 49°C for 20 minutes.

A range of temperatures have been reported for papaya storage. Fruits are sensitive to chilling injury below 10°C (Jones, 1942) with the greenest fruits most sensitive to chilling temperatures. Temperatures between 13-16°C have been shown to be adequate for storage (Jones, 1942; Sommer, 1985). Arriola et al (1980), reported that 12°C was a critical temperature for a period not greater than 2 weeks since chilling injury developed at longer times or at lower temperatures than 12°C. The literature also indicates that an optimum temperature for papaya storage varies with the variety used.

Not much work has been reported in the area of controlled atmosphere (CA) storage. Akamine (1969), stated that CA storage can be used to extend the shelf-life of papayas. Storage in 1-1.5% oxygen gave hot-water, fumigated papayas an extension in shelf-life of 1 day. Akamine and Goo (1969), also stated that fruits which were hot-water treated and stored in 1.5% oxygen at 13°C for 6 days, followed by ambient storage showed a decrease in the rate of ripening and decay. Akamine (1969), reported some benefical effect when fruits were stored in 5% CO_2 and 1% O_2 for 3 weeks at 13°C. However decay during storage and ripening was the limiting factor.

The objectives of this study were to evaluate and compare appropriate post-harvest storage systems for papayas including modified and controlled atmosphere.

2. Materials and Methods

Papayas of the variety Tainung No. 1 were obtained from the district of Cumuto in Trinidad. Fruits were carefully harvested at the colour-break stage, randomly numbered and weighed. They were then washed in tap water, treated with hot water at 48°C for 20 minutes, dipped in Benomyl (1.5 g/l) for 2 minutes at 52°C and air dried.

Eighty-six (86) fruits, each averaging 0.89 kg in weight were stored under refrigerated (16°C) and controlled atmosphere conditions (16°C, 1.5-2.0% oxygen, 5.0% carbon dioxide). Before being stored under refrigerated and controlled atmosphere conditions, fruits were randomly separated into six post-harvest treatments with fourteen (14) fruits per treatment as follows:-

(i) refrigeration:- untreated (T_1), waxed (T_2), Nutri-save (T_3) and stretch-film (T_4) fruits

(ii) controlled atmosphere:- untreated (T_5) and waxed (T6) fruits.

Packaging involved the use of a sealed, stretch-film wrap (0.5 ml), while an undiluted paraffin wax was applied to fruits at 38°C. The Nutri-save coating obtained from Nova Chem Limited, was applied by dipping the fruits in a 1.5% (w/v) solution.

Fruits were stored in a Forma Scientific "walk-in" refrigerated room maintained at 16±0.5°C. In this room, a gas tight chamber (0.61 x 1.00 x 0.61 m) was maintained under the desired CA conditions, using a flow through CO_2 and O_2 system, using commercially available oxygen, nitrogen and carbon dioxide gas in cylinders. An ADC Infrared Gas Analyser, type SS-100 was used for CO_2 analysis with a range of 0-20%, and a Servomex Gas Analyser, type 580A was used for O_2 analysis, with a range of 0-25%.

Fruit samples from refrigerated and controlled atmosphere storage were removed at specified time intervals (0, 7, 13, 17, 20, 23, 26 and 29 days). On removal from storage, 50% of the fruits were analyzed immediately while the remainder were left to ripen under ambient conditions prior to analysis. Two fruits were analyzed on the day of harvest. Analysis consisted of the following parameters indicative of fruit quality:-

(i) Percent weight loss calculated from the weights of individual fruits before and after storage.

(ii) Firmness as measured by a penetrometer, using a 0.8mm plunger with a 50 gm weight, and a penetration time of 15 seconds.

(iii) Total soluble solids in Brix (%) was measured by an Abbe Refractometer (Atago, Type 1T), using a 1:1 dilution of the papaya pulp.

(iv) Sugar/acid ratios calculated from Brix (%) values and % citric acid (AOAC, 1984).

(v) Fruit colour was determined subjectively using the following colour rating scheme:-

1 - fully grown but completely green, 2 - fully grown but showing first signs of yellowing in the apex, 3 - fully grown showing yellowing in the apex (quarter-ripe), 4 - fully grown and half-ripe, 5 - fully grown and three-quarters ripe, 6 - fully grown, yellow and firm, 7 - fully grown, yellow with softening and 8 - over-ripe, very soft on touch.

(vi) Decay was also rated subjectively using the method of Spalding and Reeder (1978), as follows:-

1 - none, 2 - trace spotting first appearing, 3 - slight spots increasing in size and numbers, 4 - moderate, 25-50% decay and 5 - severe >75% decay.

3. Results

The data of the parameters measured for fruit quality determination under both refrigerated and controlled atmosphere storage were subjected to an analysis of variance (ANOVA) using the GLIM computer program and statistical design (Baker and Nelder, 1978).

3.1 Percent weight loss

The percent weight loss under both refrigerated and controlled atmosphere was significantly affected by treatment ($p < 0.001$), storage time ($p < 0.001$), ripening ($p < 0.001$) as well as the interactions of treatment/time ($p < 0.01$) and treatment/ripening ($p < 0.01$). Percent weight loss increased for all treatments during storage as shown in figure 1. From linear regressions of the data shown in figure 1, % weight losses per day were estimated as follows:- untreated (T_1) - 0.65, Nutri-save (T_3) - 0.54, waxed (T_2) - 0.20, stretch-film (T_4) - 0.11, untreated CA (T_5) - 0.08 and waxed CA (T_6) - 0.04%/day. When fruits were taken out of storage and left to ripen under ambient conditions, there were additional weight losses at each treatment. The mean percent weight losses for the various treatments and over the duration of the trial for fruits in storage only were 10.4 (T_1), 8.7 (T_3), 4.5 (T_2), 2.3 (T_4), 2.0 (T_5) and 1.3 (T_6). On ripening however, weight losses increased and mean values for the various treatments over the duration of the trial were 16.3 (T_3), 12.3 (T_4), 11.8 (T_6), 11.4 (T_1), 10.5 (T_2) and 9.2 (T_5)

3.2 Firmness

Fruit firmness during storage at 16°C was significantly affected by treatment ($p < 0.001$), storage time ($p < 0.01$), ripening ($p < 0.001$), as well as interactions of treatment/ripening ($p < 0.01$), treatment/time ($p < 0.01$) and time/ripening ($p < 0.001$). There was a general decrease in firmness of fruits in storage as penetrometer readings during storage showed increases in penetration depths per day averaging 0.56 (T_1), 0.49 (T_3), 0.21 (T_4), 0.12 (T_5) and 0.04 (T_2) mm/day. There was a slight decrease in penetration values for CA (T_6) fruits with a decrease per day of 0.02 mm. Mean penetration values during storage were 12.6 (T_1), 11.2 (T_3), 10.6 (T_4), 2.0 (T_5), 1.5 (T_2) and 0.8 (T_6) while on ripening penetration values increased to 15.4 (T_1), 17.2 (T_4), 12.6 (T_5), 12.1 (T_3), 1.3 (T_2) and 1.0 (T_6).

3.3 Percent soluble solids, titratable acidity and sugar/acid ratios

The percent soluble solids of papayas under refrigerated and controlled atmosphere storage was significantly affected by treatment ($p < 0.001$). The mean percent soluble solids over the duration of the storage were as follows:- T_4 - 10.8, T_3 - 10.6, T_1 - 10.0, T_5 - 9.5, T_2 - 7.6 and T_6 - 7.1%. There was a general increase in percent soluble solids on ripening, when compared to storage (with mean values:- T_4 - 10.0, T_3 - 12.4, T_1 - 11.1, T_5 - 10.9, T_2 - 8.3 and T_6 - 9.1%), however this difference was not significant.

There was no significant effect of storage time or treatment on the titratable acidity (% citric acid) of papayas. Mean values obtained over the duration of the trial were:- T_1 - 0.225, T_2 - 0.228, T_3 - 0.244, T_4 - 0.242, T_5 - 0.227 and T_6 - 0.205%.

Sugar/acid ratios of papayas were significantly affected by storage time ($p < 0.05$) in refrigerated and controlled atmosphere. Sugar/acid ratios increased in storage for all fruits with mean values during storage being:- 46.7 (T_1), 45.3 (T_4), 44.8 (T_3), 42.3 (T_5), 36.4 (T_6) and 34.7 (T_2). The value just prior to storage was 27.2. On ripening, CA stored fruits (T_5 and T_6) as well as Nutri-save fruits (T_3) showed increases in the sugar/acid ratios, while the other treatments showed little change. These differences however were not significant.

3.4 Colour

Significant differences in the colour rating of papayas were found with respect to treatment ($p < 0.001$), ripening ($p < 0.001$) and the interactions of treatment/ripening ($p < 0.01$) and time/ripening ($p < 0.01$). During storage there appeared to be a general increase in the colour rating values for all fruits stored at 16°C. Mean colour scores during storage were 3.6 (T_1), 2.7 (T_2), 2.7 (T_3), 2.7 (T_4), 2.1 (T_5) and 1.8 (T_6), with the initial value being 1.5. Fruits removed from storage and ripened under ambient conditions, showed higher colour scores. Mean values of 5.7 (T_4), 5.5 (T_1), 5.3 (T_5), 4.0 (T_2), 2.6 (T_3) and 2.6 (T_6) were obtained on ripening. When the colour of fruits from T_3, T_4, T_5 and T_6 treatments on ripening and from the latter part of the storage trial were compared to ripened fruits from the early part of the storage trial, there was a decrease in the colour index. For example, 10 day old fruits removed from storage and ripened showed estimated colour indices of 3.0 (T_3), 6.2 (T_4), 5.2 (T_5) and 4.0 (T_6). However 30 day old fruits similarly treated showed corresponding values of 2.0, 5.2, 4.7 and 1.5. T_1 and T_2 stored fruits (untreated and waxed, refrigerated) did not show this decline in colour development with ripening, as the duration of storage increased.

3.5 Decay

The decay of stored fruits was significantly affected by time ($p < 0.001$), treatment ($p < 0.001$) and ripening ($p < 0.001$). During storage there were considerable increases in decay rating values as shown in figure 2 which was obtained through linear regression of the data. The slopes of the lines were 0.175, 0.140, 0.121, 0.078, 0.075 and 0.023 in decay units/day for treatments T_1, T_3, T_6, T_4, T_2 and T_5 respectively. Mean decay values during storage were 3.4 (T_1), 2.6 (T_3), 2.0 (T_4), 2.0 (T_6), 1.9 (T_2) and 1.3 (T_5). Fruits which were ripened under ambient conditions on removal from storage showed higher decay values and mean values for ripened fruits were 4.6 (T_6), 4.4 (T_3), 4.2 (T_1), 4.0 (T_4), 3.6 (T_2) and 3.0 (T_5). With increasing storage time there was an increase in the decay of fruits on ripening and after a period of 30 days, the estimated decay rating values of ripened fruits were 5.6 (T_1), 4.9 (T_6), 4.7 (T_3), 4.6 (T_4), 4.6 (T_2) and 3.9 (T_5).

3.6 Ripening

The time taken for fruits to ripen under ambient conditions and on removal from refrigerated and CA storage, reduced with the length of the storage period, under all treatments. Untreated fruits had the shortest ripening time, averaging 2.0 days, while for the other treatments an average ripening time ranging from 4.4 - 5.6 days was observed.

4. Discussion

For extended storage of papayas, it is desirable that the fruits be kept in the pre-climacteric (non-ripening) condition, and on removal from storage they should maintain their ability to ripen normally. Thus in an efficient storage system, it is expected that changes associated with weight loss, firmness, soluble solids, sugar/acid ratios, colour and decay be minimized and with the commencement of ripening, it is desirable that all the parameters stated except weight loss and decay, should increase.

The experimental data can be used as a basis for comparison of the shelf-life of papayas, untreated and stored in air at 16°C with those held in modified and controlled atmospheres also at 16°C. It is noted that:-

(i) Control (untreated, refrigerated) fruits exhibited the highest weight losses, penetration depths, soluble solids, sugar/acid ratios, colour and decay in storage. Shelf-life was therefore limited by rapid ripening, softening and consequential decay due mainly to Colletotrichum gloeosporioides and Rhizopus stolonifer after approximately 17 days in storage. A very short shelf-life averaging two days was also exhibited by these fruits on removal from storage when compared to the other treatments.

(ii) The water soluble, Nutri-save coating was expected to simulate a modified atmosphere condition by controlling respiration through the creation of a membrane around the fruit. However abnormal browning of fruits occured in storage and in addition there was no significant reduction in water loss, due to a breakdown of the coating after about 12 days in storage. This appears to be the limiting time for the storage of such fruits. Additionally, Nutri-save fruits exhibited comparitively high rates of softening and decay in storage and limited colour development on ripening.

Stretch-film fruits exhibited the lowest losses, highest soluble solids content, a high sugar/acid ratio and the overall best colour development in storage and on ripening when compared to all fruits in refrigeration (4 treatments). In fact colour development was the best for such fruits on ripening among all treatments. Decay was also comparatively low both in storage and on ripening.

Waxed fruits exhibited negligible softening with time, little change in soluble solids up to 23 days in storage, negligible changes in sugar/acid ratios and little decay up to 4 weeks in storage. Ripening time averaged 4.5 days on removal from storage and ripened fruits did not show full colour development. However colour development was not impaired by the length of storage. The wax coating was applied in an undiluted form and may have affected the ability of fruits to develop their full colours.

(iii) Controlled atmosphere stored fruits which were untreated and waxed when compared to refrigerated fruits showed the overall lowest weight losses and colour development in storage. Waxed fruits however exhibited the lowest percent weight loss and negligible changes in firmness, soluble solids and colour development during storage. On ripening fruits, colour development was low and this decreased with the duration of the storage period. Fruit firmness was also low in storage. These results indicate that respiratory activity was severly restricted for fruits in storage, and on removal from storage, normal ripening was impaired. Waxed CA fruits showed a white fungal growth after 17 days in storage, and this was exacerbated on ripening. During storage untreated fruits in controlled atmosphere developed very low decay, colour, soluble solids and loss in weight. On ripening, there was an increase in the colour of fruits with minimum decay and weight loss. Such fruits were more acceptable than the waxed fruits under controlled atmosphere.

The results indicate that for fruits stored under controlled atmosphere, ripening was suppressed due to a reduced sensitivity of fruits to ethylene and a decrease in the breakdown of chlorophyll. This was particularly noticeable for fruits stored under CA at 16°C, beyond 20 days. The waxing treatment resulted in reduced colour development under both refrigerated and controlled atmosphere storage, possibly because of the heavy application and with prolonged storage the ability of fruits to develop their full colour on ripening was impaired. Under modified atmosphere, Nutri-save fruits were unacceptable because of the resulting brown skin discolouration during storage and abnormal ripening. Stretch-film fruits showed slightly higher metabolic activity when compared to controlled atmosphere fruits and were overall the most acceptable fruits.

The results indicate that fruits held in modified atmosphere through stretch-film packaging and untreated fruits in controlled atmosphere show good potential for storage of papayas for up to 4 weeks.

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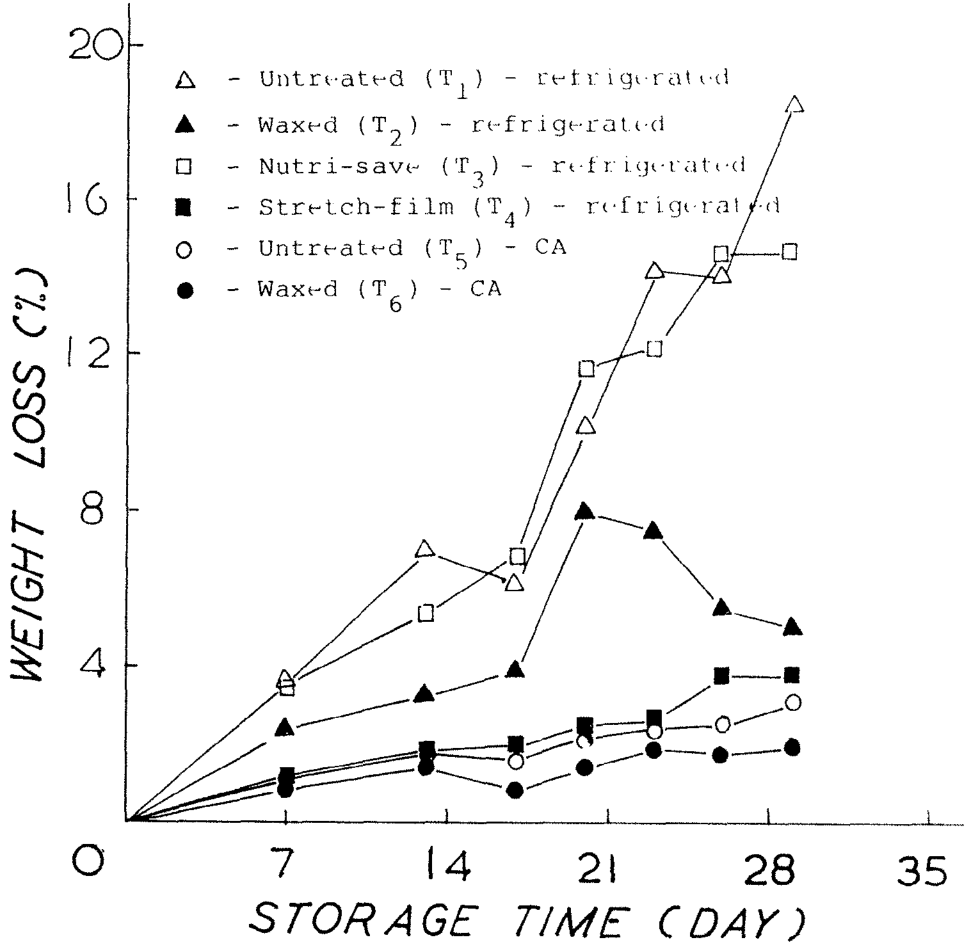

Figure 1 - Weight losses of papayas in refrigerated and controlled atmosphere storage at 16°C

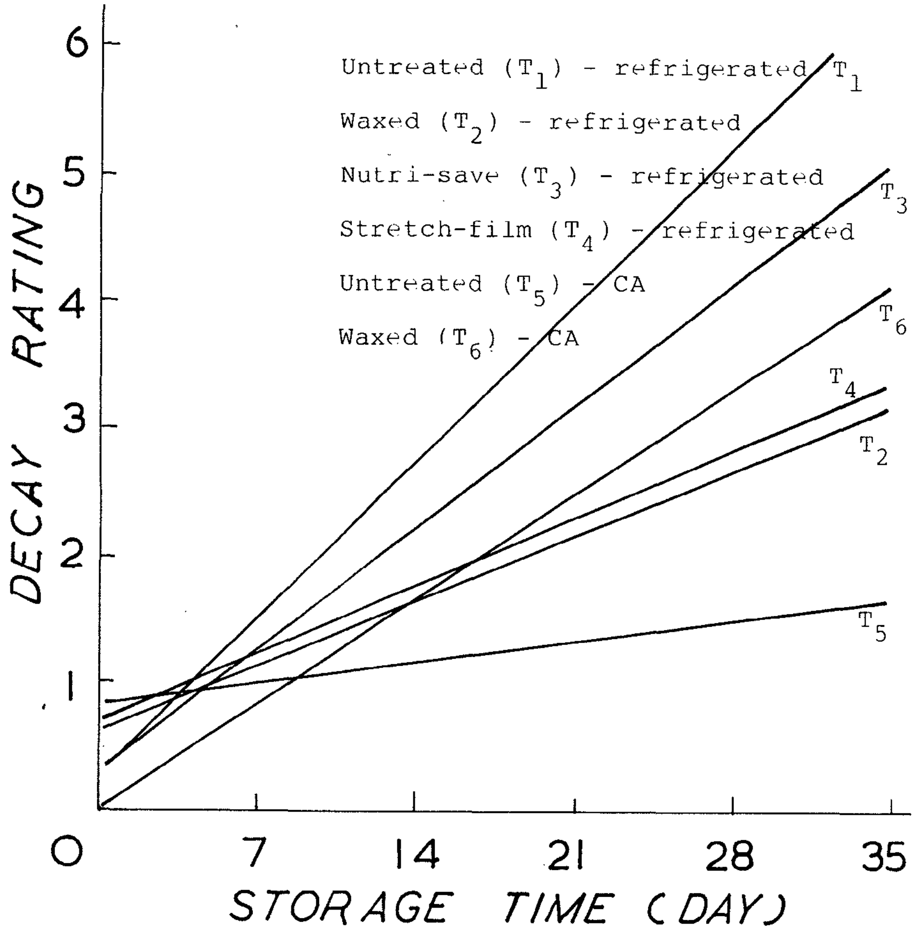

Figure 2 - Increases in decay for papayas stored in refrigerated and controlled atmosphere at 16°C