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Extending the Storage and Post-storage Shelf-life of Strawberry Fruit cv. "Sweet Charlie" using Cold Storage

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ABSTRACT

The postharvest changes in strawberry fruit cv. "Sweet Charlie" at room temperature (RT) and in cold storage (4°C and 95% Relative Humidity (RH)) were studied during the winter season (January-2018) in Pune, Maharashtra, India. The shelf life, pre-cooled shelf-life, cold storage life and post-storage shelf-life of fruit cv. "Sweet Charlie" was observed to be 2.79 days in room temperature (RT), 2.97 days at RT, 4 days in cold storage i.e. Ecofrost at 4°C with 95% RH followed by 1.90 days at RT, respectively. Average weight loss percentage of 0.58% per day (5.82 kg/ 1000 kg/day), shrinkage percentage of 73.33% at the end of sixth day, abrasion injury percentage of 10% and 23.33% at the end of day 3 and 4, respectively of strawberries were recorded in Ecofrost. Fresh fruit weight loss percentage was recorded at ordinary RT as 5.51% at the end of day 1, 6.08% at the end of day 2 and 6.18% at the end of the day 3 and 20% shriveling was observed at the end of day 3. Firmness (N/cm²) decreased with increasing storage periods. The TSS, ascorbic acid content (mg/100g of pulp) and decay % of fruit cv. "Sweet Charlie" was observed to increase during the storage period.

Key words: Strawberries, Sweet Charlie, Cold, Storage, Temperature, Shelf, Post-storage

The Mahabaleshwar strawberry is grown mainly in the hilly Mahabaleshwar-Panchgani belt in western Maharashtra, which accounts for about 85% of the total strawberries produced in India. Mahabaleshwar strawberry had obtained the geographical indication (GI) tag in 2010. Mahabaleshwar was the summer capital of the Bombay Presidency under the British Raj. Since then, local farmers have developed their own varieties of the strawberry fruit, some of which are imported. As of late 2015, it is being grown in an estimated area of 3,000 acres with about 30,000 metric tonnes of the fruit being produced annually. The cool climate and red soil of the region make it suitable for growing the fruit and give it a unique taste (Kanan 2016). The Mahabaleshwar strawberry is a seasonal fruit with the usual season lasting between October–November and April–May. Mother saplings, some of which are imported from California in the month of June, are planted in nurseries in places like Wai. The runners produced by each of these saplings are replanted in the month of September. The land is prepared after the monsoon season in September by fumigation and covering the fields with plastic sheets. Nearly half of the fruit in the region belongs to the 'Sweet Charlie' variety of California, with 'Camarosa' and 'Winter Dawn' being the other two major varieties. Other notable varieties include 'Rania' and 'Nabila'. Mahabaleshwar strawberry is used in making various food products in the region such as preserves, jams, fruit crushes, ice-creams, milkshakes, strawberries with cream, fudge and jelly toffees. Strawberries from Mahabaleshwar are exported in large quantities to other countries like France, Belgium, Malaysia and the Middle East. The fruit is frozen before being exported.

Strawberries (*Fragaria x ananassa* Duch.) are rich in ascorbic acid (vitamin C), secondary metabolites, simple sugars and acids but spoil quickly, with soft texture, high softening rate and highly susceptible to fungal attack (Shin *et al.* 2008). Appearance, quality, firmness, and shelf-life are important from the consumers' point of view. If strawberries are harvested before optimum maturity, their shelf life is extended but nutritive value and quality become reduced. On the other hand, fully mature strawberries possess high nutritive value with limited shelf-life. So, it is necessary to strike a balance between maturity stage and nutrient content of the fruit. Strawberry is a non-climacteric fruit and is harvested at different stages of maturity, depending on the cultivar and market preference. However, maturity indices as well as harvesting time mostly vary with cultivars (Kafkas *et al.* 2007) and to some extent with location and weather conditions. Unripe fruit are more prone to shrivelling and physical injuries and have poor flavour

quality when ripe. Overripe fruit become soft and mealy with insipid flavour soon after harvest. Fruits picked either too early or too late in their seasons are more susceptible to postharvest physiological disorders than fruit picked at the proper stage of maturity (Kader 1999). Temperature management during storage is the single most important factor in minimizing the deterioration of fruit quality and extending the pre-cooled shelf-life and storage-life of strawberry. However, in India most of the growers and retailers store their product at ordinary conditions due to lack of cooling facilities. Storing at ambient temperature makes post-harvest management of strawberries very difficult (Asrey *et al.* 2004), as high storage temperatures result in high respiration rates, which is associated with reduction of fruit quality (Ayala-Zavala *et al.* 2004). Cultivar quality is defined by different parameters which collectively give an integral picture of selected fruit. This research was undertaken to examine the effect of temperature on selected qualitative parameters in strawberry fruit cv. "Sweet Charlie".

MATERIALS AND METHODS

The study was carried out at the Agricultural Research Laboratory, Ecofrost Technologies Private Limited, Pune, Maharashtra, India during the winter season (January) of 2018. Selected strawberries cv. "Sweet Charlie" were collected from Mahabaleshwar, Maharashtra, India and transported to Pune in an air-conditioned vehicle. The fruit quality, chemical composition and nutritive value were evaluated as per experimental treatments.

Harvesting of strawberries: The strawberries were harvested based on optimum maturity like fruit surface exhibiting deep red colour by visual estimation. Immediately after harvest, the fruit was sorted to eliminate damaged pieces on basis of bruising, uneven shape, uneven colour, abrasion injury, small and over-sized, etc. The fruit were selected based on uniform size, shape and colour. Fully developed, well matured, healthy, uniform fruit, free from any bruising and mechanical injuries and blemishes were brought to the Agricultural Research Laboratory at Ecofrost Technologies for storage and post-storage study.

Storage conditions

Treatment of the experiment: Some fruit were placed at RT and some fruit were placed inside a cold storage i.e. Ecofrost at 4°C with 95% RH. The quality, storage life (days), vitamin C (mg/ 100 g pulp of fruit), post-storage life (days), weight loss (%), disease infection percentage such as leather rot, decay rot, rhizopus rot, and Mucor rot as well as hedonic taste values (based on 5 members) were determined. Each parameter was applied with three replications.

Method of storage: Some strawberries were placed in punnets and stored inside the Ecofrost (4°C with 95% RH) and taken out for post-storage at ordinary room conditions at Agricultural Research Laboratory, Ecofrost technologies Pvt. Ltd., Pune, 411 033. Similarly, some strawberries were placed in punnets and stored at ordinary room conditions. The experimental data were recorded on the following parameters as described below:

Loss of visual quality: The visual quality losses of strawberries were determined by visual inspection on each day during the storage period based on visible fruit surface damage including decay rot percentage, *Rhizopus stolonifer* (*Rhizopus* rot) percentage, *Phytophthora cactorum* (Leather rot) percentage, *Mucor piniformis* (*Mucor* rot) percentage, anthracnose rot (*Colletotricum acutatum*) percentage, abrasion percentage and shrivelling percentage, etc. Fruit with visible mycelia growth and/or at least $1/3^{rd}$ damaged surface area including bruising, softening or easily ruptured skin surface were removed, and the loss of fruit was determined according to the percentage of berries removed.

Shelf life at RT, pre-cooling shelf life at RT, cold storage life inside storage and post-storage shelf-life at RT

Shelf life of the strawberries was determined by observing and judging parameters like rotting, shrivelling, incidence of diseases, etc. with respect to storage days at ordinary room conditions. Similarly, cold storage life (days) was determined by observing and judging the same quality parameters with respect to storage days. Post-storage shelf-life (days) was also determined by using same parameters at RT, after fruit were taken out from cold room (4°C and 95% RH) at just after the start of the experiment, after 8 hours, end of day 1, end of day 2, end of day 3, end of day 4 and at the end of day 5. It was measured till most of the fruit were still marketable.

Abrasion injury percentage: Abrased strawberries were counted and expressed in percentage over the total number of fruits.

Weight loss of fruit (%): Ten fruit per replications were selected and weighed separately on an electronic balance and the mean of three replications was calculated. Weight loss was expressed as a percentage.

Total soluble solids (TSS): Total soluble solids were recorded by using a hand refractometer (Erma made, Japan 0.242 Brix, No. 96/88). For this purpose, fruit were selected randomly. The 10g pulp was separated from fruit. Pulp was homogenized by using mortar and pestle; filtered through a Whatman filter paper no. 2. The supernatant was collected to measure TSS using a digital hand refractometer and expressed as °B.

Ascorbic acid content: For ascorbic acid measurement, 10g pulp tissues were homogenized in 50ml 5% metaphosphoric acid (HPO_3) using a mortar and pestle and filtered through a Whatman filter paper No. 1. The clear supernatant was collected for assaying ascorbic acid by 2,6-dichlorophenolindophenol titration following the method of Ranganna (1986). 10ml aliquot was titrated with 2,6-dichlorophenolindophenolsolution until the filtrate colour

changed to pink and persisted for at least 15 seconds; the titration volume of 2,6-dichlorophenolindophenol was recorded. Prior to titration 2,6-dichlorophenolindophenol solution was calibrated by ascorbic acid standard solution. Ascorbic acid content was calculated according to the titration volume of 2,6-dichlorophenolindophenoland the results were expressed as mg per 100g fresh weight.

$$\text{mg of ascorbic acid/100g pulp} = \frac{\text{Titrate} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Weight or volume off sample taken for estimation}} \times 100$$

Fruit firmness (N/cm^2)

The hardness of the fruit was tested by using a pocket penetrometer (China, Fruit Hardness Taster FR-5120, Tip size 11mm). The penetrometer adjusted to zero was firmly pierced into the fruit up to the knob. The pressure required to penetrate the penetrometer was recorded in N/cm^2 provided on the circular disc of the pocket penetrometer. The average firmness of two opposite sides of fruit was computed and recorded.

Shrivelling percentage: Shrunken strawberries were counted and expressed in percentage over the total number of fruits.

Decay loss percentage: The number of diseased, rotten, overripe fruits were counted and expressed in percentage over the total number of fruit.

Mucor rot percentage: The number of diseased fruit with *Mucor piniformis* were counted and expressed in percentage over the total number of fruit.

Anthracnose (Colletotricum acutatum) rot percentage: The number of diseased fruit with anthracnose were counted and expressed in percentage over the total number of fruit.

Leather rot percentage: The number of diseased fruit with leather rot (*Phytophthora cactorum*) were counted and expressed in percentage over the total number of fruit.

Soft rot (Rhizopus stolonifer) percentage

The number of diseased fruit with Rhizopus were counted and expressed in percentage over the total number of fruits.

Hedonic test: The evaluation for assessing skin colour and taste were done by a panel of five judges by using 5 point hedonic scale. Skin colour scale was divided into 1. White, 2. 50% yellow, 3. 50% red, 4. 75% red and 5. 100% red. Taste scale was divided into 1. Bad taste, 2. Slight good taste, 3. Good taste, 4. Very good taste and 5. Excellent taste.

RESULTS AND DISCUSSION

Shelf-life (days) of strawberry fruit cv. "Sweet Charlie" at RT (n-10)

Shelf life of strawberry fruit was recorded to be 2.79 days at RT and varied with storage conditions (Fig 3). The decrease in shelf life may reflect degradation and solubilization of cell wall polyuronides and hemicelluloses associated with fruit softening (Huber 1984). Our result also supported the findings of Shin *et al*. (2008) who found that shelf life of fruit at the white tip (less matured) stage was higher than that of the red ripe (more matured) stage. "Sweet Charlie" fruits had potentially higher storage life than at RT. Strawberries harvested at three-quarter red ripe stage can be stored for a longer period with a better colour than the fruit harvested at full red stage (Nunes *et al*. 2006).

Pre-cooling shelf life (days) at RT (n-10): After pre-cooling till 4°C and 95% RH, post-storage shelf life of strawberry fruit has recorded 2.97 days at ordinary room conditions.

Storage life (days) of strawberry fruit cv. "Sweet Charlie" inside cold room of Ecofrost (n-10): Storage at 4°C and 95 % RH conditions (Ecofrost), cold storage life of strawberry fruit was recorded as4.00 days (Fig 1). Post-storage shelf-life (days) of strawberries at ordinary room conditions after being taken out of cold storage was observed to be 2.79 days, 2.97 days, 2.55 days, 2.05 days, 1.52 days, 1.47 days and 1.05 days, just after start experiment, after 8 hours, at the end of day 1, at the end of day 2, at the end of day 3, at the end of day 4 and at the end of day 5, respectively (Fig 2).

Abrasion injury percentage of strawberry fruit cv."Sweet Charlie" inside cold room conditions (n-10)

Abrasion injury percentage of strawberry fruit at cold storage, was recorded to be 0.00%, 0.00%, 0.00%, 0.00%, 10.00%, 23.33% and 34.67%; as on just after start of experiment, 8 hours (pre-cooling), at the end of day 1, at the end of day 2, at the end of day 3, at the end of day 4 and at the end of day 5, respectively (Fig 5-B).

Weight loss percentage of strawberry fruit at RT

Weight loss percentage of strawberry fruit at RT was recorded on the end of day 1, 2 and 3 as 5.51% (55.09 kg/1000 kg), 6.08% (60.79 kg/1000 kg) and 6.18% (61.84 kg/1000 kg) respectively (Table 1). Weight loss gradually increased over time and was affected by the storage methods.

Table 1 Weight loss percentage in strawberry fruit cv. "Sweet Charlie" at RT

Weight (g) of strawberry fruit (n=5) at RT			
Fresh fruit weight (g)	At the end of 1st day (g)	At the end of 2nd day (g)	At the end of 3rd (g)
97.66 g	92.28 g	86.87 g	81.31 g
Weight loss (g) of strawberry at RT			
0 g	5.38 g	5.61 g	5.36 g
Weight loss (%) of strawberry fruit at RT			
0	5.51	6.08	6.18
Weight loss (kg/1000kg) of strawberry fruit at RT			
0	55.09	60.79	61.84

Fig 1 Strawberry fruit inside cold room on the end of the day 1, 2, 3, 4, 5, 6 and 7 (Inside cold room of Ecofrost)

Fig 2A Strawberry fruit taken out after 8 hours from cold room and placed at RT

Fig 2B Strawberry fruit taken out after 1st day from cold room and placed at RT

Fig 2C Strawberry fruit taken out after 2nd day from cold room and placed at RT

Fig 2D Strawberry fruit taken out after 3rd day from cold room and placed at RT

Fig 2E Strawberry fruit taken out after 4th day from cold room and placed at RT

Fig 2F Strawberry fruit taken out after 5th day from cold room and placed at RT

Fig 2 Post-storage shelf life of Strawberry fruit at RT

Fig 3A Day-1 (At room temperature)

Fig 3B Day-2 (At room temperature)

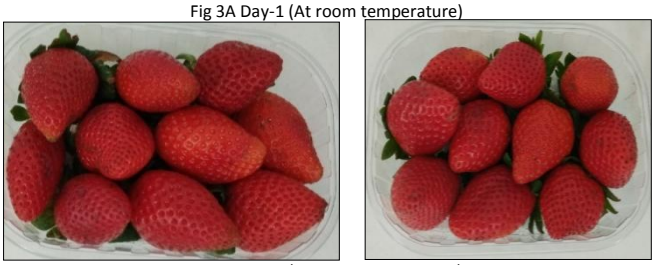


Fig 3C Day-3 (At room temperature)

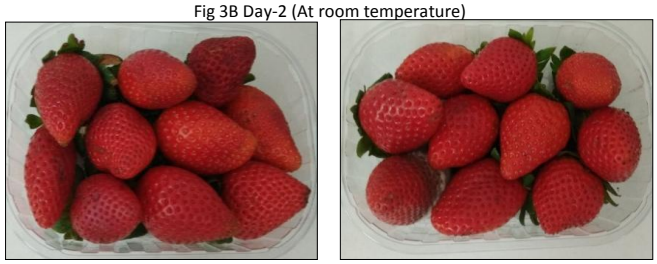


Fig 3D Day-4 (At room temperature)

Fig 3 Shelf-life (Days) of Strawberry fruit cv. "Sweet Charlie" at room temperature

Weight loss percentage and weight loss kg/1000kg/day of strawberry fruit cv. "Sweet Charlie" inside cold room

Average weight loss percentage of strawberry fruit at cold room conditions, recorded as 0.58% per day and 5.82 kg per 1000 kg per day. Weight loss was higher at initial storage days in cold storage as shown in (Table 2). "Sweet Charlie" variety fruit under study exhibited a progressive weight loss during storage inside cold room. From this study it was revealed that "Sweet Charlie" showed lower weight loss with a better visual quality in cold temperature rather than RT. Significant variation in weight loss was observed throughout the storage period in both conditions. This could

be due to more succulence. Harvested fruit continue to respire and lose water to the environment, which cannot be replaced, and weight loss occurs (Thompson 2003). The rate of water loss is largely controlled by the storage temperature and humidity. Possibly, high rate of transpiration at room temperature could be the major reason for higher weight loss. Storage duration and temperature had significant effect on weight loss. Epidermis of strawberries consists of polygonal cell having larger stomata and pith of strawberries consists of thin-walled cells often separated during growth, leaving large cavities. The large cells and thin cell walls in strawberry fruits contribute to their high level of susceptibility to weight loss. Softening of the fruits as they ripen involves thinning of cell walls and degradation of cell contents (Szczesniak and Smith 1969) which lead to weight loss from fully ripe fruit.

Table 2 Weight loss percentage and weight loss kg/1000 kg/day of strawberry fruit cv. "Sweet Charlie" inside cold room (n=10)

Strawberry fruit cv. "Sweet Charlie" held inside cold room	Initial weight, g	Final weight, g	Weight loss after day-1, g	Weight loss percentage per day	Weight loss, kg/1000 kg/day
Fresh fruit	194.31	194.31	0.00	0.00	0.00
After eight hours	194.31	193.63	0.68	0.35	3.50
After one day	193.63	192.87	0.76	0.39	3.93
After second day	192.87	189.08	3.79	1.97	19.65
After third day	189.08	188.51	0.57	0.30	3.01
After fourth day	188.51	188.16	0.35	0.19	1.86
After fifth day	188.16	188.04	0.12	0.06	0.64

Table 3 Fruit weight loss percentage in strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room on different days (n=5)

On time fruit cv. "Sweet Charlie" were taken out of cold room and placed at RT	Initial weight, g	Fruit weight loss percentage (RT)					
		At the end of 1st day		At the end of 2nd day		At the end of 3rd day	
		g	%	g	%	g	%
Fresh fruit	97.66	92.28	5.51	86.87	11.05	81.31	16.74
After eight hours	93.16	85.81	7.89	81.35	12.68	78.09	16.18
After one day	86.45	81.41	5.83	75.48	12.69	71.88	16.85
After second day	75.19	70.56	6.16	67.13	10.72	62.53	16.84
After third day	83.20	79.21	4.80	75.06	9.78	69.51	16.45
After fourth day	81.07	78.07	3.70	75.20	7.24	-	-
After fifth day	95.05	89.15	6.21	-	-	-	-

Fruit weight loss percentage at RT, after being taken out of cold room on different days

Average weight loss percentage of strawberry fruit at RT was recorded at the end of the first, second and third day, when fruit were taken out of cold room just after start of experiment, after 8 hours and on the end of day 1, 2, 3, 4 and 5. Weight loss was higher at RT as compared to cold storage (Table 3).

Table 4 TSS contents in strawberry fruit cv. "Sweet Charlie" inside cold room and at RT, after being taken out of cold room (n-4)

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room and held in RT	TSS°B			
	Cold room	RT		
		At the end of 1st day	At the end of 2nd day	At the end of 3rd day
Fresh fruit	7.44	8.00	8.66	8.66
After eight hours	6.67	8.00	8.67	8.00
After one day	8.67	9.00	8.67	9.33
After second day	7.33	9.00	9.67	8.33
After third day	7.50	9.00	8.33	-
After fourth day	7.00	8.33	8.00	-
After fifth day	7.67	8.00	-	-

TSS contents of strawberry fruit cv. "Sweet Charlie" at RT

TSS of strawberry fruit at ordinary room conditions was recorded to be 7.44°B at the time just after start of the experiment, 8.00°B at the end of first day, 8.66°B at the end of second day and 8.66°B at the end of third day, as shown in (Table 4). Total soluble solids slightly increased with progressing storage periods. The increase in soluble solid contents may be due to hydrolysis of sucrose to invert sugars as reported by Bhatti (1975), Ullah (1990). Changes in TSS during the storage period are due to respiration, changes of insoluble compounds to soluble forms and moisture loss by evaporation (Miaruddin *et al.* 2011). Increase in TSS

observed in the present study also agrees with the report of Abdullah *et al*. (1985), Tripathi *et al.* (1981).

TSS contents of strawberry fruit cv. "Sweet Charlie" inside cold room and at RT

TSS of strawberries inside cold room conditions was recorded to be 7.44°B in fresh fruit, 6.67°B after eight hours, 8.67°B at the end of first day, 7.33°B at the end of second day, 7.50°B at the end of third day, 7.00°B at the end of fourth day and 7.67°B at the end of fifth day as shown in (Table 4). Low temperature prevailing in the Ecofrost might have resulted in removing field heat, delaying the ripening process, decrease in respiration or other metabolic processes during storage. Cold storage has been found to help in maintaining fruit turgidity, which minimizes the degradation of starch to simple sugars. The changes in TSS are directly correlated with hydrolytic changes in the starch concentration during the post-harvest period.

Vitamin C contents (mg/100 g) in strawberry fruit cv. "Sweet Charlie" at RT: Vitamin C content (mg/100 g) of fresh fruit increased from 66.88 to 81.43 mg/100g (at the end of second day) in strawberry pulp at ordinary room conditions and then decreased at the end of third day in (Table 5).

Vitamin C contents in strawberry fruit inside cold room and at RT, after being taken out of cold room: Average vitamin C content (mg/100 g) was recorded to be 75.07 mg/100 g at the end of day 1 for first five days when fruit were taken out of cold storage and placed at RT. Similarly, average vitamin C content (mg/100 g) was recorded to be 80.08 mg/100 g pulp at the end of day 2 for first four days and 82.93mg/100 g pulp at the end of third day for first three days (Table 5). The ascorbic acid content of fruit slightly increased in ordinary room conditions. Haffner *et al*. (1997) found a wide variation in ascorbic acid content which ranged from 30 to 70 mg/100 g in fifteen strawberry cultivars, while change in ascorbic acid content during storage on different germplasm agrees with Lee and Kader (2000), Wills *et al*. (1984). Otta (1984) found that ascorbic acid decreased in the samples stored at room temperature. The decrease in ascorbic acid was due to prolonged storage at high temperature. Cordenunsi *et al*. (2005) stated the fluctuations in the ascorbic acid content and observed that ascorbic acid synthesis took place during the storage period.

Table 5 Vitamin C contents in strawberry fruitcv. "Sweet Charlie" at RT, after being taken out of cold room

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room and placed at RT	Vitamin C contents (mg/100 g pulp) (n-4)			
	Cold room	At the end of 1st day	At the end of 2nd day	At the end of 3rd day
Fresh fruit	66.88	71.83	81.43	71.56
After eight hours	75.13	70.16	74.74	82.47
After one day	73.03	82.32	76.10	84.27
After second day	68.79	72.76	76.06	84.21
After third day	69.18	77.77	78.29	80.32
After fourth day	70.63	72.16	89.87	-
After fifth day	68.18	70.32	-	-

Table 6 Firmness of strawberry fruit cv. "Sweet Charlie" inside cold room and at RT, after being taken out of cold room

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room	Firmness (N/cm^2) (n-4) Room Temperature			
	Cold room	At the end of 1st day	At the end of 2nd day	At the end of 3rd day
Fresh fruit	24.21	20.45	18.59	16.23
After eight hours	21.98	18.90	15.15	14.95
After first day	19.68	16.93	15.10	10.93
After second day	20.63	14.80	13.61	11.10
After third day	19.98	16.29	15.65	12.02
After fourth day	19.69	16.32	14.65	-
After fifth day	18.65	14.26	-	-

Firmness (N/cm^2) of fresh fruit cv. "Sweet Charlie" at RT: Firmness in fresh strawberries was recorded to be 24.21N/cm^2, likewise in room conditions at the end of first day, at the end of second day and at the end of third day; firmness was recorded 20.45N/cm^2, 18.59N/cm^2 and 16.23N/cm^2, respectively shown in (Table 6).

Firmness of strawberry fruit cv. "Sweet Charlie" inside cold room and at RT

Firmness was recorded as 21.98N/cm^2, 19.68N/cm^2, 20.63N/cm^2, 19.98N/cm^2, 19.69 N/cm^2 and 18.65N/cm^2 inside the Ecofrost after eight hours, after first day, after second day, after third day, after fourth day and after fifth day; respectively. Fruit were taken out from cold storage after 8 hours and held at room conditions, at the end of first day, at the end of second day and at the end of third day; firmness was recorded 18.90N/cm^2, 15.15N/cm^2 and 14.95N/cm^2, respectively. Fruit taken out from cold storage after the first day and held at room conditions, at the end of first day, at the end of second day and at the end of third day; firmness was recorded as 16.93N/cm^2, 15.10N/cm^2 and 10.93N/cm^2, respectively. Fruit taken out from cold room after second day and held at room conditions, at the end of first day, at the end of second day and at the end of third

day; firmness was recorded as 14.80N/cm^2, 13.61N/cm^2 and 11.10N/cm^2,respectively. Fruit taken out from cold storage after third day and held at room conditions, at the end of first day, at the end of second day and at the end of third day; firmness was recorded as 16.29N/cm^2, 15.65N/cm^2, 12.02N/cm^2,respectively. Fruit taken out from cold storage after fourth day and held at room conditions, at the end of first day and at the end of second day; firmness was recorded as 16.32N/cm^2 and 14.65N/cm^2, respectively. Fruit taken out from cold storage after fifth day and held at room conditions, at the end of first day, firmness was recorded as 14.26N/cm^2, shown in (Table 6). The decrease of firmness with the advancement of storage period could be due to starch hydrolytic enzyme activity.

Shrivelling percentage of strawberry fruit cv. "Sweet Charlie" at RT: Shrivelling percentage was recorded as 20% at the end of third day inside the Ecofrost for stored strawberry fruit as shown in (Table 7).

Table 7 Shrivelling percentage in strawberries fruit cv. "Sweet Charlie" at RT (n-10)

Fresh fruit	At the end of 1st day	At the end of 2nd day	At the end of 3rd day
0.00	0.00	0.00	20

Shrivelling percentage of strawberry fruit cv. "Sweet Charlie" inside cold room: Shrivelling percentage was recorded 0.00%, 0.00%, 0.00%, 0.00%, 0.00%, 73.33% and 83.33% at the end of the day 1, 2, 3, 4, 5, 6 and 7, respectively inside the Ecofrost for stored strawberries as shown in (Table 8).

Table 8 Shrivelling percentage in strawberries fruit cv. "Sweet Charlie" inside cold room

At the end of						
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
0.00	0.00	0.00	0.00	0.00	73.33	83.33

Table 9 Shrivelling percentage in Strawberry fruit cv. 'Sweet Charlie' at RT, after being taken out of cold room (n-10)

Strawberry fruit were taken out of cold room and placed at RT	Shrivelling Percentage			
	Cold room	At Room Temperature		
		At the end of 1st day	At the end of 2nd day	At the end of 3rd day
Fresh fruit	0.00	0.00	0.00	20.00
After eight hours	0.00	0.00	0.00	20.00
After first day	0.00	0.00	0.00	73.33
After second day	0.00	0.00	0.00	83.21
After third day	0.00	0.00	50.00	-
After fourth day	0.00	0.00	53.33	-
After fifth day	0.00	0.00	70.16	-

Shrivelling percentage of Strawberry fruit cv. 'Sweet Charlie' at RT, after being taken out of cold room: Shrivelling percentage was recorded as 0.00% at the end of day 1 for first five days when the fruit was taken out from Ecofrost and placed at room conditions. Shrivelling percentage increased with storage period as shown in (Table 9, Fig 5-A).

Fig 5A Shrivelling symptoms

Fig 5B Abrasion symptoms

Fig 5 Shrivelling symptoms and abrasion symptoms

Decay percentage of strawberry fruit cv. "Sweet Charlie" at Room Temperature

Decay percentage increased with storage at ordinary room conditions as shown in (Table 10). Decay incidence was found higher at room conditions than in cold storage (Nunes and Morais 2002).

Table 10 Decay percentage in strawberry fruit cv. "Sweet Charlie" at RT (n-10)

Fresh fruit	At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
0.00	0.00	13.33	73.30	93.67

Decay percentage of strawberry fruit cv. "Sweet Charlie" inside cold room: Fungal decay was the major contributor to the loss of strawberry fruit quality. Decay rot percentage in strawberries increased inside Ecofrost and at ordinary room conditions day after day with increasing storage period, as shown in (Table 11). Fruit decay increased sharply over the storage period in both conditions. The declining effects of firmness enhance fruit rotting. Also, increased C_2H_4 leads to enhanced fungal decay.

Table 11 Decay percentage in strawberry fruit cv. "Sweet Charlie" inside cold room

At the end of						
1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
0.00	0.00	0.00	0.00	73.33	83.33	93.33

Decay percentage of strawberry fruit cv. "Sweet Charlie" inside cold room and at RT during post-storage period: Decay was caused by several causal organisms. Decay percentage increased with storage period at RT, when fruit

were taken out of cold storage at the end of day 1, 2, 3, 4 and 5 as shown in (Table 12).

Table 12 Decay percentage in strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room and placed at RT	Decay Percentage (n-10)				
	Cold room	Room Temperature			
		At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
Fresh fruit	0.00	0.00	0.00	13.33	73.33
After eight hours	0.00	0.00	0.00	20.00	63.33
After first day	0.00	0.00	10.00	23.33	80.00
After second day	0.00	0.00	10.00	86.67	100
After third day	0.00	0.00	0.00	83.33	96.67
After fourth day	0.00	0.00	26.67	76.67	96.67
After fifth day	73.33	90	-	-	-

Table 13 Mucor rot percentage in strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room and placed in RT	Mucor rot percentage (n-10)				
	Cold room	Room Temperature			
		At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
Fresh fruit	0.00	0.00	0.00	13.33	20.00
After eight hours	0.00	0.00	0.00	13.33	16.67
After first day	0.00	0.00	10.00	10.00	20.00
After second day	0.00	0.00	10.00	36.67	40.00
After third day	0.00	0.00	0.00	50.00	56.67
After fourth day	0.00	0.00	6.67	30.00	43.33
After fifth day	33.33	40.00	-	-	-

Mucor rot percentage of strawberry fruit cv. "Sweet Charlie" at RT: Mucor rot percentage increased with storage period at RT; at the end of day 1, 2, 3, 4 and 5 as shown in (Table 13).

Mucor rot percentage of strawberry fruit cv. "Sweet Charlie" inside cold room: Mucor rot percentage increased with storage period inside Ecofrost as shown in (Table 14).

Mucor rot percentage of strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room: Mucor rot percentage increased with storage period at RT, when fruit were taken out from cold storage at the end of day 1, 2, 3, 4 and 5 as shown in (Table 13, Fig 4-A).

Anthracnose rot percentage in strawberry fruit cv. "Sweet Charlie" at RT: Anthracnose rot percentage increased with storage period at RT; at the end of day 1, 2, 3, 4 and 5 as shown in (Table 15).

Anthracnose rot percentage of strawberry fruit cv. "Sweet Charlie" inside cold room: Anthracnose rot percentage increased with storage period inside Ecofrost as shown in (Table 16).

Table 14 Mucor rot percentage in Strawberry fruit cv. "Sweet Charlie" inside cold room

At the end of day 1	At the end of day 2	At the end of day 3	At the end of day 4	At the end of day 5	At the end of day 6	At the end of day 7
0.00	0.00	0.00	0.00	33.33	36.67	43.33

Table 15 Anthracnose rot percentage of strawberry fruit cv. "Sweet Charlie" at RT (n-10)

Fresh fruit	At the end of first day	At the end of second day	At the end of third day	At the end of fourth day
0.00	0.00	0.00	0.00	6.67

Table 16 Anthracnose rot percentage in strawberry fruit cv. "Sweet Charlie" inside cold room (n-10)

At the end of day 1	At the end of day 2	At the end of day 3	At the end of day 4	At the end of day 5	At the end of day 6	At the end of day 7
0.00	0.00	0.00	0.00	13.33	16.67	16.67

Anthracnose rot percentage of Strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room: Anthracnose rot was caused by the fungus *Colletotricum acutatum*. Anthracnose rot percentage increased with storage period at RT, when fruit were taken out of cold storage at the end of day 1, 2, 3, 4 and 5 as shown in (Table 17, Fig 4-D).

Leather rot percentage in strawberry fruit cv. "Sweet Charlie" at RT: Leather rot percentage increased with

storage period at RT; at the end of day 1, 2, 3, 4 and 5 as shown in (Table 18).

Leather rot percentage of strawberry fruit cv. "Sweet Charlie" inside cold room: Leather rot percentage increased with storage period inside Ecofrost as shown in (Table 19).

Leather rot percentage of strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room: Leather rot was caused by the fungus *Phytophthora cactorum.* Leather rot percentage increased with storage period at RT, when fruit were taken out of cold room at the end of day 1, 2, 3, 4 and 5 as shown in (Table 20, Fig 4-B).

Table 17 Anthracnose rot percentage in Strawberry fruit cv. "Sweet Charlie" at RT, after taken out of cold room

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room and placed at RT.	Anthracnose rot percentage (n-10)				
		Room Temperature			
	Cold room	At the end of first day	At the end of second day	At the end of third day	At the end of fourth day
Fresh fruit	0.00	0.00	0.00	0.00	6.67
After eight hours	0.00	0.00	0.00	0.00	6.67
After first day	0.00	0.00	0.00	0.00	20.00
After second day	0.00	0.00	0.00	20.00	23.33
After third day	0.00	0.00	0.00	3.33	6.67
After fourth day	0.00	0.00	10.67	23.33	26.67
After fifth day	13.33	16.67	-	-	-

Table 18 Leather rot percentage in strawberry fruit cv. "Sweet Charlie" at RT (n-10)

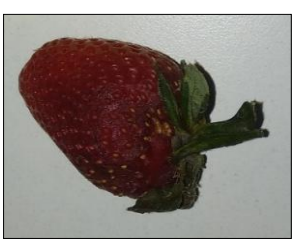
Fresh fruit	At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
0.0	0.00	0.00	0.00	16.67

Table 19 Leather rot percentage in strawberry fruit cv. "Sweet Charlie" inside cold room

At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day	At the end of 5th day	At the end of 6th day	At the end of 7th day
0.00	0.00	0.00	0.00	20.00	20.00	23.33

Mucor piniformis
Fig 4A Mucor Rot

Phytophthora cactorum
Fig 4B Leather Rot



Rhizopus stolonifer
Fig 4C Rhizopus fruit rot

Colletotricum acutatum
Fig 4D Anthracnose fruit rot

Fig 4 Diseases developed inside cold room and at room temperature

Table 20 Leather rot percentage in strawberry fruit cv. "Sweet Charlie" at RT during post-storage period

Fruit cv. "Sweet Charlie" were taken out of cold room and held in RT	Leather rot percentage (n-10)				
		Room conditions			
	Cold room	At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
Fresh fruit	0.00	0.00	0.00	0.00	16.67
After eight hours	0.00	0.00	0.00	6.67	16.67
After first day	0.00	0.00	0.00	6.67	16.67
After second day	0.00	0.00	0.00	16.67	20.00
After third day	0.00	0.00	0.00	3.33	3.33
After fourth day	0.00	0.00	0.00	10	13.33
After fifth day	0.00	20.00	23.33	-	-

Soft rot (Rhizopus rot) percentage of strawberry fruit cv. "Sweet Charlie" at RT: Rhizopus rot percentage increased with storage period at ordinary room conditions; at the end of day 1, 2, 3, 4 and 5 as shown in (Table 21).

Rhizopus rot percentage in strawberry fruit cv. "Sweet Charlie" inside cold room: *Rhizopus* rot percentage increased with storage period inside cold storage as shown in (Table 22).

Table 21 Soft rot (*Rhizopus* rot) percentage in strawberry fruit cv. "Sweet Charlie" at RT

Fresh fruit	At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
0.00	0.00	0.00	0.00	30.00

Table 22 Soft rot (*Rhizopus* rot) percentage in strawberry fruit cv. "Sweet Charlie" inside cold room

At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day	At the end of 5th day	At the end of 6th day	At the end of 7th day
0.00	0.00	0.00	0.00	6.67	10.00	10.00

Rhizopus rot percentage in Strawberry fruit cv. "Sweet Charlie" inside cold room and at RT: Rhizopus rot was caused by the fungus *Rhizopus stolonifer*. Rhizopus rot percentage increased with storage period at RT, when fruit were taken out of cold storage at the end of day 1, 2, 3, 4 and 5 as shown in (Table 23, Fig 4-C).

Table 23 Rhizopus rot percentage in strawberry fruit cv. "Sweet Charlie" at RT, after being taken out of cold room

Strawberry fruit cv. "Sweet Charlie" were taken out of cold room and placed at RT	Rhizopus rot percentage (n-10)				
	Cold room	Room Temperature			
		At the end of 1st day	At the end of 2nd day	At the end of 3rd day	At the end of 4th day
Fresh fruit	0.00	0.00	0.00	0.00	30.00
After eight hours	0.00	0.00	0.00	0.00	23.33
After first day	0.00	0.00	0.00	6.67	23.33
After second day	0.00	0.00	0.00	13.33	16.67
After third day	0.00	0.00	0.00	26.67	30.00
After fourth day	0.00	0.00	3.33	13.33	13.33
After fifth day	0.00	6.67	10	-	-

Inside cold store fruit taste: Fresh fruit taste was recorded on a scale of very good to excellent; likewise, for fruit inside cold storage at the end of day-1, at the end of day-2, at the end of day-3, at the end of day-4 and at the end of day-5, taste was recorded on a scale of very good and excellent, good and very good, good and very good, slight good and good, slight good and good, respectively (Table 24).

Table 24 Hedonic Test: Taste and color of stored strawberry fruit cv. "Sweet Charlie" inside cold room conditions (n-5)

On days tested	Taste (5 Heads)	Color (5 Heads)
Fresh fruits	4.4	4.0
At the end of day-1	4.2	4.0
At the end of day -2	3.6	4.0
At the end of day -3	3.8	4.0
At the end of day -4	2.8	4.2
At the end of day -5	2.8	4.5
Scale for taste	1- Bad; 2- Slight Good; 3- Good; 4- Very Good; 5- Excellent	
Scale for color:	1- White; 2- 50%Yellow; 3- 50% Red; 4- 75% Red; 5- 100% Red.	

Inside cold store fruit color: Fresh fruit colour was recorded to be 75% red; likewise, for fruit inside cold storage at the end of day-1, at the end of day-2, at the end of day-3, at the end of day-4 as well as at the end of day-5, colour was recorded to be 75% red, 75% red, 75% red, between 75% red and 100% red as well as between 75% red and 100% red, respectively, as shown in (Table 24).

Taste of stored strawberry fruit cv. "Sweet Charlie" under RT at the end of day 1, after fruit taken out of cold room on different days: Fresh fruit taste after the end of day 1 in RT was recorded on a scale of very good to excellent; likewise, for fruit taken out of cold room at the end of day-1, at the end of day-2, at the end of day-3, at the end of day-4 and at the end of day-5, taste was recorded on a scale of good and very good, good and very good, good and very good, slight good and good, slight good and good, respectively as shown in (Table 25).

Table 25 Hedonic Test: Taste and color of stored strawberry fruit cv. "Sweet Charlie" under RT at the end of day 1, after fruit taken out of cold room on different days

On days tested	Taste (5 Heads)	Color (5 Heads)
	At the end of day 1 (RT)	
Fresh fruit	4.2	4.0
At the end of day-1	3.2	4.0
At the end of day -2	3.8	3.8
At the end of day -3	3.2	4.5
At the end of day -4	3.0	4.5
At the end of day -5	3.0	4.5
Scale for taste	1- Bad; 2- Slight Good; 3- Good; 4- Very Good; 5- Excellent	
Scale for color:	1- White; 2- 50%Yellow; 3- 50% Red; 4- 75% Red; 5- 100% Red.	

Color of stored strawberry fruit cv. "Sweet Charlie" under RT at the end of day 1, after fruit taken out of cold room on different days: Fresh fruit colour after the end of day-1 in RT was recorded to be 75% red; likewise for fruit taken out of cold room after first day RT at the end of day-1, at the end of day-2, at the end of day-3, at the end of day-4 and at

the end of day-5, colour was recorded to be 75% red, in between 50% red and 75% red, in between 75% red and 100% red, in between 75% red and 100% red and in between 75% red and 100% red, respectively as shown in (Table 25).

Fruit storage inside cold room (4° and 95% RH) showed a longer storage life than room temperature. The shelf life (2.79 days), pre-cooling shelf life (2.97 days), cold storage life (4 days) and post storage shelf life (1.90 days) of fruit cv. "Sweet Charlie" was recorded. At room conditions, a higher rate of quality degradation was recorded. Ascorbic acid and TSS content increased with respect to weight with storage period. Firmness decreased with increasing storage periods. Weight loss, shriveling, decay rot of strawberry fruit increased inside cold room and at RT with time.

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