Influence of Storage Conditions on Ripening Behavior and Physico-Chemical Properties of Papaya (*Carica papaya* L.) Fruits

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Abstract

Papaya (Carica papaya L.) is a nutritious tropical fruit, consumed both in its fresh form and as a processed product world-wide. It was an important fruit in Ethiopia as it was a good source of vitamins, dietary fiber and minerals and provides flavor, aroma and texture to the pleasure of eating. The main objective of the study was to investigate the influence of ambient temperature and cool chamber (PZECC) storage conditions on ripening behavior and physico-chemical properties of packaged papaya fruits in plastic and wooden crates. The data obtained were statistically analyzed for Analysis of Variance (ANOVA) by using Complete Randomized Design (CRD). Aand mean separation was performed by using detect least significance difference (LSD) at the p 0.05 level. Results reveal that, TSS, weight loss and shelf-life significantly increased with every increments of storage period at both storage condition and packaging materials. However, mean value of firmness was significantly decreased as storage duration increased. It could be concluded that some physico-chemical properties were significantly increased with the advancement of storage time. Moreover, when post-harvest handling activity done properly the quality of papaya fruit was increased and the farmer incomes for local market and export market increased.

Key words: *Papaya fruit, physico-chemical properties, ripening behavior, storage conditions*

1. Introduction

1.1. Back Ground

Papaya (*Carica papaya* L.) is a nutritious tropical fruit, consumed both in its fresh form and as a processed product world-wide. It is an important fruit in Ethiopia as it is a good source of vitamins, dietary fiber and minerals and provides flavor, aroma and texture to the pleasure of eating. Fully ripened papaya fruits are usually eaten fresh as the enzymes in the fruit produce calm, soothing feelings in the stomach. Papaya is known for its fine and natural laxative virtue which aids digestion. Papaya fruits are rich in enzymes called papain and chymo-papain that breakdown the proteins from the food a person eats into amino acids and therefore helps digestion. The anti-inflammatory properties and high antioxidant content of papaya is known to prevent cholesterol oxidation and can be used in preventative treatments against strokes, heart attacks, diabetic, heart disease and blood pressure (Eno, *et al.,* 2000). Nutritionally, papaya is a good source of calcium and an excellent source of vitamins A and C (Nakasone and Paull,1998).

Papaya is native of tropical America, and has become a very popular fruit worldwide due to its fast growth, high yield, long fruiting period and high nutritive value. Raw papaya is usually consumed for vegetable purpose and also for papain production. The ripe papaya is utilized more for direct consumption rather than harnessing its potential for diversified product development. There is an increasing demand for papaya juice as ingredients for blended juices, concentrates, syrups, juice drinks and soft drinks. However, due to its chemical nature (rich in pectin, starch and fiber), the clarification process becomes difficult (Rai, *et al*, 2004)

Physico-chemical characteristics are important qualitative indexes of any fruit for fresh consumption (Zaman, *et al*, 2006). Such characteristics are yet to be reported for *Carica papaya* of Ethiopia. The proximate composition (ash, acidity, crude fat, crude fiber, sugars and moisture), ascorbic acid, soluble solids, polyphenol oxidase (PPO) activity and mineral elements present in storage-ripened papaya fruits were determined.

Papaya is a highly perishable fruit and during transportation may suffer from chill injury, bruising, wrinkling, and softening; all of these factors affect the acceptability of this fruit (Penteado and Leitao, 2004). Preservation of papayas is a needed field of study to add value, improve shelf life, and enhance accessibility of the fruit. To maintain the health benefits of this highly perishable fruit, it is important to develop processing methods that have minimal impact on its nutritional properties and flavor.

Postharvest handling of papaya requires care and attention to detail. Papaya is susceptible to several factors that can reduce its marketability, including extreme or fluctuating temperature, moisture, disease, and mechanical damage (CRFG, 1998). Exposure to these factors through inappropriate handling can cause under- or over-ripening, inconsistent quality, and poor flavor and result in high postharvest losses. If properly cared for, papayas can sustain a shelf-life of 4 to 6 days under ambient tropical conditions (25°C to 28°C), or up to 3 weeks under lower temperatures (10°C to 12°C).

Most of the horticultural crops including fruits and vegetables begin to deteriorate shortly after harvest. Refrigerated cool storage is considered to be the best method of storing fruits and vegetables. However, this method is not only highly energy-intensive but also involves huge capital investment. The present trend the world over is to develop a simple, low-cost cooling system for storage of fruits and vegetables. In order to overcome the problem of on farm storage, low-cost, environment friendly Pusa Zero energy cool chambers have been developed. The greatest importance of this low-cost cooling technology lies in the fact that it does not require any electricity or power to operate and all the materials required to make the cool chamber are available locally, easily and cheaply. Even an unskilled person can install it at any site, as it does not require any specialized skill. Most of the raw materials used in cool chamber are also re-useable. The cool chamber can reduce the temperature by 10-15^{0}C of ambient temperature and maintain high relative humidity of above 90% throughout the year that can increase the shelf life and retain the quality of fresh horticultural produce.

1.2. Statement of the Problem

Papayas are highly perishable horticultural crops with 35.5% post harvest losses estimated in Ethiopia. Arba Minch area in Gamo Gofa Zone is selected as development corridor for fruit production mainly banana, apple, mango and papaya. The current problem for papaya is concerned with lack of value addition through processing, method of transportation, storage, marketing and selection of packaging material for ripening. The estimated post harvest loss of papaya is about 60% at Arba Minch area. Careless handling during loading and shaking of the vehicle on the road further adds to the problem. Papaya producers at Arba Minch area use different packaging materials for ripening of papaya fruits, as per the information obtained from field observation. Local producers of papaya use grass straws, newspaper leaves or a combination of them to ripe their papayas for sale. These are locally available ripening materials for papaya. Scientific studies have been conducted to determine suitable packaging material for good ripening which maintain good quality of the fruit.

There are many problems during the activity of storage of papaya fruits. The major problems are extreme temperature variations; low temperature in the cool chamber and very high temperature in ambient condition, inadequate storage and transportation facilities. Fungal fruits infection may occur during the harvesting, handling, transporting and post-harvesting, storing, and marketing conditions, or after purchasing by the consumer using of mature, immature, overmature, damaged or disease infected fruits reducing the quality of papaya fruits. In addition to not giving the necessary care and attention of this activity and inappropriate preparation process reduces the consumer acceptance. The quality of the fresh and processed papaya fruit depends on the postharvest handling. Harvesting, transporting, and storing should be monitored effectively to keep the best quality of fruit during and before storage.

1.3. Objectives of the Study

The major objective of the study was to investigate the influence of different storage conditions on ripening behaviour and quality of papaya fruit, with the specific objectives:

- To explore the influence of ambient temperature and cool chamber storage on ripening behaviour of papaya fruit ;
- To determine the effect of storage conditions on physico-chemical properties of papaya fruit;
- To identify the optimal storage conditions for prolonged shelf life of papaya fruits

2. Methods and Materials

2.1. Description of the Study Area

The experiment was conducted at Kulifo Campus, College of Agricultural Science, Arba Minch University. Arba Minch is located 500km from Addis Ababa, – the Capital City of Ethiopia, and 273 km from Hawassa – the capital city of southern Nation Nationalities and Peoples Region (SNNPR), and north of Lake Abaya. It has an altitude of 1218 m.above sea level; latitude of 37.36^{0}E and 6.04^{0}N. In Araba Minch, there are two months – April and May, where the rainfall has the highest amount, with 161.8 mm and 151.2 mm, respectively, and the lowest rainfall occur in January and February which are 32 mm and 9 mm, respectively. The annual rainfall range is 500-1100 mm, and the annual temperature is 22-35^{0}c in different depth of soil.

2.2. Experimental Material

The experimental material consist one papaya cultivar, obtained from Arba Minch University demonstration farm, or purchased from Arba Minch market. Papaya fruits of uniform size, color, undamaged, free from disease and bruises and equally matured were selected for the experimental purposes and bring it to experimental site within 1 hr. after harvest.

2.3. Experimental Treatments

Papaya fruits of uniform size were selected and sorted out to eliminate bruised, punctured and damaged ones. The experimental treatment consist two storage conditions; the ambient temperature and the pusa zero energy cool chamber (PZECC). Papaya fruits were stored at both storage conditions (Ambient temperature and PZECC) for 9 days and then the data was recorded within 3 days of storage time intervals (0, 3, 6 and 9 days). The post-harvest treatments were carried out as per completely randomized design (CRD) with 16 treatments.

Table 1: Experimental Layout

Storage time (days)	Storage Condition			
	cool chamber(PZECC)		Ambient/Room temperature	
	Plastic crates	Wooden crates	Plastic crates	Wooden crates
0	Cc*Pc@0	Cc*Wc@0	RT*Pc@0	RT*Wc@0
3	Cc*Pc@3	Cc*Wc@3	RT*Pc@3	RT*Wc@3
6	Cc*Pc@6	Cc*Wc@6	RT*Pc@6	RT*Wc@6
9	Cc*Pc@9	Cc*Wc@9	RT*Pc@9	RT*Wc@9

2.4. Data Collection

2.4.1. Physico-chemical Properties of Papaya Fruits

2.4.1.1. Physical Parameters

2.4.1.1.1. Physiological Weight Loss

The weight of the papaya fruit was measured during storage period with an electric balance (Fx 3000; AD Company, Japan) with an error, range of 0.019. The loss in weight was expressed as percentage of the original fresh weight of the fruit. The weight loss of papaya fruit was calculated by differences between original weight and final weight (Moneruzzaman*et al,* 2009).

$$\text{Weight loss}(\%) = \frac{\text{Original weight} - \text{Final weight of fruit}}{\text{Original weight of fruit}} \times 100$$

2.4.1.1.2. Fruit Firmness

The fruit firmness of papaya was determined with digital hand-held penetrometer (Model xM-1, Fuji Wara, Japan) by taking five readings per fruit on opposite sides along the fruit equatorial region. The skin of the fruit was removed at the reading spot to ensure that pulp firmness, rather than skin firmness was assessed. It is expressed in Newton (N).

2.4.1.1. 3. Decay or Rotting (%)

The decay or rotting of the stored papaya fruits was determined by their visual observations. Decay percentage of papaya fruits was calculated as the number of decayed fruit divided by initial number of all fruits time 100.

$$\text{Decay or rotting }(\%) = \frac{\text{Number of decayed fruits}}{\text{Initial number of total fruits}} \times 100$$

2.4.1.2. Chemical Parameters

2.4.1.2. 1. TSS Measurement

The total soluble solid (TSS) levels of the papaya fruits were determined according to AOAC method (Anon, 1990) by using hand refractometer. An appropriate quantity of each product was placed on the prism-plate of the refractometer and the reading appeared on the screen was directly recorded as TSS results expressed in Brix^{o}.

2.5. Data Analysis

All the analyses performed were carried out in triplicate and the standard deviation was calculated. The experimental design was complete randomized design (CRD) with three replicates. Analysis of variance (ANOVA) was used to determine treatment effect. Mean separation was performed by using detect least significance difference (LSD) at the *p 0.05* level. The data was analyzed using LSD.

3. Results and Discussions

3.1. Physico-chemical Properties of Papaya Fruit

The data were determined on physical properties of papaya fruit includes physiological weight loss, firmness and decay or rotting. Chemical parameter was comprised only total soluble solids (TSS). The statistically interpreted results of all parameters were given below in the Tables 2 and 3.

3.1.1. Physiological Weight Loss

The data presented in table 2 and 3 indicate that there were significant differences in weight loss of different storage conditions. The maximum weight loss (6.84%) was recorded on papaya fruits which were stored in wooden crate at open air for 9 days followed by fruits with a loss of (5.89) stored in plastic crate at room temperature for 9 days. The difference in these packaging materials and storage conditions were significant. The minimum weight loss (1.52%) was recorded for papaya fruits which were stored in wooden crate at cool chamber for 6 days. Papaya fruits which were stored in both crates at room temperature exhibited the higher weight loss than those stored at cool chamber, may be due to the higher temperature and lower humidity surrounding the fruits which leads to higher transpiration. Weight loss of fruit increased significantly with every increment of storage periods. The cool chamber can reduce the temperature by 10-15^{0}C of ambient temperature and maintain high relative humidity of above 90% throughout the storage that can increase the shelf life and retain the quality of papaya fruits. Therefore, cool chamber was suitable to prolonged storage time of fruits by delaying ripening process due to decrease respiration rate and ethylene production. The weight loss in fruit depends on the structure of the skin and nature of waxes on the surface of the fruit (Veraverbeke, *et al*., 2003). The weight loss variations in stored papaya fruit may be due to storage conditions.

3.1.2. Total Soluble Solids

The data presented in table 2 and 3 indicate that there were significant differences in TSS of different storage conditions. The highest total soluble solid (13.00birx^o) was determined in papaya fruits which were stored in wooden crate under room temperature for 9 days followed by papaya (12.33birx^o) stored in plastic crate at room temperature for 9 days. The minimum weight loss (3.25birx^0) was recorded for papaya fruits which were stored in plastic crate at room temperature for 0 day. Total soluble solids of papaya fruits increased gradually with increasing the storage durations special under at room temperature because of high ethylene production. These results reveal that time and temperature both are equally responsible for physicochemical changes of fruits and the major changes occur when fruits are stored for long time at high temperature. For instance, Doreyappa, *et al,* (2001) reported that seven hybrid varieties of green mature papaya underwent a series of physic-chemical changes and major changes were observed in TSS (19.0 brix^o) when stored at 18 to

34°C.The data indicates that the results are statistically highly significant at 5% level of significance (<0.05).

3.1.3. Firmness

The data presented in table 2 and 3 indicates that there were significant differences in firmness of both storage conditions. The highest (21.7 N) fruit firmness was recorded for fruits which were stored in wooden crate at room temperature for 0 days followed by fruits which were stored in wooden crate at cool chamber and plastic crate at room temperature with 21.6 and 21.38 N, respectively. The fruit firmness significantly decreased with increase in storage duration at both storage conditions. Regarding the firmness, papaya fruits stored in cool chamber represented the excellent results by retaining the maximum firmness as compared to at room temperature. The current investigations confirm the view that control atmosphere conditions delay fruit ripening and softening (Kader, 1986).The firmness of the fruit depends on rate of evapo-transpiration, respiration rates, resulting in loss of solutes and water (Ghafir, *et al*., 2009).The data indicates that the results are statistically slightly significant at 5% level of significance (P<0.05).

Table 2: Effects of Cool Chamber on Physico-Chemical Properties of Papaya Fruit

Treatments	Weight Loss (%)	Firmness(N)	TSS(brix^{o})	Decay (%)
Cc*PC@0	0.00±0.00^{d}	21.08±5.14^{a}	4.17±1.26^{b}	0.00±0.00^{c}
Cc*PC@3	3.50±1.88^{bc}	10.92±2.67^{bc}	8.67±2.08^{a}	0.00±0.00^{c}
Cc*PC@6	3.54±1.21^{bc}	14.04±3.55^{b}	9.33±2.31^{a}	19.44±4.81^{ab}
Cc*PC@9	4.69±2.24^{ab}	3.92±0.95^{d}	9.83±2.36^{a}	11.11±9.62^{bc}
Cc*wc@0	0.00±0.00^{d}	21.6±5.42^{a}	3.25±0.90^{b}	0.00±0.00^{c}
Cc*wc@3	2.06±0.76^{cd}	10.46±2.54^{bc}	9.00±3.00^{a}	0.00±0.00^{c}
Cc*wc@6	1.52±0.37^{cd}	12.33±2.98^{bc}	9.00±2.65^{a}	8.33±8.33^{c}
Cc*wc@9	5.77±2.66^{a}	6.75±2.25^{cd}	10.3±2.52^{a}	27.7±9.62^{a}
CV (%)	47.62	27.51	28.13	70.71
Mean	3.13±3.09	12.6±6.63	7.95±3.17	8.33±11.26

Mean within the same column with different alphabets are significantly (p<0.05) different. Cc: Cool Chamber, *: interaction effects, Pc: plastic crate box, Wc: wooden crate box, @: at storage periods (0-9 days), TSS: Total soluble solid, N: Newton and CV: Coefficient Variance

Table 3: Effects of Ambient Temperature on Physico-Chemical Properties of Papaya Fruit

Treatments	Weight Loss (%)	Firmness(N)	TSS(brix^{o})	Decay (%)
RT*PC@0	0.00±0.00^{d}	21.38±5.44^{a}	3.25±0.90^{c}	0.00±0.00^{c}
RT*PC@3	2.74±0.66^{c}	10.92±2.67^{b}	8.67±2.08^{ab}	0.00±0.00^{c}
RT*PC@6	4.11±1.01^{bc}	5.13±1.31^{bc}	10.67±3.06^{a}	0.00±0.00^{bc}
RT*PC@9	5.89±1.43^{ab}	3.83±1.04^{c}	12.33±3.21^{a}	27.7±9.62^{a}
RT*wc@0	0.00±0.00^{d}	21.7±5.41^{a}	4.17±1.26^{bc}	0.00±0.00^{c}
RT*wc@3	2.48±0.63^{c}	10.46±2.54^{b}	9.00±3.00^{ab}	0.00±0.00^{c}
RT*wc@6	4.37±1.51b^{c}	6.54±1.59^{bc}	11.67±2.89^{a}	11.11±9.62^{bc}
RT*wc@9	6.84±2.46^{a}	4.17±1.01^{c}	13.00±3.61^{a}	16.67±16.67^{ab}
CV (%)	37.34	29.83	29.28	109.54
Mean	**3.30±2.60**	**10.52±7.46**	**9.09±4.14**	**6.94±11.95**

Mean within the same column with different alphabet are significantly ($p<0.05$) different. Cc: Cool Chamber, *: interaction effects, Pc: plastic crate box, Wc: wooden crate box, @: at storage periods (0-9 days), TSS: Total soluble solid, N: Newton and CV: Coefficient Variance

3.1.4. Decay or Rotting (%)

The data presented in table 2 and 3 indicates that there were significant differences among storage conditions. The maximum % decay incidence was observed for fruits which were stored in both crates at both storage conditions for 9 days with 27.8 %. At 0 and 3 days, there was no observed decay on fruits which were stored in both crates at both storage conditions. The soft rot of papaya fruits were increased slightly with every increments of storage time to the maximum of 27.7% at both storage conditions for 9 days. It is found that fruits are highly susceptible to decay because of soft texture and high moisture content of fruits (Spotts, *et al.*, 1999). While there was no soft rot incidence at first day storage, significant differences among storage conditions were observed after storage of 9 days with the highest soft rot in fruits which were stored at room temperature compare to cool chamber. The increase in soft rot incidence with increasing storage duration varied significantly with storage conditions and packaging materials.

4. Conclusions and Recommendation

4.1 Conclusions

Papaya (Carica papaya L.) is a nutritious tropical fruit, consumed both in its fresh form and as a processed product worldwide. It is good source of vitamins, dietary fiber and minerals and provides flavor, aroma and texture to the pleasure of eating. The main objective of the study was to investigate the influence of ambient temperature and cool chamber (PZECC) storage conditions on ripening behavior and physico-chemical properties of packaged papaya fruits in plastic and wooden crates. The data obtained was statistically analyzed for Analysis of Variance (ANOVA) by using Complete Randomized Design (CRD) and mean separation was performed by using detect least significance difference (LSD) at the p 0.05 level. Results reveal that, TSS, weight loss and shelf life were significantly increased with every increments of storage period at both storage condition and packaging materials.

However, mean value of firmness was significantly decreased as storage duration increased. It could be concluded that some physico-chemical properties include TSS and weight loss were significantly increased with the advancement of storage time whereas firmness and shelf life were decreased significantly. The papaya fruits which were stored at cool chamber have better quality and shelf life because this treatment can reduce the temperature by 10-15^{0}C of ambient temperature and maintain high relative humidity of above 90% throughout the storage time.

4.2 Recommendation

The result obtained from this research could be used as clue for further investigation. However, the study should be repeated over years to confirm the result and obtain the best combination of storage condition with proper postharvest management activities that give quality, disease free production of papaya. Recommended stand from our research activity people should store their papaya fruits in cool chamber and by used plastic crate which was increased the storage life reduce weight loss and help to maintain the quality of the fruit than to stored in at room temperature storage conditions. Further studies are required to study the assessment of different postharvest factor that affects the quality of papaya fruit.

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