Effect of Maturity and Storage Condition on Shelf Life and Post-Harvest Quality of Pineapple

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***Abstract*—** The objectives of the study were to assess the effects of various storage conditions and maturity stages of pineapple on its shelf life. Three storage conditions, viz., (a) control (60C, 85-90% RH), (b) cold storage without packaging (5-70c, 77-79% rh), (c) cold storage within porous cartoon (5-70C, 77-79% RH) were allocated to the pineapple fruits. There was significant variation between the three maturity stages, viz., (a) premature (b) 1/4th mature (c) 1/2th mature in relation to fruit characteristics. Among the physico-¬chemical parameters, some of parameters such as total weight loss, edible portion, pulp to peel ratio and total soluble solid (TSS) initially increased and then decreased gradually. On the other hand, pH and fungal incidence increased during the entire storage period. The premature fruits showed longer storage life (14.56 days) than 1/4th mature fruits (13.33 days) and 1/2th mature fruits (12.44 days). The longest shelf life (17.56 days) was observed in fruits stored within porous cartoon package at cold storage, whereas the minimum shelf life (9.78 days) was found in control fruits. The premature fruits, showed higher weight loss (22.43%), than other fruits. On the other hand, mature fruits showed higher edible portion (61.49%), TSS (16.33), pulp to peel ratio (1.607) and fungal incidence than other fruits. The storage conditions showed highly significant variation to influence shelf life of pineapple. Fruits stored within porous cartoon at cold storage (5-70C, 77-79% RH) may be used for extending shelf life of pineapple.

***Keywords*—** GMO detection, PCR, RNA, DNA, biotechnology, bio-engineering, molecular biology.

I. INTRODUCTION

Food Pineapple (*Ananas comosus* L. Merr.) is one of the most promising fruits in Bangladesh. It contributes to about 7.7% of the total fruit production in Bangladesh [1]. The area between 15°-30° south latitude and 40°-60° west longitude is considered to be the place of origin of pineapple [2]. It is believed that it was originated in southern Brazil and Paraguay. Pineapple is also widely cultivated in tropical and subtropical regions [3]. Pineapple is under the botanical family *Bromeliaceae*. The pineapples are separated from other genera of this family largely on the basis of syncarpous type of fruit which is not found in rest of the family [4]. The plant is usually perennial bushy herb with spiny leaves [5]. Each plant produces only one fruit during its life cycle [6]. Fruits are normally seedless and the ovules abort and only traces of them can be found in mature fruits [7]. The pineapple is a multiple fruit. The fruit is made up of 100 to 200 berries like fruitlets which are fused together on a central axis or core that is the continuation of the fibrous peduncle [8].

Pineapple cultivation is distributed from tropical to subtropical areas of the world. In Bangladesh, the total area under pineapple is about 5.33% of total area under fruits [9]. As a popular fruit, it is cultivated in an area of 39583 acres with a yield of 5.92 MT per acre in Bangladesh in 2010 [10]. Pineapple fruits contains 85% moisture, 13% sugar, 0.7% protein, 0.05% mineral, 0.3% fibre, 0.04% calcium, 0.011% phosphorus, 0.9% iron, 60 IU vitamin A, 120 mg/100g vitamin B2 and 63 mg/100 g vitamin C. The problems of pineapple production are delayed in flowering, irregular flowering and a short harvesting period [11]. It is reported that under optimal nutritional and environmental conditions, only 40-50% plants flower even after 15-18 months of growth (Bose, 1985). As a result, the land remains occupied by the remaining plants, which also flower irregularly in most cases, till harvesting of fruits [12]. The present research work was undertaken to study the effects of different maturity stage and storage condition on the shelf life of pineapple. The study involved postharvest application of storage condition and postharvest management of fruit, the objective being having reduced weight loss and longer shelf-life without sacrificing the quality of fruits during storage.

Taking the above considerations, the present investigation was undertaken to study:

1) the physico-chemical changes associated with maturity and ripening of pineapples;
2) the effects of different storage condition on shelf life and physicochemical changes during storage period;

3) to define a suitable maturity stage and an appropriate storage condition leading to extended shelf life of pineapple.

II. MATERIALS AND METHOD

The present investigation started initially in a pineapple plot in Modhupur Upazilla of Tangail District. Some observations on pineapple fruit have been taken in the field. Later on fruits harvested and brought to the quality control laboratory of Givensee Food and Essentials Ltd. for studies on storage behavior. Chemical analysis has been done in the quality control Laboratory of Givensee Food and Essentials Ltd.

A. Study Materials

The experimental materials were collected from Giant Kew variety cultivated in Madhupur, Tangail where pineapple is grown extensively. The farmer's plot was located at the village Chunia under Madhupur upazila in Tangial district. For the confirmation of maturity stages preliminary observations were made and finally fruits were collected at three different stages of maturity. The fruits were harvested in the forenoon, and same day transferred to the Quality Control Laboratory of Givensee Food and Essentials Ltd. During transportation adequate care was taken to prevent damages. The pineapples were placed in laboratory room (26-300C) and to the Cold storage (5-70C) for shelf life study.

B. Maturity Stages of Fruit

The pineapples were harvested at three distinct maturity stages which were as follows:

Premature: Pineapples just starting yellowing and flattening of the eyelets.

1/4th mature: Pineapples having 1/4th yellow color at the lower end and flat eyelets.

1/2th mature: Pineapples having 1/2th of flat eyelets with yellow color.

The average weight of these different mature Pineapples with crown was 1800g to 1900 g.

C. Determination of Maturity Stage

The maturity was detected based on the peel color, flatness of eyelets flowering date, and size of the pineapple. Though the maturity of pineapple is determined by its size and color, these are not the only indicators. For ensuring appropriate stage of Giant Kew, observation is done regularly after a period of flowering by observing their peel color, flatness of eyelets and uniformity of size. Three stages of fruit maturity were determined by observing peel color, flatness of eyelets of fruit. Premature fruits contain a few number of flat and yellow color eyelets, 1/4th mature fruits contain 1/4th flat and yellow color eyelets at the lower end of the fruits, 1/2th mature fruits contain 1/2th flat and yellow color eyelets at the lower end of the fruits. The maturity of Giant Kew was determined by the peel color and Flatness of eye.

D. Harvesting of Fruit

A total of 144 unblemished, more or less uniform sizes, shape and color fruits and free of visible disease symptoms were harvested manually. The fruits were cut off with a sharp knife keeping their crowns along with about 5 cm stalk with them.

The fruits were harvested separately in respect of their maturity stages. The fruits were loaded in a transport carefully, covered with straw and pineapple leaf to protect the fruits from direct sunlight and to reduce respiration rate. The fruits were then transferred to the Quality Control Laboratory of Givensee Food and Essentials Ltd. To avoid any mechanical injury, care was taken while harvesting, handling and transporting the fruits. Then the fruits were stored at different storage conditions (storage at ambient condition (26-300C), storage at cold storage at 5-70C without packaging, storage at cold storage at 5-70C in with Porous cartons packaging) within one day. The average maximum and minimum ambient temperature of the storage room receiving condition was 30 and 260C respectively. Relative humidity was from 85% to 90%. The average storage temperature of the cold storage room was 6 ± 10C. Relative humidity was from 77% to 79%.

E. Postharvest Treatments and Experimental Design

The experiment consists of two Factors as follows:

FACTOR A: Maturity stage of pineapple

Premature (M1): Pineapples just starting yellowing and flattening of the eyelets at lower end.

1/4th mature (M2): Pineapples having 1/4th of flat eyelets with yellow color at the lower end.

1/2th mature (M3): Pineapples having 1/2th of flat eyelets with yellow color.

FACTOR B: Storage Condition

Control (T0): Storage at ambient condition (26-300C temperature & 85%-90% RH).

Cold Storage without packaging (T1): Cold storage (5-70C temperature & 77%-79% RH) without packaging.

Cold Storage within Porous cartoon (T2): Cold storage (5-70C temperature & 77%-79% RH) within Porous carton package.

Experimental Design: There were 9 (3 X 3) treatments combinations. The combinations were as follows:

Maturity stage	Storage conditions		
	Control (T0)	Cold storage without packaging (T1)	Cold storage within Porous cartoon(T2)
Premature (M1)	M1T0	M1T1	M1T2

1/4th mature (M2)	M2T0	M2T1	M2T2
1/2th mature (M3)	M3T0	M3T1	M3T2

F. Details of Treatments

The levels of maturity stages of pineapples (premature, 1/4th mature and 1/2th mature) were maintained as per details presented in 3.2 and 3.3. The applied storage condition were as follows:

T0: Pineapples of different maturity stages were stored in a room at ambient temperature (26-300C temperature & 85%-90% RH) without packaging.

T1: Pineapples of different maturity stages were stored in a cold storage at 5- 70C temperature and 77%-79% relative humidity without any packaging.

T2: Pineapples of different maturity stages were stored in a cold storage at 5- 70C temperature and 77%-79% relative humidity within porous carton packaging.

F. Application of Post-Harvest Treatment

T0 (control): Fifteen pineapples of each maturity selected randomly from fruit lot were placed upon polyethylene in the QC laboratory room at ambient temperature.

T1 (Fruits were stored in a cold storage at 5-70C): Individual pineapple of different maturity stages with crown was kept upon a polyethylene vertically thus crown remain at down and stalk at up. The temperature of cold storage was maintained near at 5-70C and relative humidity at 77%-79%.

T2 (Fruits were stored within porous cartons in a cold storage at 5-70C): Individual pineapple of different maturity stages with crown was kept within a porous paper carton vertically thus crown remain at down and stalk at up. The temperature of cold storage was maintained near at 5-70C and relative humidity at 77%-79%.

G. Collection of Data

To assess the effects of different maturity stage and storage condition on the storage behavior and shelf life of pineapple (Giant Kew), the data on different physical and chemical parameters were collected during the storage period at 5 days interval. The changes in color and shelf life have been studied during the entire storage period.

H. Parameter Studied

The following physical and chemical parameters were recorded

- External fruit characteristics (color)
- Total weight loss of fruit (%)
- Edible portion of fruit (%)
- Pulp to peel ratio
- TSS content of fruit pulp
- PH of fruit pulp
- Shelf life of fruit
- Percent of fungal incidence

I. Methods of Studying Different Parameter

a. External Fruit Characteristics

External fruit characteristics such as peel color were recorded just after harvesting the Pineapple. Changes in peel color were recorded during storage by using following eleven color grades:

Trace yellow at lower end
90% eye green, 10% eye yellow
80% eye green, 20% eye yellow
75% eye green, 25% eye yellow
70% eye green, 30% eye yellow
60% eye green, 40% eye yellow
50% eye green, 50% eye yellow
40% eye green, 60% eye yellow
30% eye yellow, 70% eye green
25% eye yellow, 75% eye green
20% eye green, 80% eye yellow
10% eye green, 90% eye yellow
Entire surface yellow
Entire surface yellow with black spot
Discarded earlier

b. Percent Weight Loss of Fruit

Initially the pineapples with crown of each maturity out of each replication were weighed using an electrical balance and kept for storage at different condition. Weight loss was obtained by the following formula:

$$\text{Percent weight loss (\% WL)} = \frac{IW-FW}{IW} x100$$

Where,

% WL= Percent weight loss

IW= Initial with crown and

FW = Final weight of fruit with crown.

The weight loss of the same pineapple was recorded periodically during the storage of period.

c. Edible Portion of Fruit

Total weight of pineapple without crown was weighted by using an electrical balance and then the pineapple was peeled by sharp knife. Central core was detached and then remaining fruit pulp was weighed. Edible portion was obtained by the following formula:

$$\text{Percent edible portion of fruit} = \frac{\text{weight of pulp(edible portion)}}{\text{Total weight of fruit}} \text{x}100$$

Similarly, other criteria were obtained by following proper steps. For example, pulp to peel ratio was measured with the following formula:

$$\text{Pulp to peel ratio} = \frac{Weight\ of\ fruit\ pulp}{Weight\ of\ fruit\ peel}$$

Total soluble solid (TSS) content was obtained by Abbe refractometer. The pH meter was used for obtaining pH. The shelf life was calculated by counting the days required to attain last stage of ripening. The fungal incidence of fruit rot was determined as follow.

$$\text{Percent fungal incidence} = \frac{\text{Number of infected fruit}}{\text{Total number fruit under study}} \text{x}100$$

J. Statistical Analysis

F-variance test was applied to explore variation. Descriptive statistics was also done to present various characteristics of the experiment.

III. RESULTS AND DISCUSSION

A. External Fruit Characteristics

External feature of pineapple such as peel color is one of the most important qualitative attributes in consideration of changes in peel color, development of spots on peel and softening and rottening of pineapple occurred during the time of storage. The rate of color change was different among treatments. De-greening of fruits depends on several factors, which are responsible for the degradation of chlorophyll structure. These factors are pH changes, oxidative systems and chlorophylases. Further, de-greening of pineapple is temperature dependent and delays at low temperature. The result showed that peel color changes, softening and rottening occurred influenced by maturity stages and storage conditions in Table 1. Three type of mature pineapples were harvested by observing peel color, flatness of eyelets of fruit. Premature pineapplesa contain a few numbers of yellow color eyelets, 1/4th mature pineapples contain 1/4th yellow color eyelets at the lower end of the pineapples, 1/2th mature pineapples contain 1/2th yellow color eyelets of the pineapples.

The changes in external physical characteristics of pineapple at three maturity stages under different storage conditions. Pineapples stored within porous cartoon at cold storage had remarkable effect on external color of pineapple, probably due to less moisture loss from them. At 7th day of storage, it was observed that pineapples stored at ambient condition, without packaging at cold storage, within porous cartoon packaging at cold storage retained green color 25%, 50% and 75% respectively in premature fruits. Whereas at the same time entire surface of pineapple become yellow in 1/4th mature pineapple at ambient condition, 25% and 50% of surface of 1/4th mature pineapple retained green color stored without packaging at cold storage and within porous cartoon packaging at cold storage respectively [13]. Entire surface of 1/2th mature pineapple become yellow at 7th day of storage stored at ambient condition, without packaging at cold storage 10% and retained 25% eye green within porous cartoon packaging at cold storage [14]. At 14th day of storage, it was observed that pineapples stored within porous cartoon packaging at cold storage showed green color 10% of premature pineapple, entire surface became yellow of 1/4th and 1/2th mature pineapple. Storage within porous cartoon at cold storage is effective compared with other treatments for retaining green color and storability of pineapple [15].

Table 1. Effects of maturity and storage condition (peel colour)

Days of storage	Maturity stage	Storage condition		
		Control (To)	Cold storage without packaging (T1)	Cold storage within porous cartoon (T2)
0	(M1)	Trace yellow at lower end	Trace yellow at lower end	Trace yellow at lower end
	(M2)	75% eye green, 25% eye yellow	75% eye green,25 % eye yellow	75% eye green,25 % eye yellow
	(M3)	50% eye green, 50% eye yellow	50% eye green, 50% eye yellow	50% eye green, 50% eye yellow
4	(M1)	75% eye green, 15% eye yellow	85% eye green, 15% eye yellow	85% eye green, 15% eye yellow
	(M2)	50% eye green, 50% eye yellow	60% eye green, 20% eye yellow	60% eye green, 40% eye yellow
	(M3)	20% eye green, 80% eye yellow	30% eye green, 70% eye yellow	40% eye green, 60% eye yellow
7	(M1)	25% eye green, 75% eye yellow	50% eye green, 50% eye yellow	75% eye green, 25% eye yellow
	(M2)	Entire surface yellow	25% eye green,75 % eye yellow	50% eye green, 50% eye yellow

	(M3)	Entire surface yellow	10% eye green,90 % eye yellow	25% eye green,75 % eye yellow
9	(M1)	10% eye green, 90% eye yellow	25% eye green, 75% eye yellow	60% eye green, 40% eye yellow
	(M2)	Entire surface yellow	10% eye green,90 % eye yellow	40% eye green, 60% eye yellow
	(M3)	Discarded earlier	Entire surface yellow	10% eye green,90 % eye yellow
10	(M1)	Entire surface yellow	10% eye green,90 % eye yellow	50% eye green, 50% eye yellow
	(M2)	Discarded earlier	Entire surface yellow	30% eye green, 70% eye yellow
	(M3)	Entire surface yellow	Entire surface yellow	Entire surface yellow
11	(M1)	Entire surface yellow	Entire surface yellow	40% eye green, 60% eye yellow
	(M2)	Entire surface yellow	Entire surface yellow	20% eye green, 80% eye yellow
	(M3)	Entire surface yellow	Entire surface yellow	Entire surface yellow
12	(M1)	Discarded earlier	Entire surface yellow	30% eye green, 70% eye yellow
	(M2)	Discarded earlier	Entire surface yellow	10% eye green, 90% eye yellow
	(M3)	Discarded earlier	Entire surface yellow with black spot	Entire surface yellow
13	(M1)	Discarded earlier	same	20% eye green, 80% eye yellow
	(M2)	Discarded earlier	same	10% eye green, 90% eye yellow
	(M3)	Discarded earlier	Discarded earlier	Entire surface yellow
14	(M1)	Discarded earlier	Entire surface yellow with black spot	10% eye green, 90% eye yellow
	(M2)	Discarded earlier	same	Entire surface yellow
	(M3)	Discarded earlier	same	Entire surface yellow
15	(M1)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M2)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M3)	Discarded earlier	Discarded earlier	Entire surface yellow
16	(M1)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M2)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M3)	Discarded earlier	Discarded earlier	Entire surface yellow
17	(M1)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M2)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M3)	Discarded earlier	Discarded earlier	Entire surface yellow with black spot

18	(M1)	Discarded earlier	Discarded earlier	Entire surface yellow
	(M2)	Discarded earlier	Discarded earlier	Entire surface yellow with black spot
	(M3)	Discarded earlier	Discarded earlier	Same
19	(M1)	Discarded earlier	Discarded earlier	Same
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier
20	(M1)	Discarded earlier	Discarded earlier	Discarded earlier
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier
21	(M1)	Discarded earlier	Discarded earlier	Discarded earlier
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier
22	(M1)	Discarded earlier	Discarded earlier	Discarded earlier
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier
23	(M1)	Discarded earlier	Discarded earlier	Discarded earlier
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier
24	(M1)	Discarded earlier	Discarded earlier	Discarded earlier
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier
25	(M1)	Discarded earlier	Discarded earlier	Discarded earlier
	(M2)	Discarded earlier	Discarded earlier	Discarded earlier
	(M3)	Discarded earlier	Discarded earlier	Discarded earlier

M1: Premature fruit, M2:1/4th mature fruit, M3:1/2th mature fruit;

T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.

B. Total Weight Loss of Fruit

Maturity stage, storage condition and their combinations had significant effects on weight [16]. Different storage conditions had pronounced effects on total weight loss of pineapple. At 5th day of storage minimum weight loss was observed in pineapple stored within porous cartoon package at cold storage (7.65%, 3.53% & 2.63% respectively in premature, 1/4th mature and 1/2th mature pineapple). The rate of higher weight loss of pineapple was recorded at ambient storage condition (Table 2).

The combined effect of storage condition and maturity showed highly significant variation during storage period. Weight loss of pineapple (26.06%) was recorded highest on 25th day, in premature pineapples in control condition, while it was lowest (12.77%) at 25th days of storage in 1/2th mature pineapples those were stored within porous cartoon package at cold storage [17]. During storage period 1/2th mature pineapple stored within porous carton at cold storage shows lower weight loss (2.63% at 5th day to 12.77% at 25th day) due to physical barrier like porous paper carton package and low temperature [13].

The decrease in fruit weight may be attributed to both water losses through transpiration and substrate loss by respiration [18]. Minimum weight loss appeared to be inhibited by storage within porous cartoon packages at cold storage.

Table 2. Effects of maturity and storage condition on weight loss (%) of pineapple.

Maturity stage X Storage condition		Weight loss (%)				
		Days of storage				
		5	10	15	20	25
M1	T0	13.25	16.67	19.85	22.28	26.06
	T1	11.41	13.64	15.50	21.07	24.54
	T2	7.65	8.78	10.00	12.60	16.70
M2	T0	7.88	11.49	15.77	20.00	23.81
	T1	3.60	8.65	12.27	15.51	17.55
	T2	3.53	5.42	7.17	10.45	13.13
M3	T0	6.64	10.23	13.73	18.22	23.11
	T1	3.01	5.73	8.00	11.31	16.55
	T2	2.63	4.46	6.11	10.21	12.77

M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit;

T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.

C. Edible Portion of Fruit

Pineapple of different maturity stage contains different edible portion at initial and also varies during storage period. 1/2th mature pineapple contain the highest (58.53%) edible portion than 1/4th mature (57.41%) and premature pineapple (55.60%) at the harvesting day. The increase in edible portion of two maturity stages (1/4th and 1/2th mature) was rapid up to 15th day of storage then decreased while it was slow for premature pineapples (Table 3).

The effect of storage conditions had also affected on edible part. At the 15th day of storage, the highest (62.21%) edible portion was recorded in premature pineapple stored within porous cartoon package at cold storage while the lowest (60.41%) in control fruits (Table 3). The edible portion of pineapples stored at cold storage without packaging and within porous carton packages was enhanced up to 15th day then reduced while it was increasing up to 10th day of storage for pineapples stored at ambient condition after that it decreases with day of storage [19].

The lowest (59.51%) was recorded in pineapple stored within porous cartoon package at cold storage (Table 3). Edible portion of pineapple increases up to 15th day in pineapples stored at cold storage without packaging and after that it decreases rapidly due to spoilage [20]. The interaction effect was significant at 10th day on the edible portion of fruit daring storage.

Table 3. Effects of maturity and storage condition on changes in edible portion (%)

Maturity stage x Storage condition		Edible portion (%)				
		Days of storage				
		5	10	15	20	25
M1	T0	59.7	61.5	60.77	59.98	50.46
	T1	58.1	61.2	61.10	60.29	51.34
	T2	58.6	59.5	62.21	60.11	52.23
M2	T0	61.0	61.4	60.45	58.09	44.23
	T1	60.0	60.0	61.58	59.40	46.29
	T2	57.8	60.9	61.97	61.28	46.32
M3	T0	60.9	62.1	60.41	58.97	41.42
	T1	59.8	61.6	62.03	58.99	43.21
	T2	58.8	60.3	62.02	60.16	44.54

Note: M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit; T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.

Z: Initial value of 1/2th mature

D. Pulp to Peel Ratio

Pulp to peel ratio determines the presence of edible and non-edible portion of the fruit. Pulp to peel ratio had no significant effect among the different maturity stages. It was observed that initially after harvesting of pineapples the highest (1.411) pulp to peel ratio was found in 1/2th mature followed by pulp to peel ratio (1.348) in 1/4th mature pineapple and the lowest (1.256) in premature pineapples [21]. Different storage conditions significantly influenced pulp to peel ratio of fruits during storage. Highest pulp to peel ratio (1.565) at 5th day was recorded in premature pineapples under control, at 10th days it was observed that pineapples of different maturity stages showed higher pulp to peel ratio under control, but at 15th days it was higher in pineapples stored within porous cartoon package at cold storage. Pulp to peel ratio was increased up to certain days of storage and then declined for each storage conditions. Pulp to peel ratio of premature pineapples stored within porous carton packages shows higher pulp to peel ratio (1.64) at 15th day of storage and finally it was lowest (0.71) in 1/2th mature pineapples stored at ambient condition [22]. The pulp increase in weight due to an increase in water content. This water is obtained from the peel and probably also from the stalk. This causes weight loss in peel with concomitant rise in pulp to peel ratio. According to ANOVA, the interaction effect of pulp peel ratio was not significant. The increase of pulp to peel ratio may be due to two factors (Table 4).

Table 4. Effects of maturity and storage condition on changes in pulp to peel ratio of pineapple

Maturity stage x Storage condition		Pulp to peel ratio				
		Days of storage				
		5	10	15	20	25
M1	T0	1.48	1.60	1.53	1.49	1.02
	T1	1.39	1.58	1.61	1.52	1.05
	T2	1.42	1.49	1.64	1.54	1.09
M2	T0	1.56	1.64	1.53	1.48	0.79
	T1	1.38	1.504	1.60	1.46	0.86
	T2	1.375	1.56	1.63	1.592	0.86
M3	T0	1.56	1.64	1.52	1.44	0.71
	T1	1.48	1.63	1.51	1.47	0.761
	T2	1.43	1.52	1.63	1.55	0.803

M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit;
T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.
Z: Initial value of 1/2th mature.

E. Total Soluble Solid (TSS) Content of Fruit Pulp

Storage conditions were found to have significant effects on changes in TSS content of fruit juice during storage at 15th and 25th day of storage. The lowest TSS was recorded in pineapples stored within porous cartoon package at cold storage up to 15th day of storage and highest TSS was recorded in fruits stored at ambient condition, but after 15th day of storage it was higher in pineapples stored within porous cartoon package at cold storage and lower in pineapples stored at ambient condition [23]. Lower TSS (15.67%) was observed in premature and 1/2th mature pineapples stored at ambient storage condition at 25th day (Table 5).

TSS in fruit pulp was influenced significantly by the combined effect of maturity stages and postharvest treatments during the storage period. At 15th day of storage the highest TSS (16.67%) was recorded in 1/2th mature pineapples under control, while it, was minimum (15.67%) in premature pineapples stored without packaging at cold storage (Table 5). The interaction effect showed statistically significant differences on the change in TSS content during storage at 5th and 20th day. Increase in TSS content may be due to increase in soluble sugar, soluble pectin and soluble organic acid etc. Increasing the content of total sugar with the progress up to certain period of storage and there after declined. The initial Sugars increase up to 10 days may be due to hydrolysis of starch in to sugars, while the decline later may be attributed to utilization of sugar for respiration [24]. The apparent rise in sugar may be attributed to the loss of moisture from the fruits during storage [25].

Table 5. Effects of maturity and storage condition on changes in Total Soluble Solid (TSS)

Maturity stage x Storage condition		Total Soluble Solid (TSS)				
		Days of storage				
		5	10	15	20	25
M1	T0	14	15.33	16.00	16.00	15.67
	T1	14	15.33	16.00	16.33	16.00
	T2	14	15.00	15.67	16.33	16.00
M2	T0	15	15.67	16.33	16.67	16.00
	T1	15	15.33	15.67	16.00	15.67
	T2	15	15.33	15.67	16.00	16.00
M3	T0	16	16.33	16.67	16.00	15.67
	T1	16	16.67	16.00	16.00	15.67
	T2	16	16.00	16.33	16.33	16.00

M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit;
T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.
Z: Initial value of 1/2th mature

F. pH of Fruit Pulp

Initially lower pH (3.767) was recorded in premature pineapple, 3.833 in 1/4th mature pineapple and it was higher pH (3.867) in 1/2th mature pineapple. Pineapple juice has 3.8 pH value. pH indicates indirectly acidity of fruit, which increases with days of storage. At 25th day of storage higher pH were recorded in 1/2th mature pineapples, which followed by 1/4th mature pineapples and the lower pH value were recorded in premature pineapples (Table 6).

Storage conditions affected on changes in pH of pineapple juice [26]. At 5th day of storage lower pH (3.833) was recorded in premature pineapples stored within porous cartoon package at cold storage, it was higher pH (3.967) in 1/2th mature pineapples stored at ambient condition. The effect of storage condition showed that pH increases with days of storage [27]. Pineapples stored at ambient condition shows wide range of pH change, 3.767 at harvesting day to 4.1 at 25th day of storage in premature pineapples, 3.833 at harvesting day to 4.133 at 25th day of storage in 1/4th mature pineapples and 3.867 at harvesting day to 4.167 at 25th day of storage in 1/2th mature pineapples [28].

pH in pineapple pulp was not influenced significantly and postharvest treatments during the storage period [29]. At 25th day of storage lower pH (4.067) was observed in premature and 1/4th mature pineapples stored within porous cartoon package at cold storage, and higher pH was recorded in 1/2th mature fruits stored at ambient condition (Table 6). During storage period pH of pineapple of all maturity under all storage conditions increased with increase of storage time [30]. The interaction effect showed statistically not significant differences on the change in TSS content during storage.

Table 6. Effects of maturity and storage condition on changes in pH of pulp of pineapple during storage.

Maturity stage X Storage condition		pH of fruit pulp				
		Days of storage				
		5	10	15	20	25
M1	T0	3.83	3.933	4.00	4.06	4.10
	T1	3.86	3.90	3.967	4.03	4.06
	T2	3.83	3.86	3.933	4.00	4.06
M2	T0	3.90	3.967	4.00	4.06	4.13
	T1	3.86	3.93	4.00	4.03	4.10
	T2	3.86	3.90	3.967	4.03	4.06

M3	T0	3.96	4.03	4.067	4.10	4.16
	T1	3.96	4.00	4.033	4.067	4.13
	T2	3.90	3.93	3.967	4.03	4.10

M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit;

T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.

Z: Initial value of 1/2th mature

G. Postharvest Fungal Incidence

Symptoms of fruit soft rot disease of pineapple during storage was found to begin as scattered spots on the outer surface of the pineapples. The spots enlarged and coalesced which caused damage in a large portion of fruit. At later stage, white cottony fungal mycelia developed on the fruit surface. Sometimes the surface of the pineapples turned deep brown with numerous black dots. Gradually whole fruit were black rotted [31]. Fleshes were blackened and unfit for consumption. There had significant variation regarding the fungal incidence among different maturity stages under different storage conditions [32]. At 5th day, the top fungal incidence was in 1/2th mature pineapples which was enhanced to (100%) at 25th day of storage. The lowest fungal incidence was in premature pineapples at 5th day of storage which was gradually increased up to (100%) at 25th day of storage (Table 7).

In storage period of pineapple, fruits are infected by Ceratocystis paradoxes, Penicillium sp. and bacteria and the following diseases are developed soft rot, heart rot, and bacterial rot etc. These diseases developed rapidly at ripening but did not occur in fruit picked green [33]. There was no infection up to 5 days after storage in pineapples stored within porous cartoon package at cold storage, fungal incidence in pineapples stored without packaging at cold storage was higher than pineapples stored within porous cartoon package at cold storage, [34] and highest in fruits at ambient condition at any day of storage (Table 7). At 20th day of storage the highest (100%) fungal incidence was observed in control condition, while the lowest (50%) was observed in pineapples stored within porous cartoon package at cold storage (Table 7). The rate of increase in fungal incidence is higher in pineapples stored at ambient condition, which is lowest in pineapples store within porous carton at cold storage [14].

The joint effect of stage in relation to fungal incidence of pineapple was significant during the storage period [9]. At 15th day of storage the highest (100%) fungal incidence was observed in 1/2th mature pineapples under control treatment, premature fruits stored within porous cartoon package at cold storage were observed the minimum fungal incidence (0%). At 20th day, premature pineapples fungal incidence was lowest (50%) at cold storage stored within porous cartoon package (Table 7). Analysis of variance showed that interaction effect was not significant in this respect [35].

Table 7. Effects of maturity and storage condition on fungal incidence (%) of pineapple

Maturity stage X Storage condition		Fungal incidence (%) Days of storage					Shelf Life (Days)
		5	10	15	20	25	
M1	T0	16.67	44.44	77.77	100	100	11.33
	T1	8.33	22.22	44.44	83.33	100	13.67
	T2	0	0	0	50.0	100	18.67
M2	T0	25	50	88.88	100	100	9.67
	T1	16.67	33.33	55.55	100	100	13
	T2	0	0	11.11	66.67	100	17.33
M3	T0	33.33	66.67	100	100	100	8.33
	T1	25	33.33	66.67	100	100	12.33
	T2	0	8.33	22.22	83.33	100	16.67

M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit;

T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.

H. Shelf Life of Fruit

Longer shelf life was recorded for premature pineapples than 1/4th mature and 1/2th mature pineapples under all the storage condition (Figure 1). Storage conditions also showed a significant effect on pineapple's shelf life [36]. The longest shelf life was observed in pineapples stored within porous cartoon package at cold storage, followed by fruits stored without packaging at cold storage whereas shortest shelf life was recorded in control condition for all type of maturity [4]. There was a significant variation among the treatment combinations in the shelf life of pineapple. Higher shelf life (18.67 days) was observed in premature fruits stored within porous cartoon package at cold storage, while it was lower (8.33 days) in 1/2th mature fruits under the control.

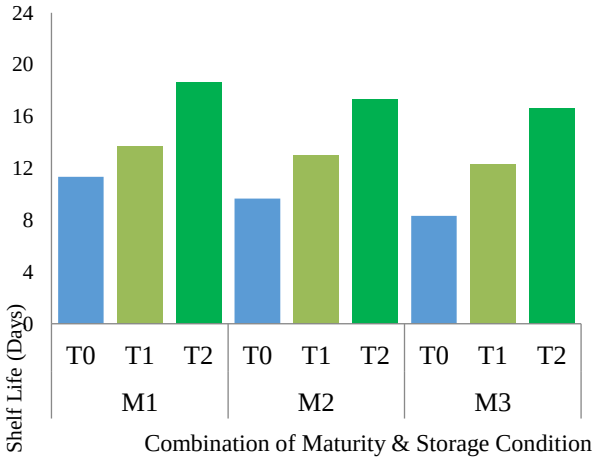

Figure 1. Effects of maturity and storage condition on shelf life of pineapple during storage.

M1: Premature fruit, M2: 1/4th mature fruit, M3: 1/2th mature fruit;
T0: Control, T1: Cold Storage without packaging, T2: Cold Storage within Porous cartoon.

IV. CONCLUSIONS

The fruits of three maturity stages were assigned to three different storage conditions. Observations on color, pulp to peel ratio, total weight loss, edible portion, pH, total soluble solids, fungal incidence and shelf life were made. Both the maturity stage of fruit and storage condition showed noticeable influence on color change of fruit during the storage period. The fruit stored in cold storage within porous cartoon retained green color up to 14 days of storage, and it was more distinctive than other storage conditions. At 14th day of storage entire surface of 1/4th mature pineapple and at 10th day of storage entire surface of 1/2th mature pineapple became yellow. Storage within porous cartoon at cold storage is effective compared with other treatments for retaining green color and storability of pineapple.

Significant variation in total weight loss between the three different maturity stages was observed. The higher weight loss was recorded in the premature fruits, followed by 1/4th mature fruits, while it was lower in the 1/2th mature fruits at 25th day of storage at every storage condition. 1/2th mature pineapples stored within porous cartoon at cold storage showed lower weight loss (2.63%, 4.46%, 6.11%, 10.21% and 12.77% at 5th, 10th, 15th, 20th, 25th day of storage respectfully).

Premature pineapple contains (55.60%) edible portion, 1/4th mature pineapple contains (57.41%) and the 1/2th mature pineapple (58.53%). The edible portion of pineapples stored at cold storage without packaging and within porous carton packages was increased up to 15th day of storage then decreased while it was increasing up to 10th day of storage for pineapples stored at ambient condition. The highest edible portion (62.21%) was recorded in premature fruits stored in cold storage within porous cartoon at 15th day of storage. Pulp to peel ratio of premature pineapples stored within porous carton packages shows higher pulp to peel ratio (1.64) at 15th day of storage and finally it was lowest(0.71) in 1/2th mature pineapples stored at ambient condition.

After harvesting 1/2th mature pineapples contained higher TSS (15.33%), 1/4th mature pineapple contained 14.67% when it was lowest (13.33%) in immature pineapples. At 15th day, the highest TSS (16.67%) was recorded in 1/2th mature pineapples under control, while it, was minimum (15.67%) in premature pineapples stored without packaging at cold storage TSS increases with day of storage gradually and after certain period it starts to decrease.

The pH of fruit pulp was showed significant effect in different maturity stages of fruits. Initially lower pH (3.767) was recorded in premature pineapple, 3.833 in 1/4th mature pineapple and it was higher pH (3.867) in 1/2th mature pineapple. The effect of storage condition showed that pH increases with days of storage. Pineapples stored at ambient condition shows wide range of pH change, 3.767 at harvesting day to 4.1 at 25th day of storage in premature pineapples, 3.833 at harvesting day to 4.133 at 25th day of storage in 1/4th mature pineapples and 3.867 at harvesting day to 4.167. At 25th day of storage and the lower pH (4.067) was recorded in premature and 1/4th mature pineapples stored within porous cartoon package at cold storage.

There was significant variation regarding the fungal incidence among different maturity stages under different storage conditions. At 5th day of storage, the higher fungal incidence (33.33%) was recorded in 1/2th mature fruits stored at ambient condition which was increased up to (100%) at 15th day of storage. The lowest disease incidence at 5th day at ambient condition (8.33%) was observed in premature fruits, which was gradually increased up to (100%) at 20th day of storage. There was no infection up to 5 days after storage in fruits stored within porous cartoon package at cold storage.

The shelf life of pineapple significantly varied between three different maturity stages. 1/2th mature pineapples were better for consumption but they were perishable, exhibited a short storage life on the other hand premature pineapples contained the minimum quality attributes but they showed longer storage life. The longest shelf life (18.67 days) was recorded in premature pineapples stored in cold storage within porous cartoon, whereas lowest shelf life (8.33 days) in 1/2th mature pineapples under control.

From the stated findings it is indicated that the edible portion, pulp to peel ratio, TSS of fruit increased initially during the storage, but declined after a certain period of storage while total weight loss, pH of pineapples increased throughout the storage. Among the storage conditions storage within porous cartoon at cold storage was found to be the best for retention of weight loss, edible portion of pineapple during storage. The treatment storage within porous cartoon at cold storage appeared to be suitable for maintaining higher shelf life, less fungal incidence as well as better quality of pineapple. The following suggestions may be considered for further studies:

- Investigation may be done on changes in respiration and ethylene production under definite storage condition.

- Other traditional techniques for storage needed to be studied thoroughly particularly in respect of efficiency and cost effectiveness.

Detail study may be conducted with treatments like, cold storage and porous packing in relation to microbial decay and storability of pineapple.

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