EPRA International Journal of Agriculture and Rural Economic Research (ARER)- Peer-Reviewed Journal
Volume: 10 | Issue: 6| June 2022 | Journal DOI: 10.36713/epra0813| Impact Factor SJIF (2021) : 7.604| ISSN: 2321 - 7847

POSTHARVEST PERFORMANCE OF STRAWBERRY (*Fragaria ananassa* Duchesne) USING DIFFERENT STORAGE CONDITION and PACKAGING MATERIALS

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ABSTRACT
Strawberry is a popular fruit crop in many countries worldwide due to its refreshing and delicious taste besides being a rich source of vitamins and minerals. Taking the benefits derived from this fruit, this study was conducted to evaluate the following aspects.

Physical characteristics of the fruit which includes weight loss, visual quality rating, degree of shrivelling, decay incidence and sensory firmness clearly showed that refrigerated storage lengthened postharvest life of strawberry fruits to fourfold than when stored at ambient condition.

Chemical characteristics also showed higher values of Total Soluble Solids (TSS) in the refrigerated storage than in the ambient condition where temperature is higher. The reverse was true with titratable acidity (TA) which was higher at ambient condition. The different packaging materials did not manifest any effect on both postharvest physical and chemical attributes of strawberry except for styrofor box which showed the highest TSS.

INTRODUCTION

Nature and Importance of the Study

The cultivated strawberry, (*Fragaria ananassa* Duchesne), is a member of the family *Rosaceae*, subfamily *Rosoideae*, along with blackberries and raspberries. It is a low herbaceous perennial with edible red fruits, native to temperate and mountainous tropical regions. There are three types of everbearer: *Long-day* where lengthening days promote more-or-less continuous flowering throughout the summer, provided temperature is not more than thirty (30) degrees Celsius. *Short day* where flowering occurs in short day less than 24 hours cycle. *Day-neutrals* where photoperiod has no effect on flowering and flower several times per year, but would do so in short as well as long days.

Strawberry plants have dark green, trifoliate leaves and white, five-petal flowers with a yellow center. There is also a variety with pink flowers. Strawberry cultivars are classified as 'June-bearing' meaning they have one main crop of fruit in early summer, convenient for those who wish to make preserves, or 'ever-bearing,' which bear smaller quantities of fruit over a longer period. A related plant, wild strawberry, has tiny, sweet fruits and bears continuously.

Strawberry is a very popular fruit. Fruits are usually consumed fresh but in addition strawberries can be frozen, made into preserves, as well as dried and used in prepared foods, such as cereal bars. Strawberries and strawberry flavorings are a popular addition to dairy products, such as strawberry-flavored milk, strawberry ice cream, strawberry milkshakes, strawberry smoothies and strawberry yogurts.

Strawberries are one of the most perishable fruit crops and are essentially fully ripe at harvest. They have a high rate of metabolism and will destroy themselves in a relatively short time, even without the presence of decay-causing pathogens (DeEll 2006). It is therefore necessary that proper packaging must be established.

The popularity and importance of strawberry as well as the interest of increasing its production constitute a challenge to researchers to come up with some appropriate means to increase its production. In addition, being a highly perishable crop, that is, having a relatively short shelf life of 5-7 days after harvest necessitates proper postharvest handling particularly storage and packaging. In view of the foregoing considerations, conducting research work in line with improved strawberry production and postharvest handling practices is deemed necessary.

This study aims to ascertain the postharvest performance of strawberry as affected by storage condition and packaging materials.

MATERIALS AND METHODS

Experimental Design and Treatments

Completely Randomized Design (CRD) in factorial arrangement (two factors) was used in this study with three replications. The treatments were as follows:

Factor A: Storage Condition

S1 - Ambient Condition (18 °C – 23 °C)
S2 - Refrigerated Condition (5 °C– 10 °C)

Factor B: Packaging Materials

P0 - Control (open)
P1- Styrofor box - (MP small styrofor box 4x4 inches)
P2 - Styrofor tray with Cling Wrap – (MP small styrofor tray 4x4 inches)
P3 - Polypropylene Box – (1B 4x4 inches)
P4 - Polypropylene Cellophane - (6 x 10 inches 0.002mm)

Preparation of Packaging Materials

Clean packaging materials were used in the study according to the treatments. There were 10 sample fruits per treatment of the study. For Po- strawberry fruits were placed in open styro tray ,P1 - with the used of small styro box, P2- strawberry fruits were placed in styrofor tray and covered with cling wrap, P3- strawberry fruits were placed inside the polypropylene box. While P4- strawberry fruits were placed inside perforated polypropylene cellophane and sealed with electronic sealer.

Description of Storage Area

For ambient conditions, the packed fruits were stored on top of a table inside a room with 18–23 ^{o}C temperature at 85% - 90% relative humidity. For the refrigerated condition, all packed fruits were stored inside a 10 cu.ft. refrigerator with at least 10 ^{o}C temperature.

Data Gathered

1. Weight loss (%) - The initial weight of fruits per treatment and the weight of the fruits were monitored daily. There were 10 strawberry fruits samples and the percentage of weight loss was computed using the formula:

$$\%\ \text{weight loss} = \frac{\text{Initial weight} - \text{weight at date of observation}}{\text{Initial weight}} \times 100$$

2. Degree of Shrivelling - The degree of shrivelling of each fruit was assessed daily using the following shrivelling index (SI).

SI	DESCRIPTION
1	Firm (unshriveled)
2	Slight (10 - 20% of the fruit surface area showed Symptoms of shriveling)
4	Moderate (21-40% of the fruit surface area was shriveled)
4	Severe (41 - 60% of the fruit surface area was shriveled)
5	Totally Shriveled, non-edible (60% fruit surface area was shriveled)

3. Visual Quality Rating (VQR) - The physical appearance of the fruits were assessed daily using the following rating scale:

VQR		DESCRIPTION
9	-	Fresh, excellent, no deteriorative changes, less than 10% of the fruit surface shows symptoms of deterioration
5	-	Fair, 11-40% of the fruit surface shows symptoms of deterioration
3	-	Poor, 41-70% of the fruit surface shows symptoms of deterioration, Low market value

1 - unusable, more than 70% of the fruit surface shows symptoms of deterioration. Unmarketable.

4. Decay incidence - Disease infection of each fruit was assessed daily using the following index.

DI	DESCRIPTION
1	Good Quality; No infection
2	Slight (10 - 20% of the fruit surface area was infected/damage)
3	Moderate (21-40% of the fruit surface area was infected/damage)
4	Severe (41 - 60% of the fruit surface area was infected/damage)
5	Non – edible (60% of the fruit surface area was Infected/damage)

5. Sensory firmness - The firmness of each fruit sample was determined by "finger feel" method by touching the individual fruit using the following sensory firmness index during termination of the study.

SFI		DESCRIPTION
1	-	Firm
2	-	Slightly soft
3	-	Moderately Soft
4	-	Very soft, almost rotten
5	-	Rotten

6. Total Soluble Solids (TSS) – juice from the fruit samples at termination were extracted and the TSS was determined using hand refractometer. Data gathered during termination of the study. Fruits samples were coming from the treatments terminated.
7. Titratable Acidity (TA) – was measured during the termination of the study. This was done following the procedure; Twenty (20) grams of sample strawberry fruits was weighed and then add it with 50 ml. of distilled water, then mixed/ macerated using (mortar and pestle) for 15 minutes until color became consistent. The mixture was filtered using funnel and fine cloth and the extracted strawberry juice was added with another 200 ml. of distilled water. Fifty (50 ml) from 200 ml. mixture was added with 1-2 drops phenolpthaline indicator solution and mix properly. Titration was then done using standardized 0.1 N NaOH. TA was computed using the formula:

$$\text{TA(\% Malic acid)} = \frac{0.1\text{N NaOH} \ \ \text{x} \ \ \text{volume of NaOH} \ \ \text{x} \ \ 0.067}{\text{Wt. of Sample}} \ \text{X}\,100$$

RESULTS AND DISCUSSION

Weight Loss (%)

The weight loss of strawberry fruits under different storage condition using different packaging materials is shown in Table 10. Weight loss of strawberry fruits was significantly affected by storage condition but was not affected by the different packaging materials.

Strawberry fruits stored under ambient condition, exhibited a significant weight loss of 1.6% right after the first day of storage. This was followed by 2.6% on the second day, 6.9% on the third day and 11.1% on 4^{th} day. There was an abrupt or drastic weight loss in strawberry stored at ambient condition due to high temperature which ranged from 28 -30°C (Figure 4). This evidently showed that high temperature would really shorten the postharvest life of perishable crops particularly strawberry fruits because of high metabolic activities which leads to faster deterioration process. The higher the temperature, the higher is the percent weight loss and the faster is the deterioration process.

Fruits and vegetables stored under ambient conditions are said to undergo several processes and changes like transpiration and respiration which may results to rapid ripening, senescence and deterioration of perishable crops (Anon, 2004 as cited by Sta. Iglesia, 2012). Moreover, higher respiration rate also resulted to higher transpiration of

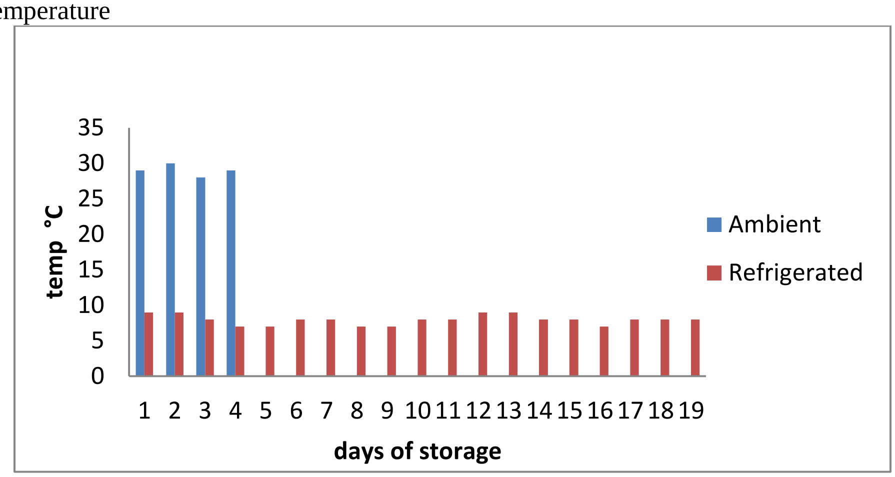
Table 10. Percentage weight loss (%) of strawberry (*Fragaria annassa* Duchense) as affected by different storage condition and packaging materials

Treatment	Number of Days of Storage																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Factor A (Storage Condition)																		
S0-Ambient	1.6a	2.6a	6.9a	11.1a														
S1-Refrigerated	0.0b	0.0b	0.0b	0.2b	1.8	2.6	3.2	3.7	4.6	5.2	6.0	6.6	7.4	7.9	8.6	9.3	9.7	10.3
Factor B (Packaging Materials)																		
P0	0.0	0.2	0.3	0.6	1.1	1.6	1.7	1.9	2.6	2.9	3.3	3.5	3.9	4.0	4.4	24.8	5.0	5.3
P1	0.0	0.0	0.0	0.0	0.3	0.8	1.3	1.5	1.8	1.8	2.3	2.7	3.0	3.3	3.8	4.2	4.5	5.1
P2	0.0	0.0	0.0	0.0	0.6	1.1	1.3	1.5	1.7	2.1	2.4	2.6	3.2	3.5	3.9	4.2	4.4	5.1
P3	0.0	0.0	0.0	0.0	1.1	1.3	1.7	1.9	2.3	2.8	3.1	3.4	3.7	4.2	4.4	4.6	5.0	5.5
P4	0.0	0.0	0.0	0.0	1.1	1.6	2.0	2.4	2.9	3.4	3.9	4.3	4.5	4.7	5.0	5.2	5.5	6.1
CV (%)	0.0	0.0	0.0	0.0	45.0	38.0	38.0	37.0	34.0	32.0	30.0	28.0	29.0	26.0	24.0	25.0	21.0	20.0

Means in a column within a factor followed by the same letters and those without letters are not significantly different from each other based on 5% level of significance, LSD.

P0- Control, P1- Styrofor Box, P2- Styrofor tray w/ cling wrap, P3- Polypropelene Box and P4- Polypropelene Cellophane

A. Temperature



B. Relative Humidity

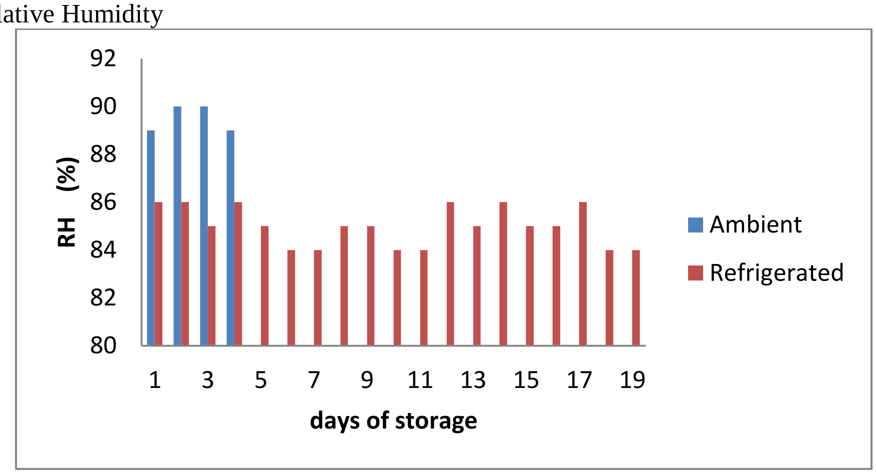


Figure 4. Temperature (A) and relative humidity (B) of strawberry fruits under different storage condition and using different packaging materials (September 2010)

water from the fruit surface which led to increase in percentage weight loss (Sergent and Moretti, 2004). On the other hand, there was no weight loss observed on the first three (3) days in strawberry fruits stored under refrigerated condition. It was only on the 4th day that the fruit started to loss weight. The loss in weight was very minimal and gradual which lengthened the postharvest life of the fruit until 18 days. The prolonged shelf life was due to lower temperature. Acedo (1990), stated that refrigerated storage prolongs postharvest life by reducing the rate of respiration and transpiration. Thus, the higher the respiration rate the shorter the postharvest life. Likewise, Bautista and Esguerra (2007) reported that high temperature, variations in storage space, low relative humidity or excessive air circulation can all result in high weight loss as manifested by wilting or shriveling.

Kader (1992) also added that fresh fruits and vegetables need low temperatures (10 – 15 °C) and high relative humidity (80 to 95 %) to lower respiration and to slow metabolic and transpiration rates. By slowing these processes, water loss is reduced and food value, quality and energy reserves are maintained. Kader (1992) also added that fresh fruits and vegetables need low temperatures (10 – 15 °C) and high relative humidity (80 to 95 %) to lower respiration and to slow metabolic and transpiration rates. By slowing these processes, water loss is reduced and food value, quality and energy reserves are maintained.

Meanwhile, the different packaging materials did not affected the weight loss of strawberry fruits. Throughout the observation period from 1st to 18th day, fruits lost the same weight each day. However, it can be noted that though the difference among treatments was not significant, P0 (control), lost weight ahead than the other four treatments. The fruits immediately lost weight 2 days after storage. While the four others P1 – (styrofor box), P2 – (stryrofor with cling wrap), P3 – (Polypropelene box), and P4 – (Polypropelene cellophane) started to loss weight only at the 5th day of storage.

Environmental factor particularly temperature greatly influence or affects the weight loss of strawberry fruits during storage. After cooling, if cold fruit contacts warm humid air a temporary loss of shine will occur due to condensation on the fruit. As the fruit warms the condensation will dissipate and the shine will return. To prevent condensation plastic can be placed over the fruit to avoid it contacting humid air (Forney, 1996).

Fruits and vegetables are living parts of plant and contain 65 to 95 percent water. When food and water reserves are exhausted, produce dies and decays. Anything that increases the rate at which a product's food and water reserves are used up increases the likelihood of losses. Increases in normal physiological changes can be caused by high temperature, low atmospheric humidity and physical injury. Such injury often results from careless handling, causing internal bruising, splitting and skin breaks, thus rapidly increasing water loss (Wikipedia 2012).

Strawberries are subject to rapid water loss, causing them to shrivel and deteriorate, as well as causing the calyx to wilt and/or dry out. These symptoms will affect berry appearance before they affect eating quality. Water loss is governed by the vapor pressure deficit between the atmosphere and the product. The skin of a strawberry offers little protection to water vapor movement, and thus readily loses moisture to the surrounding air.

Fresh strawberries are highly perishable and cannot be stored except briefly. For maximum life, perhaps of 5-7 days, fruit should be precooled immediately after harvest and placed at 0°C. The temperature of harvested strawberries in the field can get up to 30°, and higher when exposed to sun; and when fruits are allowed to remain at this temperature for 4 hours, marketability drops by at least 40 percent. Precooling of whole pallets by forced air is recommended because the desired temperature (1°) can be obtained with 1 hour, whereas air cooling takes 9 hours. After a few days in storage, the fruit loses some of its fresh bright color, tends to shrivel, and deteriorates in flavor. Deterioration is arrested by low temperature; but after removal from storage, it proceeds more rapidly than in freshly picked strawberries. The major diseases causing storage losses in strawberries are gray mold rot, rhizopus rot, and leather rot. Prompt precooling to temperatures of 5°C or below and holding at such temperatures in transit, storage, and during marketing will minimize such losses (Ryall, and Pentzer. 1982)

Holding berries under optimum storage conditions even during short marketing periods is beneficial to quality retention. Detrimental processes to berry quality such as respiration, softening, moisture loss, and decay development are reduced at low temperatures (DeEll, 2005).

Degree of Shriveling (DS)

Degree of shriveling of strawberry fruits stored under ambient and refrigerated storage using different packaging materials is shown in Table 11.

Data shows that strawberry fruits stored under ambient/ room condition obtained a mean of 5.0 (totally shriveled and non-edible) after 4 days (Figure 5), while those stored under refrigerated condition remained firmed and did not shrivel even after 4 days of storage. Shriveling was only observed starting day 5 of storage which proceeded gradually until the 18th day. While fruits at ambient condition totally shriveled at 4th day of storage and become non-edible fruits stored at refrigerated condition become non- edible only at 18th day of storage of storage.

All perishable crops like strawberry fruits after a day or number of days of storage either ambient or refrigerated condition would underwent shriveling due to the softness of the commodity that may cause faster shriveling. Good refrigeration will reduce decay, maintain fruit shine, and prevent fruit from becoming dark and overripe (Forney, 1996).

Mitcham, et. al. (2000) stated that optimum storage conditions for strawberries (7-10 days), blueberries (2-4 weeks), raspberries and blackberries (2-5 days) are 0°C and 90-95% relative humidity. Cranberries (2-4 months) are chilling sensitive and therefore, should be stored at 3°C. In general, storage-life is very dependent on the handling of berries during and after harvest.

Strawberries are most known for being eaten raw due to the fact that they are highly perishable. In general, strawberries have a maximum storage life of between 5 to 7 days at a temperature of 32°C and 95% relative humidity (Reiger, 2002).

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Volume: 10 | Issue: 6| June 2022 | Journal DOI: 10.36713/epra0813| Impact Factor SJIF (2021) : 7.604| ISSN: 2321 - 7847

Table 11. Degree of Shriveling (D.S.) of strawberry (*Fragaria ananassa* Duchesne) as affected by different storage condition and packaging materials

Treatment	Number of Days of Storage																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Factor A																		
S0-Ambient	1	2a	3a	5a														
S1-Refrigerated	1	1b	1b	1b	1.3	1.6	1.8	2	2	2.1	2.4	2.8	3.1	3.4	3.6	4	4.3	5
Factor B																		
P0	1	1.2	1.3	1.5	1.6	1.6	1.8	2	2	2.1	2.3	2.3	2.6	2.6	2.6	3	3	3
P1	1	1.4	1.6	1.7	1.5	1.8	2	2	2	2	2	2.5	2.5	2.5	2.8	3	3	3
P2	1	1.3	1.5	1.4	1.5	1.8	1.8	2	2	2	2.1	2.3	2.5	2.8	3	3	3	3
P3	1	1.4	1.4	1.5	1.5	1.8	2	2	2	2	2.1	2.5	2.5	2.8	2.8	3	3	3
P4	1	1.4	1.5	1.5	1.6	1.8	2	2	2.1	2.1	2.3	2.5	2.6	2.6	2.8	3	3	3
CV (%)	0.0	10.0	13.0	43.0	52.0	28.0	31.0	33.0	22.0	30.0	18.0	15.0	22.0	19.0	20.0	20.0	20.0	13.0

Means in a column within a factor followed by the same letters and those without letters are not significantly different from each other based on 5% level using LSD.

P0- Control, P1- Styrofor Box, P2- Styrofor tray w/ cling wrap, P3- Polypropelene Box and P4- Polypropelene Cellophane

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PO- Control- Ambient

P1- Styrofor Box

P2- Styrofor w/ cling wrap

P3- Polypropylene Box

P4- Polypropylene Cellophane

Figure 5. Strawberry fruits using five different packaging materials under ambient condition after 3-4 days of storage

On the other hand, the different packaging materials have no significant effect on the degree of shriveling, that is, regardless of the packaging materials used whether strawberry are packed or unpacked, they shriveled at the same time.

Visual Quality Rating (VQR)

Visual quality rating of strawberry fruits was significantly affected by the storage condition but was not influenced by the different packaging materials (Table 12).

Under storage condition strawberry fruits were subjected to ambient/ room condition, (Figure 6) and refrigerated condition. Data shows that strawberry fruits stored under ambient condition on the 1st day had a VQR of 9 (fresh), followed by 5 (fair with 11-40% deterioration) on the 2nd day, 3 (poor with 41% - 70% deterioration) 3rd day, and 1 (unusable, more than 70% deterioration- non- marketable) on the 4th day respectively. These results were

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due to the higher prevailing temperature in storage which ranged from 28–30 ^{O}C that greatly affected strawberry fruits. As the temperature increases, respiration process also increases.

While those strawberry fruits stored under refrigerated condition with temperature range from 6-10 ^{O}C maintain its visual quality rating (VQR) with in the first 5 days of storage. Deterioration started only on day 6 and proceeded slowly. This was due to the low temperature in the refrigerator that slowed down transpiration, respiration and other deteriorative processes, hence maintaining the quality of strawberry fruits.

Strawberries are one of the most perishable fruit crops and are essentially fully ripe at harvest. They have a high rate of metabolism and will destroy themselves in a

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Table 12. Visual Quality Rating (VQR) of strawberry (*Fragaria annassa* Duchense) as affected by different storage condition and packaging materials

Treatment	Number of Days of Storage																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Factor A (Storage Condition)																		
S0-Ambient	9.0	5b	3b	1b														
S1-Refrigerated	9.0	9a	9a	9a	9.0	7.4	5.8	5.2	5.2	5.0	4.8	4.4	4.2	3.5	3.0	3.0	3.0	1.0
Factor B (Packaging Materials)																		
P0	9.0	7.0	6.0	5.0	4.5	3.8	3.1	2.5	2.5	2.5	2.5	2.1	2.1	1.8	1.5	1.5	1.5	1.5
P1	9.0	7.0	6.0	5.0	4.5	3.8	2.5	2.5	2.5	2.5	2.5	2.5	2.1	1.5	1.5	1.5	1.5	1.5
P2	9.0	7.0	6.0	5.0	4.5	3.8	3.1	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.5	1.5	1.5	1.5
P3	9.0	7.0	6.0	5.0	4.5	3.8	3.1	3.1	3.1	2.5	2.1	2.1	1.8	1.5	1.5	1.5	1.5	1.5
P4	9.0	7.0	6.0	5.0	4.5	3.1	2.5	2.5	2.5	2.5	2.5	1.8	1.8	1.5	1.5	1.5	1.5	1.5
CV (%)	12.0	21.0	16.0	13.0	15.0	45.0	43.0	27.0	27.0	13.0	15.0	29.0	36.0	20.0	15.0	15.0	15.0	15.0

Means in a column within a factor followed by the same letters and those without letters are not significantly different from each other based on 5% level of significance, LSD.

P0- Control, P1- Styrofor Box, P2- Styrofor tray w/ cling wrap, P3- Polypropelene Box and P4- Polypropelene Cellophane

P0-Control Styrofor tray

P1- Styrofor Box

P2- Styrofor w/ cling wrap

P3- Polypropylene Box

P4- Polypropylene Cellophane

Figure 6. Strawberry fruits packed in five different packaging materials at ambient condition

relatively short time, even without the presence of decay-causing pathogens. Strawberries have a relatively high rate of respiration (50-100 mL of $C0_2$ per kg per hour at 20°C) and thus are highly perishable (DeEll, 2005)

Good temperature management is the single most important factor in reducing strawberry deterioration and maximizing postharvest life. The best way to slow spoilage is to quickly remove field heat and to maintain the berries as close to 0°C as possible. Deterioration of ripe strawberries is enhanced by high fruit temperature, which hastens metabolic activities, decay development, and internal breakdown. Any failure to maintain produce at low temperatures during handling, storage, and transportation will result in loss of quality and marketability. Berries held at 20°C have only ¼ to ½ the life expectancy of those held at 0°C and market life will be reduced to only a few hours if strawberries are held near 30°C, as may occur in the field (DeEll,2005)

Decay Incidence (DI)

The degree of decay incidence in strawberry fruits was significantly affected by storage condition but was not influenced by the packaging materials used (Table 13). Two (2) days after storage, strawberry fruits in ambient condition obtained a rating index of 2 or 10 to 20% of fruit surface area was infected with microorganisms, on the 3rd day and 4th day of storage it reached an index rating of 3.5 and finally 5 which already showed severe damage and no longer edible (Figure 6). The higher temperature at ambient condition enhanced faster metabolic activities and hence, favors fast deterioration and damage of cells which developed microbial infection.

Strawberry fruits stored under refrigerated condition retained the index rating of 1 (good quality and no infection) for first 5 days of storage. Each day, the decay progressed and at day

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Table 13. Decay Incidence (D.I.) of strawberry (*Fragaria ananassa* Duchesne) as affected by different storage condition and packaging materials

Treatment	Number of Days of Storage																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Factor A																		
S0-Ambient	1.0a	0.2a	3.5a	5.0a														
S1-Refrigerated	1.0a	1.0b	1.0b	1.0b	1.0	1.6	1.8	1.9	2.0	2.0	2.2	2.7	3.0	3.1	3.2	3.8	4.0	5.0
Factor B																		
P0	1	1.2	1.3	1.5	1.5	2	2	2	2	2	2	2.5	2.5	2.5	2.6	3	3	3.5
P1	1	1.4	1.6	1.7	1.7	1.8	1.8	1.8	2	2	2.1	2.3	2.3	2.5	2.5	3	3	3.5
P2	1	1.3	1.4	1.5	1.5	1.6	2	2	2	2.6	2.6	2.3	2.5	2.6	2.6	2.6	3	3.5
P3	1	1.3	1.4	1.5	1.5	1.6	1.8	2	2	2	2	2.3	2.5	2.5	2.6	2.6	3	3.5
P4	1	1.3	1.4	1.5	1.5	1.5	2	2	2	2	2.3	2.3	2.5	2.6	2.6	3	3	3.5
CV (%)	0.0	15.0	14.0	14.0	18.0	20.0	24.0	28.0	18.0	17.0	25.0	26.0	25.0	15.0	22.0	13.0	21.0	13.0

Means in a column within a factor followed by the same letters and those without letters are not significantly different from each other based on 5% level using LSD.

P0- Control, P1- Styrofor Box, P2- Styrofor tray w/ cling wrap, P3- Polypropelene Box and P4- Polypropelene Cellopha

18, the index rating was already 5 which mean that more than 60% of the fruit area showed decay and the fruit was no longer edible.

Disease development maybe attributed to the condition of the commodity during storage under different condition (ambient and refrigerated). Higher temperature during storage favored microbial contamination that may cause damaged to the commodity that also cases early deterioration of the perishable crops.

Strawberries are extremely perishable and should have handled carefully. Even under ideal conditions, they can rarely be kept for more than 7 days after harvest. They must be cooled immediately to their lowest safe temperature (32 to 34 F) to prevent over ripening and decay, and they must not be allowed to rewarm. The two most common types of decay are gray mold, *Botrytis cinerea*, and rhizopus rot. Even a small amount of infestation can quickly spread throughout an entire package. Berries that have been cooled and then allowed to rewarm (causing moisture to condense on them) are extremely susceptible to decay and must be processed or consumed immediately (Boyette 1989).

Diseases are the greatest cause of postharvest losses in berries. Prompt cooling, storage at the lowest safe temperature, preventing physical injury to the fruit, and utilizing high CO_2 (10-15%) are the best methods for disease control. In addition, care should be taken to keep diseased or wounded berries out of packages, as rot can spread from diseased to nearby healthy berries (Mitcham et. al., 2000).

Sensory Firmness (SF)

Fruit softened with time of storage and the rate of softening was significantly affected by the storage condition but was not influenced by the packaging materials (Table 14).

Sensory firmness of strawberry fruits was determined upon termination of the study under ambient and refrigerated condition of storage using different packaging materials. Strawberry fruits stored under ambient condition obtained a firmness index rating of 5 (very soft) while those stored under refrigerated a mean value of 4.46 (very soft, almost rotten). Strawberry fruits stored under ambient condition after 4 days became rotten, while under refrigerated condition strawberry fruits were very soft and almost rotten only after 18 days.

Strawberry firmness decreases either during ripening in the field or during storage regardless of the initial ripeness of the fruit (Nunes*et al*; 2006). According to Koh and Melton (2004) softening of strawberry fruit, either during ripening in the field or during storage is mainly due to loss of cell wall material. Softening of strawberry is mainly due to the presence of polygalacturonase which solubilizes and degrades the cell wall (Huber, 1984; Nogata *et al* 1993).

When the strawberry is removed from the plant color and flavor development continue, but there is little change in firmness or sugar and acid content. Overall, strawberry firmness decreased either during ripening in the field or during storage, regardless of the initial ripeness of the fruit (Forney, 1996).

Humidity as well as temperature must be controlled in storage facilities. If the air inside the storage room is too dry, water will evaporate from the strawberries and they will become soft and shriveled. At a storage room temperature of 32 ^{o}C, the relative humidity should be from 90 to 95 percent. Much of the water that evaporates from the fruit condenses on the inside surfaces of the room or is absorbed into packing materials. Under certain atmospheric conditions, it may be necessary to add moisture with a humidification system (Boyette, 1989)

Fresh fruits and vegetables are living tissues, although they are no longer attached to the plant. They respire, and their composition and physiology continue to change after harvest. They continue to ripen and, finally, they begin to die. Cellular breakdown and death (senescence) are inevitable, but can be slowed with optimal storage conditions. Fresh fruits and vegetables need low temperatures (10 – 15 °C) and high relative humidity (80 to 95 %) to lower respiration and to slow metabolic and transpiration rates. By slowing these processes, water loss is reduced and food value, quality and energy reserves are maintained (Kader, 1992).

Total Soluble Solids

Total soluble solids are a rough index of the amount of sugar present in the fruit.

Data revealed that storage condition did not affect the total soluble solids, while packaging materials showed significant results (Table 14).

Although total soluble solids of strawberry fruits are statistically similar in ambient (2.07 Brix) and refrigerated storage (2.24 Brix) numerically refrigerated storage had higher total soluble solids. The report of Reyes et al (1982) pointed out a decline in

Table 14. Total soluble solid (TSS), titratable acidity (TA) and sensory firmness of strawberry as affected by different storage condition and packaging materials

Treatment	Sensory Firmness (SF)	Total Soluble Solid (TSS) °Brix	Titratable Acidity (%)
Factor A - Storage Condition			
S0- Ambient Condition	5.00a	2.07	0.92a
S1- Refrigerated Condition	4.46b	2.24	0.57b
Factor B - Packaging Materials			
PO- Control	4.66	2.10b	0.65
P1- Styrofor Box	4.66	2.36a	0.24
P2- Styrofor Tray with Cling Wrap	4.83	1.48bc	0.20
P3- Polypropelene Box	4.66	1.38bc	0.38
P4- Polypropelene Cellophane	4.83	1.31d	0.21
CV (%)	8.7	45.7	80.9

Means in a column within a factor followed by the same letters and those without letters are not significantly different from each other based on 5% level of significance in ANOVA using LSD.

soluble solids in over ripe strawberries. This holds true with the current study where total soluble solids as well as the Titratable Acidity were determined at the termination period. After 8 days at 10 C the soluble solid concentration (SSC) of half mature strawberries was found to be lower than that of fruit at the time of harvest.

Brix shows slight variations in the first stages of sampling without significant differences, increasing sharply from day 21 after fruit set, when fruit ripening seems to start. The maximum content of soluble solids was seen after approximately 28 days, decreasing significantly from that time. The increase in soluble solids when ripening occurs was described by Salunkheand Desai (1984) in other strawberry varieties. Soluble solids concentrations (SSC) decreased at higher storage temperatures. (Youngjae *etal*., 2007).While on packaging materials, P0- styro tray – open (control) with a mean of 2.10°Brix, followed by P1- styro box -2.36°Brix, P2- styro tray with cling wrap- 1.48°Brix, P3- polypropylene box 1.38°Brix and 1.31°Brix for P4 – polypropylene cellophane.

It was further observed that the P1 – styro box obtained the highest due to the type of the box in which the fruit were totally enclosed compared to the other packaging materials used were transparent and some were open. The enclosure down respiration and other degradative process.

Titratable Acidity

Storage condition significantly affected titratable acidity (TA) of strawberry fruits but packaging materials did not influence this parameter (Table 14). Although values in both storage conditions were relatively lower, fruits stored at ambient condition had significantly higher, 0.92 compared to 0.57 in refrigerated storage. As mentioned by Pantastico, 1975, TSS usually increased with ripening as a result of starch hydrolysis. However, some of the sugars, a major TSS component are partially broken down to organic acids which correspondingly increased TA content. This behavior was manifested by fruits stored at ambient condition where temperature is higher. Hydrolytic activities may have been lower in refrigerated storage, hence lower TA.

All berries should be harvested near ripe, as eating quality does not improve after harvest. Appearance (color, size, shape, and freedom from defects), firmness, flavor (soluble solids, titratable acidity, and flavor volatiles), and nutritional value (vitamin C) are all important quality characteristics. For acceptable flavor, a minimum of 7% soluble solids and/or a maximum of 0.8% titratable acidity are recommended (DeEll, 2005).

According to Shamaila*et al*. (1992), this is the most abundant acid present in strawberry fruit. Acidity declines as fruit mature. It could be considered that fruitsstart to ripen after 21 days from fruit set. Spayd and Morris (1981) found that total acidity increases modestly to a maximum in mature green fruit before declining more rapidly in the later stages of ripening. The percentages of titratable acidity (TA), of strawberry were between 0.6 and 0.7 during the storage period. These values are close to the lowest value mentioned in the literature, between 0.6 and 2.3% (Green, 1971; Montero *et al*., 1996)

CONCLUSION

From the studies conducted, the following conclusions were drawn: Refrigerated storage lengthened postharvest life of strawberry fruits to four folds than when stored at ambiemt condition. Total Soluble Solids (TSS) was higher in the refrigerated storage than in the ambient condition where temperature is higher. The reverse was true with titratable acidity (TA) which was higher at ambient condition. The different packaging materials did not manifest any effect on both posharvest physical and chemical attributes of strawberry except for styrofor box which showed the highest TSS.

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