Effects of Different Storage Temperatures and Durations on Physiochemical Properties and Nutritional Composition of Banana and Papaya

Suaad Ghait Abdarrahan Abuhamra*, Alona Cuevas Linatoc
Faculty of Science, Universiti Tun Hussein Onn Malaysia (UTHM) 86400 Parit Raja, Batu Bahat, Johor Darul Takzim, Malaysia

ABSTRACT

Banana (Musa sp.) and papaya (Carica papaya) cultivars harvested from Johor Bahru Malaysia. The fruits were stored up to 30 days at (4 ±1, 10 ± 2, 30 ± 3) °C. The aim of the research is to recommend the proper storage conditions of Malaysian fruit (Papaya and Banana). Therefore, main physiochemical attributes (weight loss, peel colour, Total soluble solids (TSS), Titratable Acidity (TA), pH, Brix:acid ratio TSS:TA, Total phenolic content TPC) and nutritional composition (total polysaccharide and total protein content) were then determent. During the storage, the fruits were browning by increasing time and temperatures. In addition, TSS, total polysaccharide, TA and TPC increased during cold storage. On the other hand, pH, weight loss and protein estimation whereas decreased during 4 C°. Finally, the overall of this research might be to provide science-based management tools for the storage performance of banana and papaya fruits.

1. Introduction

Banana is a general term including a number of species or hybrids in the genus Musa of the family Musaceae. Almost all of the known edible-fruited cultivars arose from two diploid species, Musa balbisiana and Musa acuminate which are local to Southeast Asia conventionally 1,2. Banana is one of the sixteen fruit types that have been identified by the Malaysian Ministry of Agriculture and Agro-based Industry as having commercial potential either as fresh or processed fruit. Banana is a great economic importance in the moister areas of tropical agriculture and is a significant fruit crop in Malaysia 2-4. Banana also is a soil conservative, productive, and almost non-seasonal. In some countries where commercial plantations exist, considerable revenues from exporting bananas are generated 4, 5. Papaya (Carica papaya L.) belongs to Caricaceae family 6,7. It is common in central and northern South America 6, 8 and widely cultivated in most tropical countries such as Malaysia, Brazil and India which are the highly producers of papaya 9. The fruit is ripe and its skin attains amber to orange hue. Scientific evidence has mentioned that increasing consumption of papaya to improved human health as a result of bioactive compounds such as phenolic compounds that have potent pharmacological activities, including, anti-mutagenic, antioxidant, anti-inflammatory, anti-
hypertension activities anti-fungi and anti-virus\textsuperscript{10-13}. The availability and consumption of papaya fruit in the market are largely restricted to the harvesting season. Postharvest handling practices like packaging and postharvest conditions such as temperature may be used to keep the fruit quality for prolonged storage periods\textsuperscript{14}. Storage temperature is a very important environmental factor which affects the postharvest life of fresh fruit due to its role in regulating the rate of all associated physiological processes and biochemical reactions\textsuperscript{15}. Many reports have shown that physicochemical, physiological, phytochemical, mechanical, sensory qualities of papaya fruit are influenced by packaging, storage temperature, and atmospheric conditions\textsuperscript{6}. Generally, papayas cultivate in tropical countries. Therefore, many non-tropical countries import papaya from Malaysia and other tropical countries. The fruit may be stored for several months at temperatures below 10°C to extend the marketing value\textsuperscript{7, 16}. Temperature influences the uptake and metabolism of mineral nutrients in the plants as a result of increasing of transpiration rates. Lower temperature (less than 10°C) decreases fruit growth, sweetness, and fruit size of papaya. It also influences flower and fruit setting\textsuperscript{17}. For instance, stamen carpelloidy is expressed under cool temperatures, with increasing severity at lower temperatures in the coming 40 days before anthesis. The fruit that develop from this carpelloidy are severely misshapen and unmarketable\textsuperscript{18}. At higher temperatures (>35°C), there is a tendency of bisexual cultivars to form functional male flowers with poorly developed and non-functional female parts. This tendency may varies with cultivars\textsuperscript{19}. The previous studies indicated that fluctuating temperatures for as little as a few hours during handling operations may lead to reject a considerable amount of papaya\textsuperscript{20}. The Malaysian fruits industries face problems in quality losses after storage of banana and papaya fruits due to the lack of knowledge on optimal storage. The cultivar Papaya (\textit{Carica papaya} L.) and Banana (\textit{Musa acuminate}) are the widely grown in Malaysia; to date, there is currently limited scientific knowledge on the storage requirements to keep the high quality of banana and papaya fruits. To develop quality standards for the export markets, the knowledge of the optimum storage conditions are required to get more understanding of postharvest quality for these fruits.

2. Material and Methods

2.1 Chemicals and reagents

Ethanol (95%) was purchased from HMBG Company, Sulphuric acid (95-98%) from R&M Chemicals Company. Sodium hydroxide pellets and potassium sodium tartrate tetra hydrate grade AR were purchased from QREC Company. Sodium chloride and D+ Glucose were purchased from DRY Company. Sodium carbonate was purchased from BENDOSEN Company. (BSA) Bovine serum albumin fraction (V) and gallic acid were purchased from Sigma Company. In addition, copper sulphate pent hydrate, folin ciocalteu’s phenol reagent for total phenolic content and lorry testes and anthrone were purchased from SIGMA ALORICH Company.

2.2 Source of banana and papaya

Fresh fruit samples with no apparent physical or microbial damage were collected separately, at different times, from local orchards in Johor Bahru, Malaysia. Samples included Papaya (\textit{Carica papaya} L.) and Banana (\textit{Musa acuminate}). All the fruits were of eating quality, and were identically selected in terms of shape, size, colour, and ripening stage.

2.3 Storage conditions

Each fruit has its own ideal set of conditions at which it will store most successfully for the maximum length of time. In addition, banana and papaya were
kept in a dark and aerated environment in proper temperature.21-23

2.4 Preparation of the banana and papaya samples

The fruits were rinsed by water tap then dried by air dried. After that the fruits were storage at different temperatures (4 ±1, 10±2, 30±3) ºC for (0, 3, 6, 14, 30) days. The clear juice of banana and papaya were obtained by one of the follows method: First method was used to cut fruit, press with a hand press, and filters through cheesecloth. The second method was applied to place the pieces of fruit into the blender (PANASONIC), homogenize, centrifuge slurry, and then pour off the clear liquid. All samples were prepared freshly at room temperature before taking measurements.

2.5 Effects of physiochemical analysis

Physiochemical evaluation is a scientific discipline used to evoke measure, analyse and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing.

2.5.1 Physical

2.5.1.1 Weight loss

Cumulative weight losses for banana and papaya fruits were determined for each storage condition under different temperatures of storage (4±1, 10±2, 30±3) ºC and durations (0, 3, 6, 14, 30) days. Fruit weight loss was measured by an electronic scale SHEMADZU with respect to storage period. The loss in weight is calculated by using the formula mentioned below.14

\[ W = \frac{(W_i - W_f)}{W_i} \times 100 \]

Where: \( W \) = cumulative weight loss (%) of fruit, \( W_i \) = initial weight (g) of the fruit at the beginning of storage, \( W_f \) = final weight (g).

2.5.1.2 Peel color

The color of banana and papaya were coordinate with a calibrated by human eyes under different temperatures storage (4±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days.24

2.5.2 Chemical

2.5.2.1 Determination of Total soluble solids (TSS)

Total soluble solid (TSS, °Brix) of banana and papaya were measured at different temperatures storage (4±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days by a digital refract meter ATAGO PAL-BX/RI devise.25

2.5.2.2 Determination of Titratable Acidity (TA)

At least 50 ml of clear juice of banana and papaya was used under different conditions of temperatures of storage (4 ±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days. All samples were at room temperature before taking measurements.25

2.5.2.3 Measurement of pH

pH of samples were measured by using a pH meter EUTECH (PH 700). For each sample, 6 grams of juice were weighted into a 100 ml beaker. 50 ml of water was added to each sample. The titrate acidity were calculated by the formula mentioned below.25

\[ \% \text{ Acid} = \frac{[\text{ml NaOH used}] \times [0.1 \text{ N NaOH}] \times [\text{ml equivalent factor}] \times [100]}{\text{grams of sample}} \]
2.5.2.4 Determination of total phenolic content (TPC)

The total phenolic content were determined in papaya and banana under various conditions of temperatures storage (4±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days by TPC assay. 1, 2, 3, 5 and 10 mg/ml of gallic acid concentration were used for calibration curve. Fruits squeeze stocks were prepared by dissolving 5 mg of each sample in 5 ml of deionized distilled water to obtain a 1 mg/ml concentration. 30µl of each sample diluted up to 3000 µl by deionized distilled water. Then 150 µl of Folin-Ciocalteu reagent added to the test solution, and then mixed using for a few second in the test tube by vortex mixer brand AGON. After that, the mixture incubated for 1 minute in dark place at room temperature. Next, 450 µl of 20% (w/v) sodium carbonate solution added to the mixture. The reaction tubes incubated in the dark incubator brand MEMMENT at 40ºC for 30 minutes. After the incubation, 1ml transferred in spectrophotometer tubes. The absorbance measured at 750 nm using spectrophotometer reader brand THERMO BIOMATE 3S 26. Each analysis was carried out in triplicate.

2.6 Determination of nutritional composition

2.6.1 Determination of total polysaccharide content

Based on Gerhardt et al (1994) 27 with a slight modification, the Anthrone reagent was prepared by dissolve 200 mg of analytical grade Anthrone in 100 ml of sulfuric acid in ice bath. 20, 40, 60, 80, 100 ppm of glucose analytical grad were prepared for calibration liner curve. The samples were prepared by dissolved 200 mg of dry sample (the juice was dried by oven at 80ºC) with 7 ml of 80% ethanol in water bath 40ºC then mix and centrifuge at 2700 rpm for 10 min, this manor was repeated several times until the washing does not give color with Anthrone reagent. The dry residue was well over a hot water bath 80ºC. Then, 5 ml of distilled water and 5ml of 25% HCl extracted at 0ºC for 20 min and extraction repeated using 25% HCl. Centrifuge the supernatant and make up to 100 ml with distilled water. Pipette out 0.1 ml of supernatant into test tube make the volume up to 1 ml with distilled water. 4 ml of Anthrone reagent was added to each test tube of blank, samples and standards. Each tested tube was heated for 8 minutes in boiling water then cool rapidity and read the intensity of color produced using spectrophotometer at 630 nm. Each test was repeated in triplicate.

2.6.2 Determination of protein content

There were many steps to prepare the solutions. Firstly, solution A (alkaline solution) was prepared by dissolve 5.0 g of sodium carbonate in 250 ml of 0.1 N sodium hydroxide solution to get 2% of sodium carbonate solution in 0.1N of sodium hydroxide. Secondly, 0.5% of copper sulphate was mixed in 1% potassium sodium tartrate for preparing solution B. Thirdly, solution C (prepare freshly) was prepared by mixing between solution A and solution B in ratio (50:1) (vol:vol). Finally, solution D (Folin Ciocalteau Reagent) was prepared by mixing between distilled water and solution C in ratio (1:1) (vol:vol). The protein was estimated in papaya and banana at different temperatures storage (4±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days. 50, 100, 150 and 200 ppm of Bovine Serum Albumin BSA (Fraction v) concentration were use for calibration liner curve. The samples have been centrifuged for 10 min at 2700 rpm, then pipette out 0.1 ml from the supernatant into tested tube make the volume to 1ml with distilled water. Add 3.0 ml of solution C to each tested tube of blank, standards, and samples. Mixed well for 10 min. 200 ml from solution D was added to all tested tubs. Then, incubate for 10 min at room
temperature. Finally, the amount of proteins in the samples was estimated using spectrophotometer at 600 nm.

2.7 Statistical Analysis

The results of experiments were collected and expressed as mean ± standard deviation (SDev) and the diagrams were generated by using Excel program.

3. Results and Discussion

3.1 Influence of storage temperature and duration on postharvest physiochemical properties

3.1.1 Physical properties

3.1.1.1 Weight loss

Table 1 shows weight loss percentage of papaya and banana fruits under different temperatures storage (4 ±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days. The study reported that weight loss at 30°C was higher than at 4°C and 10°C for both banana and papaya. The average weight losses of banana were 5.30%, 23.66% and 67.32% at 4°C, 10°C and 30°C respectively. Regarding papaya, the average weight losses were 6.81%, 13.33% and 65.71% at 4°C, 10°C and 30°C accordingly.

One of the major problems associated with banana and papaya fruits are excessive weight loss which may result in hardening of the husk and browning of the rind and arils. The shrivelling and water loss can cause undesirable textural and flavour changes, ultimately resulting to loss of visual appeal. The highest weight loss observed in control sample placed in the home room at ambient temperature. The potential storage life of the banana and papaya fruit may not be more than 30 days at 4°C (Figure 1a, b). However, under refrigerated conditions most cultivars can be stored for prolonged periods. Storage trials conducted on banana cultivar stored at 5°C showed weight loss which increases with increasing temperature and prolonged storage duration.

Table 1 Weight loss percentage of papaya and banana fruits

<table>
<thead>
<tr>
<th>Temperature</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>4°C</td>
<td>0.66</td>
<td>1.99</td>
<td>2.65</td>
<td>5.3</td>
<td>1.08</td>
<td>1.79</td>
<td>5.02</td>
<td>6.81</td>
</tr>
<tr>
<td>10°C</td>
<td>0.61</td>
<td>1.53</td>
<td>10.69</td>
<td>23.66</td>
<td>0.75</td>
<td>2.08</td>
<td>5</td>
<td>13.33</td>
</tr>
<tr>
<td>30°C</td>
<td>5.75</td>
<td>13.73</td>
<td>35.95</td>
<td>67.32</td>
<td>1.46</td>
<td>3.5</td>
<td>8.09</td>
<td>65.71</td>
</tr>
</tbody>
</table>

Figure 1a Weight loss% of Banana

Figure 1b Weight loss% of Papaya

3.1.1.2 Peel colour

Fruit ripening is a complex, genetically programmed process that culminates in dramatic changes in texture, colour, flavour and aroma. Figure 2a,b shows...
the changes in peel colour of banana and papaya under different temperatures storage (4 ±1, 10±2, 30±3) °C and time (0, 3, 14, 30) days. The significant change in colour was observed 35,36.

Similar results were observed for fresh-cut ‘Smooth Cayenne’ pineapple when stored at 10°C, reporting small changes in values due to the browning reactions caused by polyphenol oxidase activity 37. As a result of increasing storage temperature and duration, the severity of external disorders became more obvious. The percentage of fruit affected by shrinkage at 4°C was relatively lower than those stored at 10°C Figure 2a. In addition, it was observed that fruit decay increased with temperature and storage period. A similar observation was observed for decay, where the severity of internal decay was enhanced with increasing storage temperature and prolonged duration. On the other hand, fresh papaya did not present severe browning, mostly appearing only after storage for 14 days at 30 °C Figure 2a. Browning is a serious problem and could affect flesh appearance 38,39. The results obtained in this work showed that papaya conserved its natural yellow-red colour during the storage period. This results confirm that neither temperature nor storage time significantly promote oxidative or enzymatic browning of papaya. Lower changes in the fruit have been reported to be a good indicator of absence of oxidative browning of flesh pulp 40. Gorny et al (2000)41 reported that storage temperature had an effect on colour of peach at 3 ripeness stages, mature-green, partially ripe, and ripe fruit. Other studies on fresh-cut revealed the importance of colour changes on pulp, which contrast with those obtained papaya. Finally, it was suggested may be the enzymatic and non-enzymatic oxidation of phenolic compounds cause the browning in banana and papaya. Thus, our study suggested that cultivar are more susceptible to disorders when stored at temperature of 4°C for more 14 days for banana and stored at temperature of 4 °C and 10°C for more than one month for papaya.

<table>
<thead>
<tr>
<th>Banana (a)</th>
<th>4°C</th>
<th>10°C</th>
<th>30°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>At harvest</td>
<td>Entirely green</td>
<td>Entirely green</td>
<td>Entirely green</td>
</tr>
<tr>
<td>3rd days</td>
<td>Still green</td>
<td>More green than</td>
<td>More green than</td>
</tr>
<tr>
<td>6th day</td>
<td>More green than</td>
<td>More yellow than</td>
<td>More yellow than</td>
</tr>
<tr>
<td>14th days</td>
<td>Entirely yellow with</td>
<td>More brown than</td>
<td>More brown than</td>
</tr>
<tr>
<td>36th days</td>
<td>More brown than</td>
<td>Brown spots</td>
<td>Brown spots</td>
</tr>
<tr>
<td></td>
<td>yellow</td>
<td>yellow</td>
<td>yellow</td>
</tr>
</tbody>
</table>

**Figure 2a** Peel colour of banana

It is clear from Figure 2a, the storage of banana at (4 ±1, 10±2, 30±3) °C for one month led to the occurrence of physiological disorders. At 30°C, about 70 to 99% of fruit were affected by internal disorders such as browning and decay, whereas 98% of all fruit stored displayed external disorders such as shrivelling and fruit decay, resulting in discoloration and complete fruit loss at the end of one month Figure 2a. No external disorders were observed at 4°C and 10°C in the first 14 days of storage, however, less than 5% of the fruits affected by internal disorders Figure 2a.
3.1.2 Chemical properties

3.1.2.1 Total soluble solids (TSS)

After 30 days, the highest values of the total soluble solids (TSS) of banana were 22.5±4.1 and 22.1±0.1 at 4 ºC and 10ºC respectively. Regarding papaya, the total soluble solids (TSS) were 6.8±0.05 and 8±0.05 at 4 ºC and 10ºC accordingly (Fig 3a,b). Table 2 showed the values of TSS under various conditions.

Table 2 Total soluble solids (TSS) of papaya and banana squeeze at different temperatures of storage (4 ±2, 10±5, 30±5) ºC and time (0, 3, 6, 14, 30) days. Values are mean ± standard deviation of triplicate tests.
TSS contents in fruits depend on storage conditions, cultvar types, agro-climatic regions and fruit maturity at harvest. Decrease in TSS content during this study could be attributed to degradation of sugars with prolonged storage period. On the other hand, increase in TSS has been attributed to moisture loss, leading to concentration of sugars inside the banana fruits.

### 3.1.2.2 Titratable acidity (TA)

As shown from table 3, the highest value of titratable acidity (TA) of banana was recorded after 14 days at 10 °C. TA values of papaya increased during 6 days of storage at 30 °C, while a slow increase were observed at 4 °C and 10 °C. The highest levels of TA were recorded at 4 °C after 30 day, while the lowest levels were found at 10 °C after 3 days (Fig4a,b). These findings are comparable to those reported by 47, who reported an increase in (TA) levels for untreated pomegranate fruit when stored at 6°C for 6 months.

**Table 3** Titratable acidity (TA) of papaya and banana under various conditions. Values are mean ± standard deviation of triplicate tests

<table>
<thead>
<tr>
<th>T°C</th>
<th>At harvest</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient</td>
<td>0.48±0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 °C</td>
<td>-</td>
<td>0.51±0.017</td>
<td>0.51±0.005</td>
<td>0.8±0.02</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>10 °C</td>
<td>-</td>
<td>0.67±0.006</td>
<td>0.66±0.01</td>
<td>0.89±0.02</td>
<td>0.65±0.006</td>
</tr>
<tr>
<td>30 °C</td>
<td>-</td>
<td>0.32±0.008</td>
<td>0.28±0.004</td>
<td>0.27±0.03</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T°C</th>
<th>At harvest</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient</td>
<td>0.065±0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 °C</td>
<td>-</td>
<td>0.12±0.001</td>
<td>0.22±0.01</td>
<td>0.23</td>
<td>0.24±0.022</td>
</tr>
<tr>
<td>10 °C</td>
<td>-</td>
<td>0.095</td>
<td>0.144±0.003</td>
<td>0.122±0.06</td>
<td>0.11±0.012</td>
</tr>
<tr>
<td>30 °C</td>
<td>-</td>
<td>0.15±0.004</td>
<td>0.21±0.012</td>
<td>0.19±0.002</td>
<td>-</td>
</tr>
</tbody>
</table>

### 3.1.2.3 pH

Slowing down the respiration rate by means of cold storage, controlling the atmosphere composition could explain the delay in the use of organic acids in the enzymatic reactions of respiration. No difference was found in the pH of control and cold storage (Fig 5 a,b). Table 4 displays the pH value of both fruit under different conditions.

**Table 4** pH of papaya and banana at different temperatures of storage (4 ±2, 10±5, 30±5) °C and time (0, 3, 6, 14, 30) days. Values are mean ± standard deviation of triplicate tests.
during postharvest storage. Therefore, the Brix:acid ratio (TSS:TA) of papaya and banana were estimated under different temperatures of storage (4 ±1, 10±2, 30±3) ºC and time (0, 3, 6, 14, 30) days (Table 5). No significant differences has been noticed in Brix:acid ratio during first 14 days storage of banana, however, the Brix:acid ratio of papaya at 30 ºC was higher than 4 and 10 ºC storage (Fig 6a, b).

Table 5 Brix:acid ratio (TSS:TA) of papaya and banana.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>At harvest</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient</td>
<td>5.9±0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 ºC</td>
<td>5.35±0.1</td>
<td>5.3±0.01</td>
<td>5.44±0.01</td>
<td>5.4±0.01</td>
<td></td>
</tr>
<tr>
<td>10 ºC</td>
<td>5.3</td>
<td>5.22±0.18</td>
<td>5.44±0.4</td>
<td>5.38±0.01</td>
<td></td>
</tr>
<tr>
<td>30 ºC</td>
<td>5.35±0.01</td>
<td>5.05</td>
<td>5.18±0.02</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

3.1.2.4 Brix:acid ratio (TSS:TA)

Brix:acid ratio (TSS:TA) determines the taste and flavour of banana and papaya fruits at harvest and

![Figure 5a pH of banana](image)

![Figure 5b pH of papaya](image)

![Figure 6a Brix:acid ratio of banana](image)
Changes in Brix:acid ratio is dependent on changes in both TSS and TA contents in fruit juice \(^{42-45}\). It has been reported that the starch was transformed into soluble sugar (sucrose, glucose, fructose) during banana ripening, and acid phosphatase was increased in the storage at same time. In contrast, acid phosphatase activity decreased while starch synthesis increased \(^{49, 50}\). The high value of Brix: acid ratio of papaya could cause appear some of solid texture during the papaya ripping.

### 3.1.2.5 Total phenolic content (TPC)

Banana and papaya squeeze were subjected to TPC estimation test after storing them for one month. Banana fruit at 6th day reached the highest total phenolic content value (682±27 ppm (GAE/CE)). Similarly, the highest value of TPC which obtained from papaya juice was (569±53 (GAE/CE)) at 14th day. On the other hand, the lowest concentration of total phenolic content in postharvest of banana and papaya at the first days were (239±2 ppm (GAE/CE)) and (177±24 ppm (GAE/CE)) respectively (Table 6).

<table>
<thead>
<tr>
<th>Figure 6b</th>
<th>Brix:acid ratio of papaya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 7a</td>
<td>TPC in banana</td>
</tr>
<tr>
<td>Figure 7b</td>
<td>TPC in papaya</td>
</tr>
</tbody>
</table>

Table 6 Total phenolic content of papaya and banana squeeze.

Total phenolic content (TPC) concentration increased in fruit stored for one month. However, there were no significant differences noticed for cold storage temperatures (4, 10) °C during first 14 days. At the
end of month, there were further significant increases in TPC in fruit stored at 4°C, and 10°C. The increase may be related to the continued accumulation of anthocyanins at low temperatures because antioxidant activity, TPC and anthocyanins content are strongly correlated to one another. Furthermore, in the (30°C) of storage, TPC concentrations showed a significant increasing trend with increase in temperatures, the highest phenolic concentration being 682 ppm at 30°C at the 6th day. The storage of banana after one month has been thoroughly damaged and unable to analyse it Figure 7a. The resulted were obtained from papaya confirmed that TPC concentration has been increased in the first 3 days. Our findings are in agreement with what was already reported by Pilar Cano et al (1996) that shown the increasing in TPC compounds. In addition, storage of fruit for 14 days or longer at 4 and 10°C led to decrease TPC concentration as compared to 30°C. Rivera-Pastrana et al (2010) reported that a decline in total phenolic concentration in papaya fruit may be related to the breakdown of phenolic compounds as a result of enzymatic activity occurring during storage Figure 7b. Furthermore, Nunes et al (2006) and Parkin et al (1989) reported a decrease in TPC concentration after long harvest period for untreated cold stored.

3.2 Evaluation the effects of Postharvest Storage on Nutritional Composition

3.2.1 Total polysaccharide

The amount of total polysaccharide in fruit is considered as one of the basic criteria to evaluate the fruit quality during the storage. According to Paliyath et al (2009), polysaccharide level could be reduced during fruit storage time due to a conversion of it into glucose and fructose. Total polysaccharide content of papaya and banana squeeze were estimated at different temperatures of storage (4 ±1, 10±2, 30±3) °C and time (0, 3, 6, 14, 30) days. The results indicated that as the storage time increased, the total polysaccharide content of banana samples decreased gradually at 4°C. On the 1st day, the concentration of total polysaccharide was 20.7±2 ppm, after 30 days storage, the polysaccharide concentration decreased gradually to 19.15±2.9 ppm. In addition, the polysaccharide concentration diminished also gradually at10°C and 30°C (Table 7). The obtained results from papaya samples during different storage conditions were similar with banana fruit. Likewise, the total polysaccharide content of papaya samples gradually decreased during storage time.

**Table 7** Total polysaccharide content of papaya and banana squeeze at different temperatures of storage (4±1, 10±2, 30±3) °C and time (0, 3, 6, 14, 30) days. Values are mean ± standard deviation of triplicate analyses.

<table>
<thead>
<tr>
<th>T °C</th>
<th>At harvest</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient</td>
<td>20.7±2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4°C</td>
<td>-</td>
<td>20.5±1.4</td>
<td>20.1±2.6</td>
<td>19.6±6</td>
<td>19.15±2.9</td>
</tr>
<tr>
<td>10°C</td>
<td>-</td>
<td>20.7±1.9</td>
<td>20±2.9</td>
<td>20.3±2.5</td>
<td>20.8±1.5</td>
</tr>
<tr>
<td>30°C</td>
<td>-</td>
<td>17.6±2</td>
<td>16.9±2.7</td>
<td>16.02±3.2</td>
<td>-</td>
</tr>
</tbody>
</table>

Polysaccharide slightly decreased in both samples stored at 4°C due to that oligofructose slightly hydrolyses at this temperature as compared to fruit samples stored at 10°C and 30°C, and this decrease in total polysaccharide contents was caused by the hydrolysis of polysaccharide to producing sugars (glucose and fructose) (Figure 8a,b). Glasstone et al (1946) reported that the rate of polysaccharides hydrolysis is a function of reactants, temperature and acid catalyst concentration. On the hand, maybe the amylolytic activities in the pulp of both cultivars at
different temperature storage were correlated to starch degradation, but there was a consistent increase in α-amylase activity in both cultivars.

![Total polysaccharide in Banana](image)

**Figure 8a** the changes of total polysaccharide in Banana during different durations and temperatures storage conditions

![Total polysaccharide in Papaya](image)

**Figure 8b** the changes of total polysaccharide in papaya during different durations and temperatures storage conditions

Previous studies with fruit of the banana cultivar 57, 58, have suggested that gene expression is an important component of the regulation of amylases enzyme. The transient induction of β-amylase in cold-acclimated bananas suggests that this enzyme can be synthesized in response of ethylene at low temperature 58, 59, which could be part of the mechanism of cold storage of banana fruit. Results obtained from this study for the hydrolysis of polysaccharide at different storage temperatures were found comparable with results obtained by Babsky et al (1986) 60 who reported the hydrolysis of polysaccharide in apple during different storage times at 37 ºC. Similarly, 61 also noted a similar decrease in polysaccharide contents at different temperatures for apple and pineapple juices stored for a 12 month period at 5, 24, 33 and 42ºC. Moreover, about 10% hydrolysis of oligofructose have been reported at pH > 4 and temperature >10 ºC 62. Papaya fruit also showed a similar phenomenon. The amount of total polysaccharide of papaya fruit decreased with the period of storage. The amount of reducing total polysaccharide might be attributed to enzymatic conversion of starch to sugar 63. Many researchers were observed same of decrease of polysaccharide concentrations in the fruits during different periods, reported a steady increase in total sugar content in bananas during storage 64.

### 3.2.2 Total Protein estimation

Our present results indicate that there is a differential protein accumulation during banana and papaya storage. For banana fruits, the concentration of total protein in postharvest of banana was 1459.3 ppm. During first 3 days the total protein decreased and then the concentration increased again in all storage conditions until the end of the month except at 30 oC which could not be tested due to thoroughly decay. In addition, the protein level dropped after 14 days in 10 ºC storage and then slightly increased again at the end of the storage period. Regarding papaya, the protein content was 1012.5 ppm at harvest; however, it decreased after 3 days. The protein concentrations increased in both cold storages till 6th day and then decreased on the 14th day. On the other hand, it reached the highest values at 30th day in the storage (Table 8).
Table 8 Total Protein estimation of papaya and banana squeeze. Values are mean ± standard deviation of triplicate analyses.

<table>
<thead>
<tr>
<th>T °C</th>
<th>At harvest</th>
<th>3 days</th>
<th>6 days</th>
<th>14 days</th>
<th>30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 °C</td>
<td>1459.3±0.2</td>
<td>880.16±0.04</td>
<td>1155.16±0.2</td>
<td>1198.6±0.17</td>
<td>1943.16±2.9</td>
</tr>
<tr>
<td>10 °C</td>
<td>1007.17±0.2</td>
<td>1009.8±0.6</td>
<td>1013.5±0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 °C</td>
<td>-</td>
<td>1639.6±0.4</td>
<td>1632.3±0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Most of protein sources in the fruits are enzymes. Therefore, the total protein estimation may give the aspect activates such as transcriptional events in the fruits during different storage conditions. Increasing protein level in the fruit might be due to the ripening of fruits during the storage. On other hand the decreasing of the total protein concentrations in banana (Figure 9a) at the temperature (10±2) °C and in papaya fruit at temperatures (4±1 and 10±2) °C (Figure 9b) have been observed. This might be attributed to high microbial growth which has used a part of protein as nutrient for growth. In addition, the protein concentration was very high in banana at 4 °C and papaya at 10 °C. This may be due to degradable or subvert of the fruits by hydrolysis enzymes. (The fruits could not be analysed at 30°C after 30 days because too decomposition and rot of fruits). Many researchers were found the same results whether during the ripening or during the storage of fruits. For example, the results provided by Dominguez-Puigjaner et al (1992) confirm the existence of variation in the protein accumulation during the ripening of fruits. It has been reported that the protein levels of α- amylase and β-amylase increased during the storage time.

Conclusion

This study showed that overall fruit quality was primarily influenced by temperature and storage duration as demonstrated by the instrumental quality parameters. However, postharvest storage temperature played a significant role in several quality parameters (colour, TSS, TA, pH, total phenolic content). Overall quality of fruit was reduced by prolonged storage as evident in both physical and chemical instrumental attributes. Discriminant analysis showed that fruit stored for 14 days could be distinguished from each other based on quality attributes such as overall banana and papaya flavour. For desirable sensory
attributes, optimum storage temperature and duration for banana were found to be 4°C and 14 days and one month for papaya fruit, when overall flavour and overall appearance values were highly rated. Likewise, according to the instrumental measurements, fruit could be successfully stored for 14 days for banana and one month for papaya without significant reduction in health-benefiting and colour parameters (total phenolic, total anthocyanin and aril colour). Furthermore, prolonged storage led to a reduction in overall quality and may cause development of undesirable off flavours if fruits are stored longer than 14 days of banana and one month of papaya. The storage conditions proposed in the current study for the investigated cultivar could be used as a guideline to establish suitable postharvest handling and storage conditions to ensure best fruit quality attributes for long supply chains.

Conflict of interest

The authors declare no conflict of interest.

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References


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