EFFECT OF STORAGE TEMPERATURE AND DURATION ON PHYSICOCHEMICAL PROPERTIES, MICROBIAL GROWTH AND NUTRITIONAL COMPOSITION OF PAPAYA AND BANANA FRUITS

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In the name of Allah, Most Gracious, Most Merciful
All praise and thanks are due to Allah Almighty and peace and
blessings be upon His Messenger

The results of this effort are truly dedicated to my mother and father whose
example as devoted professionals, as well as, parents taught
me to be perseverant, responsible and loyal
to my belief.

To my brothers, and sisters, and my best friend for all their support, encouragement,
sacrifice, and especially for their love.

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ABSTRACT

Banana (*Musa sp.*) and papaya (*Carica papaya*) cultivars were harvested and stored for a month at different storage temperatures and durations. These fruits were collected from an orchard which located in Johor Bahru, Malaysia. Ripening in undesired period, change skin color, weight loss, fruits quality loss such as nutrition, high microorganisms infestation rate and fruit damage due to improper storage. The fruits were stored at different durations (0, 3, 6, 14, 30 days) and at varying storage temperatures (4 ±1, 10±2, 30±3 °C). The color changing, weight loss, total polysaccharide and protein, total soluble sugar (TSS), titratable acidity (TA), pH, free phenolic content (FPC) and microbial growth were determined. The results revealed that parameters were significantly affected by temperature and time. For instance, banana polysaccharide was 20 at 4 °C, 20 at 10 °C and 16 mg/L at 30 °C, banana protein was 1155 at 4 °C, 1315 at 10 °C and 1640 at 30 °C, total soluble sugar was 6.8 at 4 °C, 7.9 at 10 °C and 8.2 at 30 °C, banana pH was 4.8 at 4 °C, 4.8 at 10 °C and 5.9 at 30 °C, papaya free phenolic content (FPC) was 184 at 4 °C, 245 and 569 mg/L at 30 °C, and papaya weight loss was 7 at 4 °C, 15 at 10 °C and 65% at 30 °C. However, it was not changed at cold storages prolonged storage period. In addition, the banana peel color was affected by browning and chilling injury into cold storages. Moreover, during storage, total soluble sugar (TSS), total polysaccharide, titratable acidity (TA) and free phenolic content (FPC) increased during cold storage. However, pH, microbial growth, weight and protein estimation whereas decreased during cold storage. In conclusion, according to the obtained results, the optimum storage temperature and duration for banana were found to be 4 °C and 14 days and one month for papaya fruit. The overall findings of this research might be able to provide science-based management tools for the storage performance of banana and papaya fruits.
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CHAPTER 1

INTRODUCTION

1.1 Research Background

1.1.1 Papaya

Papaya (*Carica papaya* L.) belongs to Caricaceae family (Williams, 2005). It is common in central and northern South America (Whipkey *et al.*, 1999; Williams, 2005). There are about sixty countries produce papaya. The total world production of papaya in 2013 (Fact fish, 2015) has been evaluated at 12.419 million tons and 11.22 million tons in 2010. The leading papaya producing region is considered Asia. Therefore, the world production has been assessed between 2008 and 2010. So, the Asia, South America, Africa, Central America, Caribbean, North America and Oceania produced about 52.55%, 23.09%, 13.16%, 9.56%, 1.38%, 0.14%, 0.13% of the global production respectively (Evans and Ballen, 2012). The fruit may be ripe when it becomes soft and its skin attains amber to orange hue. Scientific evidence has mentioned that papaya improves 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 (da Silva *et al.*, 2007; Nishijima *et al.*, 1987;
Parris, 1938; Evans and Ballen, 2012). Consequently, the consumption of papaya is increased.

The consumption of papaya fruit in the market are largely restricted to the its quality. The lack of appropriate postharvest technology such as storage conditions may effect on fruits demand. Postharvest handling practices which include packaging and postharvest conditions such as temperature control may be used to keep the fruit quality to prolong storage periods (Rivera-Lopez et al., 2005). Storage temperature is one of the very important environmental factors that affect postharvest life of fresh fruit. The temperature regulates the rate of all associated physiological processes, microbial growth and biochemical reactions (Li and Kader, 1989). Many reports have shown that physico-chemical, physiological, phytochemical, mechanical, sensory qualities and microbial properties of papaya fruits are influenced by packaging, storage temperature, and atmospheric conditions (Williams, 2005). The papaya is very popular worldwide. Furthermore, it is mainly cultivated in tropical countries. Therefore, many non-tropical countries import papaya from Malaysia and other tropical countries. The fruit may be stored at temperatures below 10 °C to extend the marketing value (Azarkan et al., 2003).

The metabolism of mineral nutrients in the plants is influenced by temperature. For instance, the increasing of the transpiration rates in the plants is due to increasing of the environment temperature. The low temperature that less than 10 °C may decreases fruit development, sweetness, and size of papaya. It also influences flower and fruit setting. For instance, stamen carpellody occurs at low temperatures. Therefore, the fruits that develop under the carpellody are severely misshapen and unmarketable (Gonzalez-Aguilar et al., 2003). At higher temperatures that more than 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 vary with cultivars. Previous study indicated that fluctuating temperatures may cause to reject the amount papaya. In addition, high and low temperature is often encountered for few hours during fruits handling operations (Nunes et al., 2006).
1.1.2 Banana

Banana fruits are produced in tropical and subtropical areas in large quantities. Banana is globally important as a food crop because it is the staple food for millions of people worldwide (Sagi et al., 1995). The previous study reported that world production of Musa in 2003 was estimated at 102 million tons of which about 68% was classified as bananas and 32% as plantains (Fao and Foods, 2004). The crop of banana is very important for the human being in the growing areas that it forms a major portion of the annual income and a source of food. Production, as well as exports and imports of bananas are highly concentrated in many countries. Ecuador, India, Brazil and China are considered the major banana-producing countries of total global production which reached about 75% in 2003. Furthermore, Latin America and the Caribbean islands are the major suppliers of banana. Malaysia, Costa Rica, Ecuador, the Philippines and Colombia are exporters countries of banana (Fao and Foods, 2004). There are four common banana cultivars widely grown in all regions in Malaysia. These cultivars are Mas (AA), Embun (AAA), Rastali (AAB) and Berangan (AAA) (Abdullah, et al., 1990). The bananas are exported to Singapore and Brunei Darussalam by loading onto open conventional trucks at ambient temperature (Ratule et al., 2006).

Banana is one of the sixteen fruit types that have been identified by the Malaysian Ministry of Agriculture as having commercial potential either as fresh or processed fruit. Banana is a great economic importance in the moister areas of tropical agriculture and it is an important fruit crop in Malaysia as well. Banana is a soil conservative, productive, and non-seasonal fruits. It is sweet fruits which contains staple starch and other nutrition. In addition, there are some useful secondary products such as fibers, beverage, dyes, cordage and wrappings materials. The commercial plantations are consider revenues from exporting bananas (Noor, 2002).

Banana is a general term including a number of species in the genus Musa of the family Musaceae. There are two species in the section Musa which are M. acuminate and M. balbisiana. These cultivars are considered diploid that contain two sets of chromosomes. Therefore, the classification of M. acuminate and M. balbisiana are AA and BB groups respectively. In addition, M. acuminate and M.
`balbisiana` are edible bananas (Ortiz et al., 1998; Robinso, 1996; Zhang et al., 2005). *M. acuminate* developed primarily in tropical of Southeast Asia. Consequently, *Musa acuminata* (AA group) has been selected in this research.

Banana is considered very important for human diets. So, the quality of this fruit can significantly affect consumer appeal, handling practice, storage potential, and market selection. In addition, the ripening changes of banana might be influenced by storage temperature. It has been reported that the storage temperature of 16 °C to 18 °C may be the better commercial ripening of banana (Ahmad, et al. 2006). Therefore, the control of the ripening temperature is important to obtain the best quality fruit within in specific marketable life.

1.2 Problem Statement

The cultivar Papaya (*Carica papaya* L.) and Banana (*Musa acuminate*) are the widely grown in Malaysia. Malaysian fruits industry encounters problems in quality losses after storage of banana and papaya fruits due to the lack of knowledge on optimal storage during different durations. These issues such as weight loss, fruit ripening at shipping or storage periods which is attributed to temperature (Workneh et al., 2012), fruit damage, loss of fruits quality such as nutrition, peel color, browning as well as microorganisms infestation (Gayoso-García et al., 2010) which cause to become unhealthy food. Consequently, papaya and banana cultivars may be exposed to harmful bacteria and other contaminants prolonged storage periods as a result of inappropriate storage conditions. Therefore, the fruits can become a source of pathogens food. So, the contaminated fruit cannot be healthy food and cause diseases to human body. To date, there is currently limited scientific knowledge on the storage requirements to keep the high quality of (banana and papaya) fruits. The storage conditions are not convenient yet to guarantee the continuous supply of fresh and healthy fruits of acceptable standards to national and international markets. The storage conditions must be convenient to guarantee the continuous supply of fresh and healthy fruits of acceptable standards to national and international markets. The papaya and banana must be in good quality and good condition at market. In other
words, the fruits must be not over ripening, high rate of chilling injury, damage, infested fruits.

In addition, the fruits taste, texture and appearance may suffer as well. The fruits may lose their pharmaceutical properties and nutrition such a proteins, sugar, phenolics which are considered antioxidant compounds as a result of spoilage. In the current time, many diseases have been globally increasing. As a result of this, the consumption of fruits has been increased by human being because the research studies referring that fruits may help prevent particular sorts of illnesses, due to their potentially high antioxidant properties (Gayosso-García, et al., 2010). Consequently, it is necessary to indicate that if fruit storage conditions are not convenience, metabolism accelerates and could exhaust its energetic reserves, resulting in the loss of nutritional value of the fruit (Gonzalez-Aguilar et al., 2009; Gayosso-García, et al., 2010). In this case, the technology of postharvest is essentially required to reserve the harvested fruits otherwise, the rate of deterioration of this produce might be augmented. Furthermore, the fruits cannot be satisfactory to customers which leads to reduce salesman income.

To develop quality standards for the export market, the knowledge of the optimum storage conditions are required to get more understanding of postharvest quality improves and consumer organoleptic perceptions. The Malaysian Papaya (Carica papaya L.) and Banana (Musa acuminate) industries are currently classed with fruit quality loss as a result of inappropriate storage. Currently, there has been a little scientific information on the storage requirements for the Malaysian Papaya (Carica papaya L.) and Banana (Musa acuminate). These fruits have been selected for this research because high rate of papaya and banana consumption at market (Fao and Foods, 2004; Ratule et al., 2006). In order to take full support of the existing export market. Therefore, this study focused on storage to find out the optimum storage conditions for papaya and banana fruits.
1.3 Objectives of Research

The objectives of the study are as follows:
1. To evaluate papaya and banana fruits physico-chemical properties (weight loss, peel color), (TSS, TA, PH, TSS:TA, FPC), total polysaccharide and total protein content responses under different temperatures of storage and durations.
2. To evaluate the effect of temperature and storage period on the microbial growth in papaya and banana fruits.
3. To recommend the optimum storage conditions for papaya and banana fruits in tropical setting.

1.4 Scope of the Study

The domestic papaya and banana cultivars fruits are considered a common food in Malaysia. So, these fruits has been subjected to experimental evaluation in this research. Therefore, the scope of this research is to study the effects of different storage temperatures of 4 ±1, 10±2, 30±3 °C and durations of 0, 3, 6, 14, 30 days on physico-chemical properties of papaya and banana such as skin color of fruits, weight loss, soluble sugar, titratable acidity, pH, total soluble sugar to titratable acidity ratio and total phenolic concentration. In addition, the experiments has been conducted to evaluate the effectiveness of temperatures of 4 ±1, 10±2, 30±3 °C and durations of 0, 3, 6, 14, 30 days on the total polysaccharide concentration and total protein content. The ambient conditions was selected because fruits are sold at most markets in this conditions and 4 and 10 °C were selected because this range have been tested for other foods in the previous studies. Furthermore, one of the most important study is the microorganisms contamination such as bacteria and fungus growth which has been investigated and correlated it to the temperatures of 4 ±1, 10±2, 30±3 °C and periods of 0, 3, 6, 14, 30 days.
1.5 Significance of the study

This study has focused on some factors that may have effectiveness such as temperature and time on the papaya and banana fruits into the storage. The deterioration of the food in the storage is an indicator to the responsible competent authorities to take into consideration the temperature and storage period and find out the best resolution to protect the stored products against deterioration, harmful bacteria, fungi, which cause diseases to human body as well as loss of quality and weight during storage and transportation.

Papaya and banana are considered nutritious fruits and consumed widely and particularly throughout tropical regions. Therefore, the accomplishment of this research would greatly contribute into the research community. The outcome of this research might provide a further insight into the stored papaya and banana fruits. Good comprehension study on total polysaccharide, protein estimation, total soluble sugar, titratable acidity (TA), pH, total phenolic content (FPC), fruits weight and microbial growth needed, consequently, it may improve this research approach on these parameters prolonged storage period and enable the authors to add more information to find out the convenient storage conditions. Extensive research on stored papaya and banana fruits can improve the probability of this study into a full scale large quantities of banana and papaya application in a near future in Malaysia. Consequently, this significance of evaluation of total polysaccharide, protein estimation, total soluble sugar, titratable acidity (TA), pH, free phenolic content (FPC), fruits weight and microbial growth will surely become a factor of attraction in implementation in order to reduce losses, clean, fresh quality hygienic produce providing customer satisfaction, increase sale and increase farmer income which leads to improve marketing.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Papaya (*Carica papaya* L.) and Banana (*Musa acuminata*) are a tropical crops that capable to grow in different soil types (Sagnia *et al*., 2014; Sahaa *et al*., 2013). The commercial farming of papaya and banana fruit significantly increases, because it has multifunctional and nutritional benefit in the human diet, satisfying the medicinal of consumers in many countries (Finkel, 2003; Floyd, 1990; L. Huang *et al*., 2011; S.-S. Huang *et al*., 2013; Kumar *et al*., 2012; Morris *et al*., 2013; C. Rao *et al*., 2007; Sripanidkulchai *et al*., 2001; Valko *et al*., 2007; Valko *et al*., 2006). Therefore, the requirements are necessary for development of optimum postharvest storage conditions for papaya and banana. The literature review discussed the past and current knowledge on the effects of storage duration and temperature on sensory properties, nutritional composition and microbial growth of papaya and banana.
2.2 Papaya

Papaya is a fast growing tree that may reach three to ten meters high. It has only one stem without branches at initial growth. Some new shoots appear after about one year at the lower trunk and some branches may grow (Jiménez et al., 2014). Figure 2.1 shows the papaya tree and fruits. The mass of leaves at the apex and along the top of the stem. The leaves are about fifty (50) to seventy (70) centimeter in diameter, deeply palmate lobed, with about seven to eleven lobes. The leaves contain white milk latex. Papaya flowers appear in the axils of leaves. The fruit is ripe when it feels soft and its skin has attained an amber to orange hue (Gross et al., 2014; Nakasone and Paull, 1998).

![Papaya tree and fruit](image)

Figure 2.1: Papaya tree and fruit (Jiménez et al., 2014)
2.2.1 Papaya Maturity

The papaya fruits maturity can be determined by property of texture which include some characteristics such as firmness, color and latex. In addition, the taste of papaya can be one of the properties that determines the maturity of it. For example, sweetness, acidity and total soluble solid (TSS) (Basulto et al., 2009).

2.2.2 Skin Color of Papaya Fruits

The skin color of papaya can be used to determine its maturity. Figure 2.2 shows different stages of maturity papaya. These stages are classified by the skin color of papayas. Figure 2.2 (a1) and (a2) depict green skin without yellow stripe; pulp very hard and white in color; seeds well-formed but white or slightly dark in color. Figure 2.2 (b1) and (b2) show green skin with a light yellow stripe; pulp exhibits some areas with orange color, is very hard and contains large amounts of latex. Figure 2.2 (c1) and (c2) show green skin with well-defined yellow stripe; pulp is orange in color near seed cavity and light green near skin, although still hard and with large amounts of latex. Figure 2.2 (d1) and (d2) demonstrate one or more orange-colored stripes in skin; pulp almost completely orange in color, except near skin, still hard but contains less latex. Figure 2.2 (e1) and (e2) show skin clearly orange in color with some light green areas; pulp completely orange, except near peduncle, softer than in stage 3, but still too hard for consumption, low latex content. Figure 2.2 (f1) and (f2) show skin displays orange color characteristic of Maradol variety; pulp firmness appropriate for consumption, latex no longer present. Figure 2.2 (g1) and (g2) depict the conditions similar to stage 5, but with more intense orange color in skin and softer pulp still adequate for consumption (Basulto et al., 2009).
2.3 Banana

The word banana is a general term embracing a number of species or hybrids in the genus *Musa* of the family *Musaceae* (Zhang *et al.*, 2005). Banana cultivars are yellow when it is ripe. Consequently, the ripe banana may be damaged and lost its quality during transportation from farm to the market. Banana is one of important foods that source of energy, mineral salts and vitamins. Furthermore, sensorial attributes of the banana, as flavor, taste, texture, and color, are significantly influenced by its chemical composition, especially by acids, sugars, and phenolic compounds (Carvalho *et al.*, 2009).

The potential life of fruit after harvest depends on factors such as maturity, care and storage conditions (airflow and temperature). Several pre-harvest parameters may indeed contribute to successful development of good quality fruit and vegetables. Agricultural practices, soil, climate and harvesting conditions all affect the banana. The disease effectiveness such as *Fusarium* wilts and damages banana leaves (Jamaluddin, 2000). Usually, such disease outbreaks in bananas which associated with the presence of plant-parasitic nematodes in the cultivation areas, as...
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