

**EFFECT OF CALCIUM CHLORIDE AND PACKAGING ON
POSTHARVEST QUALITY OF STRAWBERRY**

A THESIS

BY

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STUDENT ID.: MS-200809



A Thesis (Course No. HRT-6104) Submitted to the Agrotechnology Discipline in Partial
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**KHULNA UNIVERSITY
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AGROTECHNOLOGY DISCIPLINE

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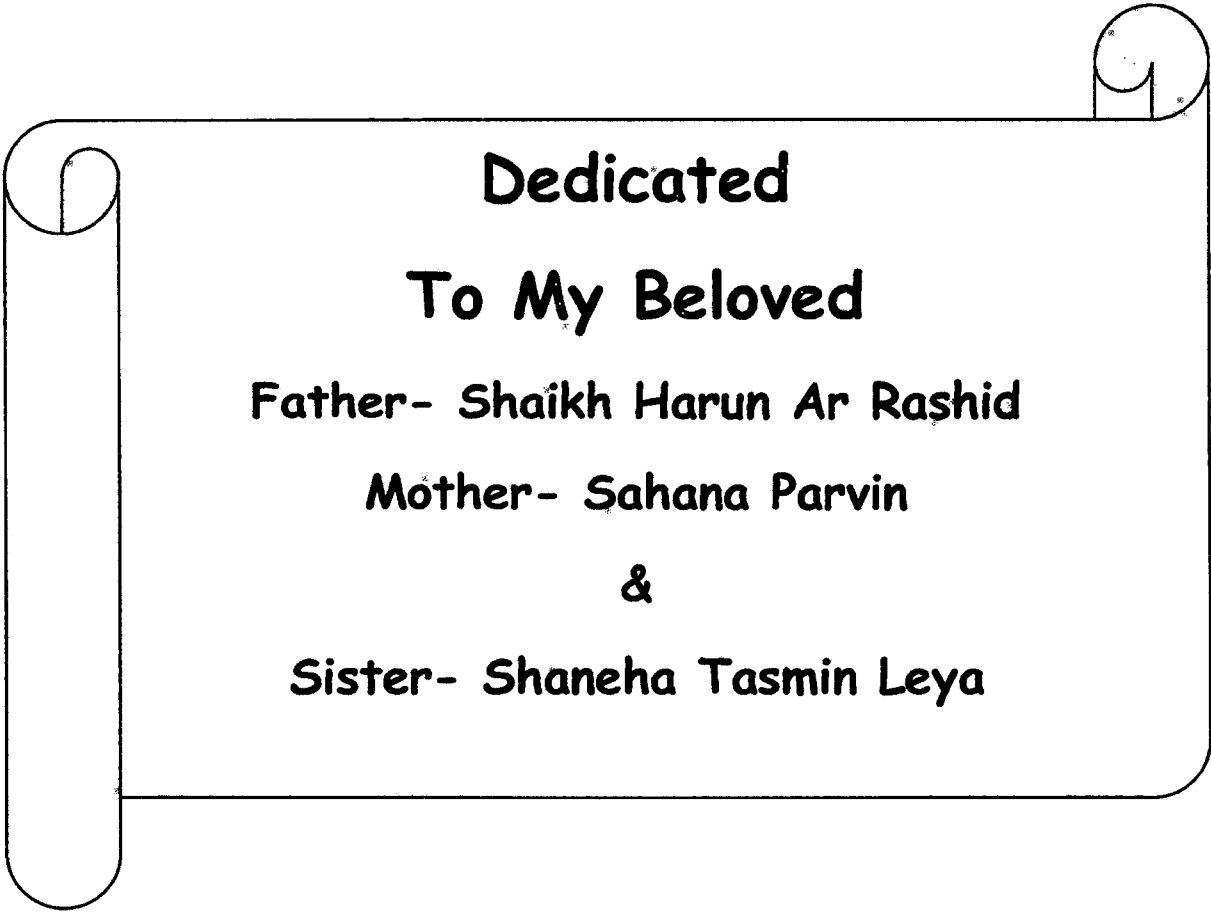
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JUNE 2022



Dedicated

To My Beloved

Father- Shaikh Harun Ar Rashid

Mother- Sahana Parvin

&

Sister- Shaneha Tasmin Leya

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ABSTRACT

Strawberry is an attractive and nutritious fruit grown all over the world. However, its quality is deteriorated rapidly after harvest due to inappropriate postharvest management. The objective of the experiment was to evaluate the effectiveness of calcium chloride and packaging on postharvest quality of strawberry varieties viz. RABI-3 (V1), BARI strawberry-3 (V2) and Festival (V3). The six treatments used here are viz. Control- Ambient condition (T1), No packaging + CoolBot (T2), Paper box packaging + CoolBot (T3), Calcium chloride 1% + paper box packaging + CoolBot (T4), Calcium chloride 2% + paper box packaging + CoolBot (T5) and Calcium chloride 3% + paper box packaging + CoolBot (T6). The experiment was laid out in factorial completely randomized design (CRD) with three replications for the treatments. Changes in physico-chemical characteristics, fruit spoilage and shelf life of fruits were studied during storage. There was marked variation among the varieties RABI-3, BARI strawberry-3 and Festival. Festival (V3) performed best during the study period for minimum fruit weight loss (16.63%), polar diameter (3.99 cm), firmness (15.04 N), p^H (3.56), TSS (8.60%), less fruit spoilage (18.36%) and shelf life (8.55 days). BARI strawberry-3 (V2) showed maximum equatorial diameter (3.74 cm) and ascorbic acid (41.69 mg/ 100 g). RABI-3 was the best for total carbohydrates (7.72 g/100 g), TA (0.65%) and anthocyanin (38.19 mg/100 g). Color values did not differ among the three varieties. On the other hand, T6 (Calcium chloride 3% + paper box packaging + CoolBot) resulted the best for minimum weight loss (6.33%), firmness (13.10 N), total carbohydrates (7.92 g/100 g), TA (0.66%), polar diameter (4.25 cm), anthocyanin (39.68 mg/100 g) and shelf life (9.81 days). T5 (Calcium chloride 2% + paper box packaging + CoolBot) expressed highest ascorbic acid (44.21 mg/100 g) and p^H (3.54). T4 (Calcium chloride 1% + paper box packaging + CoolBot) showed best result for equatorial diameter (4.08 cm) and less fruit spoilage (13.52%) while T3 (Paper box packaging + CoolBot) was higher in TSS (7.36%). Color values were almost similar in all treatments applied to strawberry. As Festival (V3) is superior to other varieties, it could be concluded that Festival (V3) with T6 (Calcium chloride 3% + paper box packaging + CoolBot) would be the best choice for successful postharvest management of strawberry.

Keywords: Strawberry, variety, postharvest, fruit quality, CoolBot, calcium chloride, packaging.

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LIST OF ABBREVIATIONS

CaCl₂	:	Calcium chloride
CRD	:	Completely Randomized Design
DAT	:	Days after Treatment
KU	:	Khulna University
LSD	:	Least Significant Difference
°C	:	Degree Celsius
TA	:	Titrateable Acidity
TSS	:	Total Soluble Solid

CHAPTER I

INTRODUCTION



CHAPETR I

INTRODUCTION

The cultivated Strawberry (*Fragaria x ananassa* Duch.) is an attractive, tasty, luscious and nutritious fruit with a distinct, pleasant aroma and delicate flavor. It is a hybrid of two Native American species; *Fragaria chiloensis* and *Fragaria virginiana*, belongs to the Rosaceae family. The plant comprises a shorten stem or crown from which arises leaves, runners, roots, auxiliary crowns and inflorescences (Maas, 1998; Bowling, 2000; Darnell et al., 2003). Botanically it is an aggregate non-climacteric fruit (Coombey, 1976). The fruit is extensively cultivated in the temperate and subtropical regions in the world. They are grown throughout the Europe, the United States, as well as in Canada, China, Russia, South America and many other countries.

Strawberry comes in Bangladesh as an exotic fruit. Bangladesh has suitable climate in terms of photoperiod, temperature and humidity to cultivate strawberry. A number of varieties have been developed by different research organizations such as Bangladesh Agricultural Research Institute (BARI) (BARI Strawberry-1, BARI Strawberry-2, BARI Strawberry-3); Rajshahi University (Rabi-1, Rabi-2 and Rabi-3); Bangladesh Agricultural University (FTIP-BAU Strawberry-1); Bangladesh Agricultural Development Corporation (BADC Strawberry); Modern Horticulture Center, Natore (Modern Strawberry-1, Modern Strawberry-2, Modern Strawberry-3, Modern Strawberry-4, Modern Strawberry-5). Significant differences on field- and postharvest performances were reported among strawberry cultivars in Bangladesh (Ahsan et al., 2014; Rahman et al., 2014; Chowhan et al., 2016). In this instance, choice of cultivars is of paramount importance (Asrey and Singh, 2004; Ahsan et al. 2014).

The postharvest quality of fruit comprises of fruit weight, color index, polar diameter, equatorial diameter, TSS, p^H , anthocyanin content, carotenoid content, flavonoids, total phenol content, carbohydrate content, ascorbic acid, firmness of fruit, titratable acidity, riboflavin content, decay (%), shelf life of fruit etc. (Kader, 2002). These quality parameters can be retained by refrigeration, precooling, edible coatings, water/ heat/ edible oil or chemical treatments and packaging (Azam et al., 2019).

Strawberry is a highly perishable fruit due to their soft texture, extreme tenderness, high level of respiration, high rate of softening and excess sensitivity to fungal attack (Hernández-Muñoz *et al.*, 2006). Postharvest losses of strawberry are extreme (25-40%) due to inappropriate management practices, poor handling, low quality packaging and poor storage condition (Aday and Caner, 2014). Quality declines rapidly after harvest may be less than a week (Wills *et al.*, 1998). Strawberries should be kept at 0-4°C to retain fruit quality (Khreba *et al.*, 2014).

Besides this, Calcium Chloride application can be useful for maintaining strawberry fruit quality (Astuti *et al.*, 2013). Calcium contributes in improving the rigidity of cell walls; retard tissue softening also reduces the accessibility of cell wall degrading enzymes to their substrates (Lurie, 2009). Moreover, calcium is considered to be an important mineral element that regulates fruit quality such as maintenance of fruit firmness, retaining ascorbic acid, decreasing postharvest decay and fungal attack without affecting sensory quality (Garcia *et al.*, 1998; Luna-Guzman and Barrett, 2010).

Additionally, packaging is also an eco-friendly approach to retain the fruit quality of strawberry during storage condition (Khalid *et al.* 2020). Polythene, plastic box, paper box, plastic punnets, zipper box and aluminum foil paper box can be used as packaging material. Fruits packed with bio-based film and stored at 2°C showed best results to maintain fruit quality during storage (Peano *et al.*, 2014).

However, some postharvest treatments have negative impact on flavor, taste, color and texture resulting in decline of the consumer acceptability in the market. Therefore; the use of harmless materials as calcium chloride and use of paper box packaging to control physiological processes draws increasing interest (Garcia *et al.*, 1996).

In Bangladesh, no or very little research work are available on the effect of calcium chloride and packaging on strawberry. Considering above facts, the present study has been undertaken with a view to evaluate the effect of calcium chloride and packaging on postharvest performance of different strawberry varieties with following objectives-

1. To evaluate the effectiveness of calcium chloride and packaging for improving fruit storability of strawberry varieties.
2. To identify the best concentration of calcium chloride to extend the shelf life and maintain the fruit quality of strawberry.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

Strawberry is a popular fruit in Bangladesh as well as all over the world. There are many popular strawberry varieties in cultivation. Physico-chemical properties of strawberry vary from variety to variety. Researchers have done many varietal evaluation of strawberry in respect of postharvest performance. In Bangladesh, some developed varieties are available but there is lack of data regarding postharvest performances of strawberry varieties. Azam et al. (2019) stated the available postharvest treatments of strawberry eg. physical treatments, chemical treatments, thermal treatments, modified atmosphere, edible coatings and combined treatments with several packaging materials. Among these, calcium chloride and packaging were chosen for present study as there is a scarce of detailed study in this regard in Bangladesh. Some existing and important research works related to present study have been reviewed below.

2.2 Postharvest performances of strawberry varieties

2.2.1 Festival

Ahsan et al. (2014) and Das et al. (2015) expressed the superiority of Festival over RABI-3 and Camarosa in respect of fruit weight, fruit length, disease resistance and TSS (%). Similarly Rahman et al. (2014) reported higher fruit weight in Festival than Sweet Charlie, Camarosa and BARI strawberry-1. Chowhan et al. (2016) found maximum non reducing sugar in Festival.

2.2.2 RABI-3

Chowhan et al. (2016) observed highest ascorbic acid and iron content in RABI-3 compared to Camarosa, Festival and BADC strawberry. But Ahmed et al. (2014) found minimum fruit weight, fruit length and TSS (%) in RABI-3 compared to Festival and Camarosa.

2.2.3 Camarosa

Maximum reducing sugar was observed in Camarosa as reported by Chowhan et al. (2016). Ahmad et al. (2018) and Neetu and Verma (2020) also recommended Camarosa for its maximum fruit length, fruit diameter, fruit weight, ascorbic acid, TSS, TA and organoleptic score.

2.2.4 BARI strawberry-1

According to Chowhan et al. (2016), BARI strawberry-1 contains highest potassium. Akter et al. (2018) also found maximum ascorbic acid and carotene content in BARI strawberry-1.

2.2.5 Chandler

Nagre et al. (2005), Kumar et al. (2016) and Sharma and Thakur (2008) expressed highest fruit weight, TSS and total sugar in Chandler.

2.2.6 Other varieties

Temocico et al. (2019) and Hossain et al. (2016) analyzed seven and four genotypes respectively for nutrient composition and found significant differences. Uddin et al. (2016) stated that SAU germplasm-1 contains maximum fruit weight. Dhakal et al. (2022) recommended EMCO-32 and EMCO-33 variety for best postharvest performances. Kim et al. (2018) observed higher ascorbic acid content in Arihyang variety than Seolhyang. Nabila variety is recommended by Neetu (2018) and Sweet Ann and Ruby June is recommended by Das and Samtani (2021). Elsanta variety showed maximum disease resistance as reported by (Nes, 1996). Chandel and Badiyala (1996) and Ram and Yadav (2006) identified Belrubis variety containing highest TSS and total sugar. Kumari et al. (2020) recommended Elyana variety for bigger fruit size, Selva for TSS content and Sweet Charlie for total sugar.

2.3 Physical characteristics of strawberry varieties

2.3.1 Fruit diameter

Festival provides maximum fruit diameter as reported by Ahsan et al. (2014), Das et al. (2015) and Rahman et al. (2014). But Ahmad et al. (2018) and Neetu and Verma (2020) recommended Camarosa for maximum fruit diameter.

2.3.2 Fruit weight

Rahman et al. (2014) found maximum fruit weight in Festival where Ahmad et al. (2018) and Neetu and Verma (2020) expressed Camarosa as best in respect of individual fruit weight. Nagre et al. (2005), Kumar et al. (2016) and Sharma and Thakur (2008) observed highest fruit weight in Chandler variety.

2.3.3 Fruit firmness

Nes (1996) reported that Elsanta variety retains fruit firmness highly. Better firmness as observed in chandler as reported by Nagre et al. (2005).

2.3.4 Fruit color

There is significant variation present in varieties of strawberry as reported by Koyuncu (2004).

2.4 Chemical characteristics of strawberry varieties

2.4.1 p^H

Dhakal et al. (2022) showed highest p^H in EMCO-33 and Aziz et al. (2018) found the highest p^H in Chandler variety.

2.4.2 TSS (%)

Ahsan et al. (2014) and Das et al. (2015) expressed the superiority of Festival in respect of TSS (%). On the other hand, Ahmad et al. (2018) and Neetu and Verma (2020) recommended Camarosa for TSS. Nagre et al. (2005), Kumar et al. (2016) and Sharma and Thakur (2008) expressed highest TSS in Chandler. Chandel and Badiyala (1996) and Ram and Yadav (2006) identified Belrubi variety containing highest TSS and Kumari et al. (2020) recommended Elyana variety for higher TSS.

2.4.3 Total carbohydrates

Nagre et al. (2005), Kumar et al. (2016) and Sharma and Thakur (2008) found highest total carbohydrates in Chandler. Chandel and Badiyala (1996) and Ram and Yadav (2006) identified Belrubi variety containing highest total carbohydrates. Kumari et al. (2020) recommended Sweet Charlie for total carbohydrates.

2.4.4 Ascorbic acid

Chowhan et al. (2016) observed highest ascorbic acid in RABI-3. Akter et al. (2018) found maximum ascorbic acid in BARI strawberry-1. Kim et al. (2018) observed higher ascorbic acid content in Arihyang variety than Seolhyang.

2.4.5 Mineral nutrients

Aktar et al. (2018) and Hossain et al. (2016) found significant variation on mineral nutrients (Ca, P, MG, Na, K, Mn, Zn, Cu and Fe) among strawberry genotypes.

2.5 Shelf life of the fruit

Shelf life of fruit varies from variety to variety as reported by Akter et al. (2018) and Nes (1996).

2.6 Fruit spoilage

The varietal differences may be a cause for fruit spoilage. Das et al. (2015) got Festival variety as superior in respect of high disease resistance. Nes (1996) reported that Elsanta variety of strawberry is more resistant to spoilage than other varieties.

2.7 Effect of postharvest treatments

Calcium chloride, packaging and some other postharvest treatments on strawberry significantly influence the fruit quality parameters. The literature on postharvest treatments related to present study are reviewed below.

2.7.1 Treatments with calcium chloride

Turmanidze et al. (2016) conducted an experiment on Calcium chloride treatments on quality characteristics of Strawberry after cold storage. After harvesting, Strawberry fruits were immediately treated with 1% and 2% Calcium Chloride by immersion at $20\pm 1^{\circ}\text{C}$ for 2.5 minutes and kept for 8 days at $0\pm 0.5^{\circ}\text{C}$ and relative humidity (RH) of $90\pm 5\%$. They observed maximum weight loss in untreated berries and minimum in 2% Calcium Chloride treated ones. They also observed highest retention of ascorbic acid, polyphenol content, antioxidants in strawberry while the fruits were treated with 2% Calcium Chloride.

Effect of 3% Calcium Chloride increased the strawberry fruit hardness and shelf life (Zun et al., 2020).

CaCl₂ maintains the postharvest quality of strawberry. Strawberry fruit treated with 10% CaCl₂ were freshest during the whole storage. CaCl₂ could also retard the mycelial growth and spore germination of *Botrytis cinerea*, and decrease the incidence of gray mold rot in strawberry fruit significantly (Zhao et al., 2013).

According to Cheour et al. (1991), Calcium chloride has considerable effect on amounts of free sugars and organic acids, color, texture, and disease development in Strawberry fruits during storage at 4°C.

However, Calcium Chloride 1% treatment on strawberry showed no effect on the sensory quality of strawberry fruits. It also enhanced the Ca content, controlled Postharvest decay, maintained firmness and total soluble solid content as reported by Garcia et al. (1996).

Atri et al. (2008) found that two and three times of foliar application of CaCl₂ with zero, 0.3 and 0.5 percentages (w/v) significantly reduced strawberry fruit decay and enhanced the fruit shelf life. They added that foliar application of CaCl₂ has less effect on other fruit quality parameters.

According to Dukani et al. (2018), 0.5% of CaCl₂ treatment showed the decrease in the loss of fresh weight (%) and decay (%) while retain berry hardness (N), increased total soluble solids (TSS %) and calcium content (mg/100 g) in strawberry fruits.

Calcium chloride 300 mg/l have been found to increase the Polyphenol Oxidase activity and enhance the antifungal properties of strawberry as it was reported by Jannati and Abdoosi, (2014).

Wan Mahfuzah et al. (2012) evaluated the physical changes (weight loss, colour and firmness), chemical changes (TSS and pH), sensory evaluation and overall appearance on 0, 3, 8 and 12 days of storage (10°C) of strawberry fruits. Calcium chloride (1%) treatment showed less weight loss (0.123%) as compared to fruits treated with 2% (0.17%) and 3% (0.5%) at the end of storage period. Calcium chloride (1%) treatment also maintained more fruit firmness with deep red color development than the other fruits (2 and 3% calcium treated

and control fruits) as observed on day 8 and 12. They did not observe any fungal attack for both treated and control fruits and concluded that both control and treated fruits still could be eaten after 12 days of storage while 1% treated fruits showed better taste acceptance. P^H and TSS values showed no significant changes throughout the 12 days storage period as noted both in the control and treated fruits.

According to Langer et al. (2019), Strawberry fruits dipping in 10 gm per liter of Calcium Chloride solution increased fruit firmness, polyphenol oxidases, chitinases, peroxidases and β -1, 3-glucanases as well as prevented fungal pathogen growth effectively.

Moradinezhad et al. (2019) suggested that dipping of Jujube fruits in 1% Calcium chloride solution increased the crispness of fruit but decreased the amount of Total soluble solids (TSS). There was no change in pulp color and anthocyanin content of fruits after treatment.

Akhtar et al. (2010) carried out an experiment on the effectiveness of Calcium chloride treatments on postharvest quality and storage behavior of “Surkh” cultivar of loquat. They concluded that 1% $CaCl_2$ has no significant effect on quality parameters of the fruit compared to control treatment, whereas, 2% and 3% $CaCl_2$ were effective for retaining maximum firmness, TSS and ascorbic acid content. It also reduced browning index (BI), relative electrical conductivity (REC) and weight loss.

Minh (2022) reported that Banana fruits dipped in 3% $CaCl_2$ has a positive effect in reducing spoilage (2.24 ± 0.11 mark); retaining texture firmness (7.25 ± 0.10 N); increasing the extractable juice recovery ($85.49 \pm 1.12\%$); maintaining ascorbic acid (12.79 ± 0.13 mg/100 g), total soluble solid (16.40 ± 0.13 °Brix), phenolic retention (161.35 ± 1.19 mg GAE/100 g), flavonoid content (64.41 ± 0.25 mg QE/100 g) and H_2O_2 accumulation (20.09 ± 0.10 μ mol/g); improving carotenoid (21.83 ± 0.13 μ g/100 g), catalase (15.28 ± 0.12 U/g), superoxide dismutase activity (5.60 ± 0.10 U/g), antioxidant capacity of banana fruit ($46.20 \pm 0.15\%$) during cold storage (at $4 \pm 0.5^\circ C$ with 85-90% relative humidity).

Kirmani et al. (2013) applied 0.5% $CaCl_2$ on Plum which showed minimum weight loss, maximum retention in fruit firmness and minimum spoilage.



Reyes-Medina et al. (2017) proved that application of calcium chloride on Gooseberry delayed ripening and stopped early fruit deterioration. But it did not change the color properties of fruits.

Sati and Qubbaj (2021) recommended 6% calcium chloride in combination with postharvest coating with either 10% Arabic gum or 50% cactus mucilage for 3 minutes for high fruit firmness, titratable acidity, less weight loss and less spoiled tomato fruits.

According to Mahmud et al. (2008), Papaya fruits treated with 2.5% calcium chloride has the ability to control disease incidence, prolong the storage life and retain valuable attributes of postharvest papaya.

Awang et al. (2011) conducted an experiment on effect of calcium chloride on anthracnose disease and postharvest quality of red-flesh dragon fruit (*Hylocereus polyrhizus*). The fruits were treated with CaCl_2 varying concentrations of 0, 1.0, 2.0, 3.0 and 4.0 $\text{CaCl}_2 \text{ gL}^{-1}$. Calcium chloride applied at different concentrations did not produce major effect on anthracnose incidence, but the size of lesion was linearly reduced with increasing Ca concentration.

Sohail et al. (2015) carried out an experiment on effect of calcium chloride treatment on post-harvest quality of peach fruit during cold storage. They used CaCl_2 (1%, 2%, 3%) solution for dipping peach fruit for 5 minutes. After that, they placed those fruits in cold storage at 10°C and $75\pm 5\%$ RH. Calcium chloride 1% treated fruits did not represent any significant results. 2% calcium chloride treated fruits showed little improvement, while 3% CaCl_2 retained maximum firmness, TSS, ascorbic acid content and reduced decay index and weight loss as compared to control.

Bagheri et al. (2015) evaluated the storage life and quality of persimmon (*Diospyros kaki* Thunb.) fruit cv. 'Karaj induced by 0.5%, 1% and 2% CaCl_2 . They observed that the fruit weight loss and chilling injury significantly decreased by CaCl_2 treatments compared with the control. CaCl_2 treatments also increased fruit firmness and catalase and antioxidant activities. They concluded that 2% calcium chloride is best in almost all the studied parameters during cold storage (4°C) for 4 months.

2.7.2 Treatments with packaging materials

According to Khalid et al. (2020), packaging materials significantly reduce the fruit weight loss. They used polyethylene package. The p^H , TSS, titratable acidity were decreased during storage condition.

Godana et al., (2018) reported that different packaging materials with controlled atmosphere can enhance shelf-life and postharvest quality of fruits. Three different packaging materials (carton, jute bag, and newspaper) and three different post-harvest treatments (ginger, clove, hot water) treatment at 55°C for 40 seconds were used. An ambient control was also employed. Fruits packed in cartons and treated with ginger (8 days) showed the best results, followed by fruits packed in cartons and treated with clove (8 days). All three postharvest treatments and packaging methods can extend the shelf life and improve other quality criteria of fruits.

Life⁺ system packaging has a positive influence on the visual appearance, the organoleptic traits and the weight loss of strawberries. Active packaging reduced the microbial proliferation and the loss of product (Giacalone and Chiabrando, 2017).

Peano et al. (2014) compared bio-based and polypropylene perforated films as packaging materials. Fruits packed with bio-based film and stored at +2°C showed the best results to retain fruit quality for all the storage time.

Panda et al. (2016) packed freshly harvested fruits in plastic punnets and wrapped with different packaging materials viz., low-density polyethylene (LDPE) 25, 50 and 75 micron, polypropylene (PP) 25 micron, cellophane paper and cling film. Effect of all the packaging materials was observed in ambient storage condition (18-25 °C and 80-90% RH). They found that LDPE 50 micron packaging material was the most effective one to control the weight loss (5.49%) and all of the LDPE films along with the PP and cling films appeared best to minimize decay loss. Ascorbic acid in strawberry fruits packed with LDPE 50 (31.56 mg/ 100g) and 75 micron (29.86 mg/ 100g) packaging films retained successfully. The organoleptic rating of strawberry fruits was best in fruits packed with LDPE 50 micron (7.90) packaging films.

According to Lee et al. (2003), strawberry packaged with low density polyethylene (LDPE) and stored at 4°C showed decreased decay of fruit and weight loss percentage for packaged.

Nunes et al. (2015) compared wrapped PVC polymeric film and non-wrapped fruits. Evaluations were done after storage for one week at 1°C plus one day at 20°C. They observed that wrapped strawberries maintained better appearance and quality than non-wrapped berries.

2.7.3 Combined effect of CaCl₂ and other materials

Amal et al. (2010) stated that all treatments including soy protein + CaCl₂ coating film and Wheat gluten + CaCl₂ coating film maintained ascorbic acid content, firmness, TSS, total sugar and reduced the colony, molds, yeasts compared to control. CaCl₂ coated fruits also showed lowest weight loss percentage.

Nguyen et al. (2020) recommended that storing the strawberry fruit with 3% CaCl₂ and 0.5% Nano chitosan at 0°C is highly effective in retaining the overall quality index of strawberries up to 21 days. The treatment also significantly reduced weight loss, preserved ascorbic acid content, antioxidant capacity, and total anthocyanin content, prevented microbial growth and prolonged storage-life of treated strawberries up to 21 days.

Suutarinen et al. (2000) studied that CaCl₂ and sucrose prefreezing treatments stabilized the structure of strawberry tissues positively with more stable pectin, lignin, protein and structural carbohydrate components after freezing and thawing.

Kumar et al. (2020) observed the biochemical properties of Strawberry cv. camarosa by the pre-harvest application of Chitosan, Calcium Chloride and low temperature storage (7°C) condition. The experiment showed higher TSS, anthocyanin and marketability than untreated fruits. The results also suggested that environment friendly chemical compounds can be a suitable option for reducing weight loss and extending shelf life of strawberry fruits.

Shahzad et al. (2020) described that pre-harvest application of Calcium Chloride and salicylic acid (SA) may be used as an alternative to synthetic fungicides for controlling decay problem and to extend the shelf life of harvested strawberry fruits. They dipped marketable fruits in different concentrations of CaCl₂ (2, 4, 6 mM) and SA (3, 5, 7 mM) solutions for 10 minutes along with control (simple water) and stored at 4°C with 80-85% relative humidity for 15 days. They collected data on fruit quality parameters during 0, 3, 6, 9, 12, 15 days after storage. Finally, they concluded that pre storage dipping of strawberry fruits in CaCl₂ (6mM) and SA (5mM) for 10 minutes can be used successfully to minimize the decay %, weight loss % and

to maintain the quality related parameters of strawberry fruits during 15 days of cold storage (4°C).

According to Rahimi et al. (2018), coated strawberry with Chitosan and CaCl_2 significantly reduced the loss of weight and firmness of fruit. These fruits also retained higher TSS, anthocyanin and ascorbic acid. They mentioned, “Edible coatings have potentials as a means to reduce postharvest spoilage in strawberry fruit.”

Guan et al. (2006) conducted an experiment on effect on quality of strawberry fruit by dipping in Calcium solution with modified atmosphere (MA) packaging. They dipped fresh Strawberry fruits at 1% CaCl_2 for 20°C and 45°C for 15 minutes. Then they packaged the fruit with or without PE film (0.011 mm thickness) before storing it into cold storage at 5°C. It showed that CaCl_2 treatment at 45°C with packaging expressed with lowest rate of rot incidence, higher vitamin C, higher firmness and best superficial appearances of Strawberry fruits. They also observed a decrease in the P^{H} and increase in titratable acidity and suggested that the combination of postharvest calcium dipping and packaging could result in more effective preservation than individual treatment.

Bola et al. (2017) carried out an experiment on efficacy of calcium chloride, carboxymethyl cellulose (CMC) and chitosan on the shelf-life of strawberry (*Fragaria x ananassa* D.). They dipped Strawberry fruit for 5 min in Calcium Chloride (1%, 2% and 3%) and CMC (1%, 2% and 3%) alone and in combination with chitosan 1% for 5 minutes and kept them on paper sheet for air drying in shade for 30 minutes. After treatment, they packed the fruits of each lot in specially designed “punnets” which are made up of propylene material. Then they stored these fruits in refrigerated condition at $4\pm 10^\circ\text{C}$ and 85-90% relative humidity. The uncoated fruit were treated as control. The researchers observed significant delays in the change of weight loss, spoilage percentage, P^{H} , total soluble solids (TSS) and anthocyanin content in case of fruit coated with edible coatings as compared to uncoated control fruit.

Mozhdehi et al. (2012) evaluated the effect of packing system, calcium chloride and chlorine on storage life of strawberry fruits. Fresh fruits were treated with chlorine (calcium hypochlorite at 0, 25, 50 and 100 ppm and sodium hypochlorite at 0, 25, 50 and 100 ppm with distilled water) for one minute and then again treated with different grades of Calcium Chloride 0, 0.5, 1 and 1.5 percentage for five minutes. These fruits were then divided to two

groups; packed and non-packed with plastic cover. The fruits were then evaluated for changes in quantity parameters; pH, TA (Titratable acidity), TSS (Total soluble solids), Dry and fresh weight ratio, water content, Anthocyanin, Ascorbic acid, Ca^{2+} , Sugar and pectin. They observed that the packed fruits treated with Calcium Chloride (at 0.5% and 1%) and chlorine (at 50 ppm) survived better when compared with non-packed fruits. Combined effect of CaCl_2 and chlorine showed significant effect on anthocyanin, ascorbic acid and sugar content and these traits were increased. Other interaction effects were not considerably significant.

Alharaty and Ramaswamy (2020) worked on the effect of a sodium alginate-Calcium Chloride edible coating on quality preservation and shelf-life extension of strawberry cut fruits stored at cold storage (4°C). The coated fruit samples were mold free up to 15 days whereas control samples showed mold growth after one week of storage at 4°C . The sodium alginate-Calcium Chloride edible coating was highly efficacious in lowering respiration and transpiration rates and slowed down the increase of the pH and soluble solid content. Moreover, the coating retarded surface mold growth for up to 15 days and preserved the sensory properties of the Strawberry fruits such as color, odor, texture and general appearances.

Kumar et al. (2021) reported that storability and biochemical quality of strawberry fruits (cv. Winter Down) stored in cold conditions ($3\pm 1^\circ\text{C}$) are significantly influenced by packaging material (PET Punnet and HDPE crates) and calcium compound (CaCl_2 and $\text{Ca}(\text{NO}_3)_2$) compared with untreated control fruits stored at ambient conditions ($26^\circ\text{C}\pm 3^\circ\text{C}$). CaCl_2 (2%), packed in polypropylene terephthalate (PET) stored in cold conditions showed best results for enhancing the storability of Strawberry fruit by a significant reduction in the physiological loss in weight and decay percent and sustained the biochemical quality of fruit. Untreated fruits at ambient conditions spoiled faster than the treated fruits in respect of physiological loss in weight and fruit decay.

2.8 Effect of CoolBot storage on fruits

According to Sunil et al. (2013), CoolBot is a device which turns a conventional room air conditioner into a produce cooler. It is a low cost storage system which is highly-insulated room and can be transformed into a walk-in cooler. It is thermostatically controlled and keeps the commodity fresh by cooling it down to $4\text{--}5^\circ\text{C}$. They studied the effectiveness of Coolbot storage using vegetables viz. cauliflower, cabbage, tomato and okra. Different parameters viz.

physiological weight loss and visual quality which determines the shelf life and marketability of the produce were studied. A significant variation was recorded in physiological weight loss of all the vegetables under control and CoolBot condition. Vegetables stored under cool room conditions showed higher visual sensory score than those stored under ambient conditions. A direct relationship was observed between pulp temperature and physiological weight loss. They stated that the Coolbot storage maintains the low storage temperature and optimum relative humidity thus keeping produce fresh, firm, visually appealing and marketable. Besides it is low cost and therefore, can successfully be used by the farmers for storage of their fresh produce to maintain their market quality and to get good price from the market even after storage.

Poudel et al. (2021) kept capsicum at coolbot storage ($9.8 \pm 2^\circ\text{C}$, $86 \pm 5\%$ RH) till 30 days and analyzed for various postharvest physical, chemical and physiological parameters at every 10, 20 and 30 days of storage. The result showed that in CoolBot condition, Low Density Polyethylene (LDPE) packaging influenced on reduction of physiological loss in weight (PLW), spoilage loss, ascorbic acid content, TA, freshness, firmness and shelf life.

Tac-an et al. (2019) evaluated the quality of two maturities (reddish purple, dark purple) of mangosteen fruit stored in ambient and CoolBot (10°C) conditions for 14 and 42 days, respectively. CoolBot is an electronic gadget attached to a digital air conditioner to adjust the temperature of an insulated room. All sample fruit had at least seven days of shelf life in ambient while 28 days in Coolbot conditions. Peel color was maintained until four days under ambient condition. In both storage conditions, total soluble solids (TSS) and pericarp hardening were higher in dark purple fruit. Reddish purple fruit had higher L^* (lightness), a^* (green-red scale), b^* (blue-yellow scale), chroma, and hue. Fruit in CoolBot storage conditions had better visual and calyx quality, lower weight loss, higher total soluble solids (TSS), delayed onset of pericarp hardening, delayed peel color development, and higher L^* , a^* , b^* . Chilling injury did not vary between fruit maturities stored in CoolBot. TSS, visual and calyx quality of mangosteen fruit at 7 and 14 days were not affected by the interaction of maturity and storage condition. Storage in CoolBot (10°C) of reddish purple mangosteen fruit is a potential technique in maintaining fruit quality until 28 days.

Weight loss was lower in chitosan treated tomato fruit stored in the CoolBot chamber than that under ambient conditions (Leak et al., 2015). Peoun et al. (2015) got similar effect on CoolBot storage using leaf mustard vegetable.

According to Karithi (2016), conventional cold rooms are expensive and unaffordable for majority of the horticultural smallholder farmers. This has necessitated research in alternative low-cost storage systems. The CoolBot technology is one such technology that has been used effectively in many countries for various commodities. He confirms the efficacy of the CoolBot technology to lower and maintain low temperatures in an insulated storage room thereby preserving quality and extending shelf life of mango fruits. The technology can therefore be promoted as a low-cost alternative cold storage option for adoption by smallholder mango farmers.

2.9 Conclusion

From the above review of literature it could be said that CaCl_2 treatments in combination with packaging may be suitable for selecting successful postharvest management of strawberry which increases the shelf life and retains fruit physical and chemical properties. But there is a scarce of research works present based on Calcium chloride and packaging on strawberry varieties in Bangladesh. For this instance, the present study was undertaken to provide an eco-friendly and cheap method of postharvest management of strawberry.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials used and methods followed during conducting the experiment. It includes detailed information about experimental site, storage room, experimental design and layout, varieties and treatments with determination of physical and chemical characteristics of fruit.

3.1 Experimental Site

The experiment was conducted at the Horticulture Laboratory of Agrotechnology Discipline and CoolBot Storage room, Khulna University (KU), Khulna, during the period from 30th March to 12th April 2021.

3.1.1 CoolBot storage room

A CoolBot room was developed following the procedure outlined by the Horticulture Innovation Laboratory, USA. The room was totally concealed and insulated, and the temperature was adjusted by a CoolBot (Store It Cold, USA) panel. The developed CoolBot facility takes <2 hours to reach the lower limit of room temperature ($6 \pm 2^{\circ}\text{C}$). The relative humidity (RH) of the CoolBot room is 90-95 % and the different dimensional factors of the CoolBot room are as follows-

Storage room facility outside dimension: 7 ft $\times$ 9 ft $\times$ 10 ft

Storage room facility inside dimension: 6 ft $\times$ 8 ft $\times$ 9 ft

Storage room facility door dimension: 0.1 ft $\times$ 3 ft $\times$ 7 ft

Floor area= 48 sq-ft

3.2 Climate

The maximum and minimum temperature of the CoolBot storage room was maintained as 8^oC to 4^oC with relative humidity of 90-95%. The temperature of Horticulture Laboratory ranged from 26^oC to 31^oC with relative humidity 80-90%. The temperature and relative humidity were recorded with a digital thermo-hygrometer.

3.3 Experimental materials

Three Strawberry varieties, namely, Rabi-3, BARI strawberry-3 and festival were collected from farmer's field of Jhikargacha of Jashore under Khulna division during morning hours. Mature harvested fruits were almost uniform in size. The total amount of fruits harvested was approximately 15 kg. After harvesting, the fruits were precooled through fan to remove field heat. These fruits were then transferred immediately to Khulna University area (storage room) without any physical damage. A short description of three strawberry varieties is presented below.

3.3.1 RABI-3

Professor Dr. Manjur Hossain of the Department of Botany of Rajshahi University (RU), pioneered the local strawberry farming using tissue culture method. Dr. Manjur's research evolved RU-1, RU-2 and RU-3 (RABI-1, 2, 3) varieties of strawberry through tissue culture method using 'Somaclonal Variation Technology' at the Plant Breeding and Gene Engineering Laboratory at Botany Department of RU in 2007.

Planting time of RABI-3 is September to October. Suitable soil P^H is 6-7. Average number of this fruit and fruit weight is 39 and 20-25 g respectively. Fruit shape is conical, reddish in color with good aroma. Average shelf life of fruit is 2-3 days. The variety RABI-3 grows well in all over the country (Ara et al., 2013).

3.3.2 BARI Strawberry-3

This variety was developed by Horticulture Research Center, Bangladesh Agriculture research institute, Gazipur in 2015. Number of fruits per plant is 38.63 (avg.). Single fruit weight is 19.97 g. It is a high yielder (770.86 g/plant) variety. Fruit is long conic shaped, highly uniform, larger in size, attractive dark red color, very firm textured with excellent flavor. Ripe fruits are sour and sweet in taste (TSS 10.5%). It also contains ascorbic acid as 72 mg/100g. Average shelf life of this fruit is 3 days in ambient condition. Planting season and time is 1st week of October. Harvesting time is January to April. Yield is 14-18 t/ha (Mia, 2022).

3.3.3 Festival

Strawberry Festival was originated from a cross between 'Rosa Linda' (Chandler et al., 1997) and 'Oso Grande' (Voth and Bringhurst, 1989). Festival is a short-day variety which produces multiple runners if planted in early October in central Florida. Average petiole length is 120 mm. Average length and breadth of leaflets is 78 and 73 mm for terminal leaflets, respectively, and 69 and 72 mm, respectively, for secondary leaflets. The calyx is big and showy. The fruits are generally conical in shape. The external color of fully mature fruit is deep red and glossy; internal color is bright red. Average fruit weight is 15-18 g. These fruits have a very firm texture and excellent flavor (Chandler et al., 2000).

3.4 Experimental design and layout

The experiment was laid out in the factorial Completely Randomized design (CRD). Here the factors were considered as the strawberry varieties and postharvest treatments. Days after treatment (DAT) was also considered as one of the factors in this study. For each replication of a treatment, approximately 250 g of freshly harvested strawberry fruits were used.

3.5 Treatments

Factor A. Variety (3)

- (a) RABI-3 (V1)
- (b) BARI Strawberry-3 (V2)
- (c) Festival (V3)

Factor B. Postharvest treatments (6)

- (a) Control- Ambient condition (T1)
- (b) No packaging and keeping in CoolBot storage room (T2)
- (c) Paper box packaging and keeping in CoolBot storage room (T3)
- (d) Treatment with 1% calcium chloride with paper box packaging and keeping in CoolBot storage room (T4)
- (e) Treatment with 2% calcium chloride with paper box packaging and keeping in CoolBot storage room (T5)
- (f) Treatment with 3% calcium chloride with paper box packaging and keeping in CoolBot storage room (T6)

3.6 Application of postharvest treatments

The postharvest treatments were applied to randomly selected strawberry fruits. Freshly harvested fruits were dipped in Calcium chloride solution for 2 minutes. Some fruits as control were left at Horticulture Laboratory in ambient conditions. Fruits treated with Calcium chloride were kept in CoolBot storage conditions. Each treatment comprises of 250 g of fruits in each of the three replications. Postharvest treatments used in each variety are described below.

Control in ambient condition (T1)

Strawberry fruits (250 g) of each variety were selected randomly and the fruits were kept on paper in the Laboratory room at ambient conditions in three replications.

No packaging and keeping in CoolBot storage room (T2)

Randomly selected 250 g of Strawberry fruits of each variety were kept on paper without packaging and left in the CoolBot storage room in three replications.

Paper box packaging and keeping in CoolBot storage room (T3)

Strawberry fruits (250 g) of each variety were selected randomly and the fruits were placed in a paper box packaging at CoolBot storage room in three replications.

Calcium chloride (1%, 2% and 3%) treated fruit packed in paper box and kept in CoolBot storage room (T4, T5 and T6)

Randomly selected Strawberry fruits (250 g) of each variety were dipped in 1%, 2% and 3% CaCl_2 for 2 minutes. The Calcium chloride solutions were prepared by dissolving 1g, 2g or 3g of CaCl_2 in 100 ml of distilled water and stirred gently by a glass rod. After dipping, the fruits were allowed to air dry for 10 minutes and transferred to CoolBot storage room with paper box packaging.

3.7 Collection of data

Fruits used in the experiment were observed regularly to collect data on the following parameters.

- Polar diameter (cm)
- Equatorial diameter (cm)
- Fresh weight (g)
- Weight loss (%)
- Colorimetric parameters of fruit (L^* , a^* , b^* and h°)
- Firmness (N)
- p^H
- Total soluble solids (TSS) (%)
- Titratable acidity (TA) (%)
- Anthocyanin (mg/100 g)
- Ascorbic acid content (mg/100 g)
- Total carbohydrates (g/100 g)
- Fruit spoilage (%)
- Shelf life (days)



3.8 Methods of studying parameters

By using the following methods physico-chemical characteristics and shelf life of the Strawberry varieties were studied. Data on physico-chemical properties were recorded in every one day, two days or three days interval during the study period.

3.8.1 Physical characteristics

3.8.1.1 Equatorial and Polar diameter (cm)

The equatorial diameter (D_e) and polar diameter (D_p) were measured using digital slide calipers. Equatorial diameter is the maximum width of the Strawberry in a plane perpendicular to the polar diameter. Polar diameter is the distance between the Strawberry crown and the point of fruit attachment to the strawberry (Afrisal et al., 2013).

3.8.1.2 Fresh weight (g) of strawberry fruits

The fresh weight of strawberry fruit was measured by an electric balance. At first, the balance was adjusted to zero mark. The fruits were weighted by keeping the Strawberry on the chamber of the balance. Then the reading was taken in gram (g).

3.8.1.3 Determination of weight loss (%)

Fruit weight loss (%) was determined according to Wang et al. (2005). The Strawberry was selected randomly from each treatment to assess the weight every day during storage and the weight difference was compared day to day. The electric balance was used to measure the weight and expressed the value in percentage. The following equation was used to assess weight loss:

$$\text{Weight loss (\%)} = \frac{M_0 - M_1}{M_0} \times 100$$

Where, M_0 is the fresh weight of Strawberry fruit on the first day, and M_1 is the measured weight on next day of storage.

3.8.1.4 Colorimetric parameters of fruit (L^* , a^* , b^* and h°)

The surface color of the Strawberry was determined using a colorimeter (CR-410, Konica Minolta, USA). The readings were obtained at the basal portion of the pericarp and expressed as L^* , a^* , b^* modulus in accordance with the International Commission on Illumination (CIE) color system for color measurement, specification, and adjustment. In this system, a color solid is defined by three rectangular coordinates from which units or points of approximate visual uniformity are obtained (McGuire, 1992). Coordinate L^* indicates lightness, and it varies from zero (completely black) to 100 (completely white). Coordinate a^* expresses the degree of green-red variation (increasingly negative values indicate stronger green and increasingly positive values indicate stronger red) and coordinate b^* expresses blue-yellow variation (increasingly negative values indicate stronger blue and increasingly positive values indicate stronger yellow). In addition to these variables, the hue angle (h°) which indicates the observable color, were also determined. The hue angle can vary between 0° and 360° , where 0° corresponds to red, 90° corresponds to yellow, 180° corresponds to green, and 270° corresponds to blue.

3.8.1.5 Firmness measurement

A texture analyzer (Shimadzu EZ-SX, USA) was used to determine the firmness of treated Strawberry equipped with a cylindrical probe (2 mm diameter). Each fruit was penetrated four different equilateral locations to assess the firmness. The penetration depth of the probe was 5 mm and the crosshead speed of the texture analyzer was 2 mms⁻¹. The maximum force firmness was stated in N-mm from the force vs. time curve.

3.8.2 Chemical characteristics

The chemical analyses of Strawberry fruit were conducted according to Mazumdar and Majumdar (2001) and Saini et al. (2006). The methods have been described below.

3.8.2.1 Determination of p^H of strawberry fruit

The p^H of Strawberry fruit was measured by a desktop p^H meter.

Preparation of standard buffer solution

p^H 7 and p^H 4 buffer tablet were dissolved in water separately and made up the mark of 100 ml with distilled water.

Extraction of Strawberry juice

For the determination of fruit p^H, 5 g of fresh fruit was taken in a conical flask with 10 ml of distilled water. Then the fruit was crashed by using blender and extract was filtrated through two layers of cloth.

Procedure

The standard buffer solution of p^H 7 was taken into a clean and dry beaker. The electrode assembly of the p^H meter was dipped into the solution. The temperature correction knob was set to 28°C and the fine adjustment was made by asymmetry potential knob to p^H 7. After washing with distilled water, the electrode assembly was dipped into a solution of standard p^H 4 and adjusted to the required p^H by fine asymmetry potential knob. The electrode assembly was raised, washed twice with distilled water then rinsed with Strawberry juice and finally it was dipped into the juice of Strawberry. The p^H was recorded from the meter.

3.8.2.2 Determination of total soluble solids (TSS) (%)

Equipment

Digital Brix meter (Digital/Brix/RI-Check Refractometer, Reichert Technologies, Inc. Japan) was used.

Procedure

A drop of juice from the fruit of strawberry was placed on the prism of the refractometer and percentage of total soluble solid (TSS) (%) was obtained from direct reading.

3.8.2.3 Determination of titratable acidity (TA) (%) of strawberry fruit

Strawberry fruit contains organic and inorganic acids. These acids are important constituents in fruits as together with sugars, they determine quality and taste of the strawberry fruit. Maturity stages of Strawberry fruits at their harvest is also judged from their level of acids along with sugars or the soluble solids.

Reagents:

A. Sodium hydroxide (NaOH): 0.1 normality (N)

B. Indicator: Phenolphthalein ($C_{20}H_{14}O_4$) [approx. 0.5 % in 80% ethanol (W/V)]

Equipment:

Ten milliliter pipette, 25 ml burette, small glass funnel, dropper, blender, 250 ml measuring cylinder, burette stand and beaker.

Procedure:

- 30 g of tissue sample by weight was taken. This was extracted with distilled water by thorough crushing in blender. Extract was filtered and the filtrate was made up to 100 ml with distilled water.
- 15 ml of aliquot was taken into a conical flask. Three to four drops of phenolphthalein solution were added to this aliquot and shaken well.
- A burette was filled with the sodium hydroxide solution after washing and rinsing.

- Titration was done and end point was determined by the appearance of pink color and its persistence for at least 10 to 15 seconds.

Calculation

In term of citric acid 1 ml of 0.1N NaOH solution can neutralize 0.064 g of citric acid. Therefore, percentage of titratable acidity in the sample as equivalent of citric acid is calculated as follows-

$$\text{Titratable acidity (\%)} = \frac{d \times 0.064 \times c}{a \times b} \times 100$$

Where, a = Weight of sample (g), b = Volume of aliquot taken for examination (ml),

c = Volume made with distilled water (ml), d = Average burette reading for sample.

3.8.2.4 Determination of anthocyanin (mg/100 g) of strawberry fruit

Principle

Anthocyanin is extracted with ethanolic-hydrochloride and the intensity of the color appeared is measured calorimetrically. From the reading, the amount of the pigment present is determined.

Reagents

(A) Ethanol: 95%

(B) Hydrochloric acid (HCl): 1.5 N.

(C) Ethanol -hydrochloric acid mixture: It was prepared by mixing 85 parts of reagent A and 15 parts of Regent B by volume.

Procedure

1. 5 g of tissue sample by weight was taken. This was extracted with ethanol hydrochloric acid mixture. It could stand overnight at a temperature of about 4°C.
2. After extraction, the mixture was filtered through filter paper (Whatman No.1). The extraction was repeated for maximum recovery of the pigment.
3. The extract was then made up to 15 ml with the solvent.

4. 15 ml of aliquot from the above extract was taken. It was filtered through fine (milli-pore) filter paper.
5. The filtered aliquot was maintained in darkness for about 2 hours with cover of the container.
6. This was then made up to 25 ml with the solvent (for color measurement). The optical density (O.D.) value of the solution was then measured through 535 nm wavelength in a colorimeter against blank.

Calculation

$$\text{Total absorbance value of the sample (per 100 g)} = \frac{e \times b \times c}{d \times a} \times 100$$

Where,

a = Weight of sample, b = Volume made for color measurement, c = Total volume made, d = Volume of aliquot taken for estimation, e = Volume for 535 nm

Anthocyanin (mg/100g) = *Total absorbance* ÷ 98.2

98.2 = Constant value for equation

3.8.2.5 Determination of ascorbic acid (mg/100 g) content

Apparatus: Volumetric flask 250 ml, conical flask 250 ml, beaker 150 ml, blender, burette 250 ml and pipette.

Reagents used for the estimation of ascorbic acid content

Meta phosphoric acid (HPO₃) (3% and 6%): It was prepared by dissolving exactly 30 g or 60 g of Meta phosphoric acid in 80 ml or 160 ml of acetic acid (for 3% and 6%) respectively and 500 ml of distilled water was added to it. For proper mixing the solution, hot plate and magnetic stirrer were used. Finally, the volume was made to 1000 ml and the solution was filtered and stored.

Preparation of dye solution: Accurately 50 mg of 2, 6- dichloro-phenol indophenol dye and 42 mg of sodium bicarbonate was weighed on a chemical balance. Both the chemicals were dissolved in 150 ml of distilled water. The solution was heated gently on a water bath to make

it homogenous and raise the volume to 200 ml after cooling at room temperature. Then the filtrates were transferred to an airtight container and placed it in a refrigerator.

Preparation of standard ascorbic acid solution: 100 mg of ascorbic acid was weighed on a chemical balance and dissolved in 3% Meta phosphoric acid and the volume was made to 500 ml.

Standardization of dye solution: 5 ml of standard ascorbic acid solution was taken in a clean beaker to which 5 ml of 3% Meta phosphoric acid solution was added with the help of a pipette. This solution was titrated against the dye till a faint pink color was obtained which persisted for more than 15 seconds.

Estimation of ascorbic acid by titration method

Fruit flesh (30 g) was weighed and blended with equal weight of 6% Meta phosphoric acid for 3 to 4 minutes. Then 15 g of this slurry was taken in a 100 ml volumetric flask and volume was made by adding 3% Meta phosphoric acid. This juice was filtrated through a fast filter paper (Whatman No. 42).

The burette was filled with standardized 2, 6-dichlorophenol, indophenols dye reagent. Only 10 ml of filtered solution was taken in a conical flask and titrated immediately against standard dye solution, till faint pink color was observed which persisted for not less than 15 seconds.

Calculation:

$$\text{Ascorbic acid (mg per 100 g) sample} = \frac{V \times T \times W}{100}$$

Where,

V= Volume of dye used in titration against an aliquant diluted sample,

T= Value of standardized dye,

W= Weight of fruit (g)

3.8.2.6 Determination of total carbohydrates (g/100 g)

Materials

1. HCl (2.5N)
2. Anthrone Reagent: 200 mg anthrone was dissolved in 100 ml of ice cold 95% sulphuric acid. It was prepared fresh before use.
3. Standard Glucose Stock: 100 mg glucose was dissolved in 100 ml water. For working standard, 10 ml of the stock is diluted to 100 ml with distilled water. Final concentration is 0.1 mg/ml. It was stored in refrigerator after adding a few drops of toluene.

Procedure

1. Only 100 mg of the sample was weighed into a boiling tube.
2. It was hydrolyzed by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N HCl and cooled to room temperature.
3. It was neutralized with solid sodium carbonate until the effervescence ceases.
4. The volume was made up to 100 ml and centrifuged.
5. The supernatant was collected and 0.5 and 1 ml aliquots were taken for analysis.
6. The standard curve was prepared by taking 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard. Zero serves as blank.
7. The volume was made up to 1 ml in all the tubes including the sample tubes by adding distilled water.
8. Then 4 ml of anthrone reagent was added.
9. The solution was heated for eight minutes in a boiling water bath.
10. It was cooled rapidly and the green color was read at 630 nm on spectrophotometer.
11. A standard graph was drawn by plotting concentration of the standard on the x-axis and absorbance on the y-axis.

12. From the graph the amount of carbohydrate present in the sample tube was calculated.

Calculation

$$\text{Amount of carbohydrates in 100 mg of the sample} = \frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

3.8.3 Fruit spoilage (%)

Spoiled fruit (%) was counted on visual deterioration measurement of strawberry as described by Matar et al. (2018).

$$\text{Fruit spoilage (\%)} = \frac{\text{No. of spoiled fruit}}{\text{Total no. of fruit}} \times 100$$

3.8.4 Shelf life (Days)

Shelf life was determined on the basis of the physical parameters as weight loss, change in color, firmness and % spoiled fruit. These parameters were judged through eye observation and the judgement criteria was determined in a consumer perspective to consider the fruit as acceptable for buying or selling. In this light, the average days required for losing a cumulative weight of 25%, change of color from deep red to pale red, retaining at least eating softness and reasonably minimum spoiled fruit (maximum 5%) was noted as shelf life of the fruits (Tabassum et al., 2018).

3.9 Statistical analysis

The collected data were statistically analyzed by Analysis of variance one, two or three way method of analysis by using STATISTIX 10 computer package program. The mean differences were tested by LSD at 5% level of significance as described by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The effects of different postharvest treatments on physical and chemical characteristics, fruit spoilage (%) and shelf life of strawberry were studied in this experiment. The results of the present investigation have been presented and interpreted in this chapter under following headings:

4.1 Physical characteristics

4.1.1 Fruit weight loss (%)

Fruit weight loss (%) varied significantly among three strawberry varieties after 11 days of storage. V1 showed higher weight loss (25.42%) compared to V2 and V3. Weight loss (%) of V2 and V3 were 22.57 % and 16.63 % (Fig. 4.1). Koyuncu (2004) also found differences among Camarosa, Cavendish and Chandler variety of strawberry in case of fruit weight loss (%).

The highest weight loss (32.42%) was observed in T1 (Control- Ambient condition) and the lowest in T6 (11.68%) treated fruit after 11 days of storage. Non-treated fruits in Coolbot Storage (T2 and T3) showed almost similar weight loss (26.72% and 23.52%). However, all CaCl_2 treatments significantly reduced the weight loss (%) during storage compared to control (Fig. 4.2). The present result is similar to the findings reported by Mooto (1991) where the researcher observed that the rate of fruit weight loss was highest in untreated fruit. The loss in fruit weight was mainly due to evaporation and transpiration loss of water and somewhere dry matter lost by evaporation. The lower weight loss in samples treated with calcium chloride dip may be due to increased water holding by formation of calcium pectate hydrogel and delay in dehydration process (Lester et al., 1999). Rahman et al. (2016) also stated that application of CaCl_2 significantly reduced weight loss.

The combined effect of varieties and treatments on weight loss (%) are also significant. However, V1T1 showed maximum weight loss (45.37%) which is minimum in V3T6 (7.0%) (Table 4.1) after 11 days of storage. So, V3 with T6 was found to be best in case of combined effect of varieties and treatments. Shahzad et al. (2020) also showed that combined effect of

Calcium chloride and salicylic acid reduced the fruit weight loss (%) during 15 days of cold storage (4°C). Findings from Rahimi et al. (2018) also supports the finding from the current study.

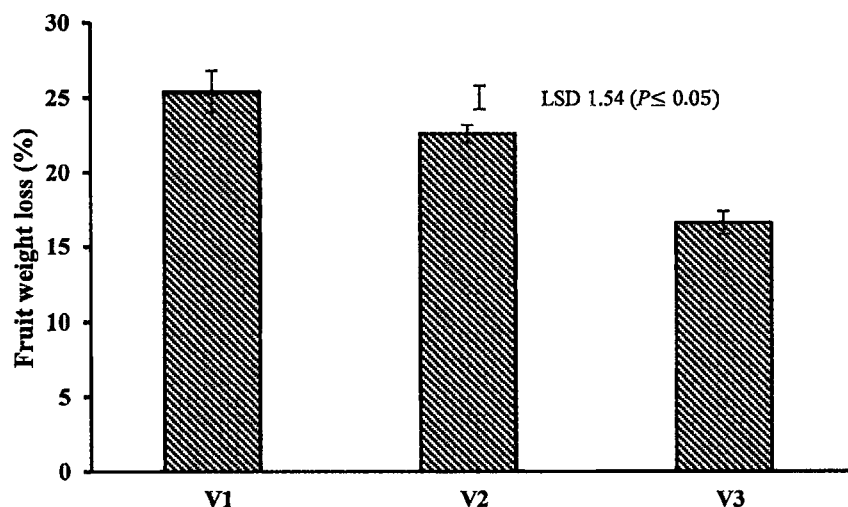


Fig. 4.1. Varietal difference in respect of fruit weight loss (%) of strawberry

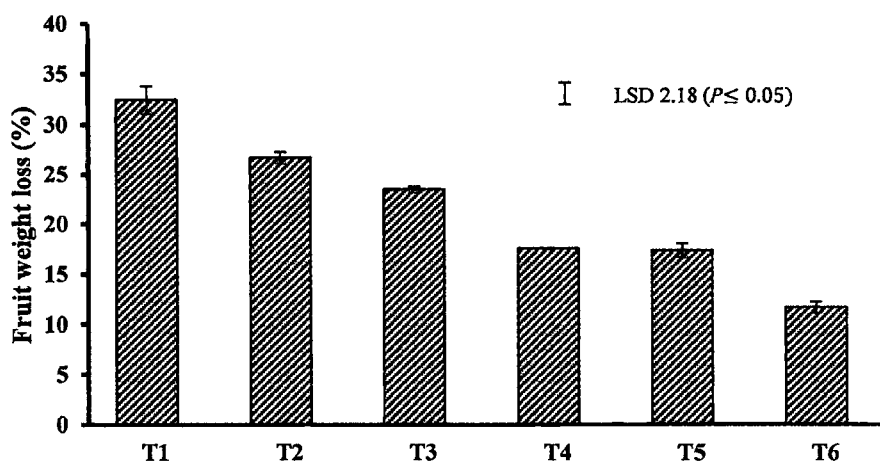


Fig. 4.2. Effect of treatments on fruit weight loss (%) of strawberry

V1: RABI-3	T1: Control- Ambient condition	LSD (0.05): Significant at 5% level of probability
V2: BARI Strawberry-3	T2: No packaging + CoolBot	
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.1. Combined effect of varieties and treatments on fruit weight loss (%) of strawberry

Variety x Treatments	Fruit weight loss (%)
V1T1	45.37 A
V1T2	33.19 B
V1T3	23.18 C
V1T4	18.01 DE
V1T5	21.57 CD
V1T6	11.17 F
V2T1	31.52 B
V2T2	24.10 C
V2T3	24.10 C
V2T4	17.85 DE
V2T5	21.01 CD
V2T6	16.84 E
V3T1	20.35 CDE
V3T2	22.85 C
V3T3	23.27 C
V3T4	16.76 E
V3T5	9.50 FG
V3T6	7.00 G
LSD (0.05)	3.78

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	LSD (0.05): Significant at 5% level of probability
V2: BARI Strawberry-3	T2: No packaging + CoolBot	
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

4.1.2 Polar Diameter (cm)

V3 was bigger in polar diameter (4.48 cm) followed by V1 and V2. All of the three varieties showed decreasing trend from DAT 2 to DAT 11 (Table 4.2). Rolle (2006) reported that fruit diameter decreases day by day on different fruits and vegetables. It may be due to genetic composition of specific fruits, vegetables or their different variety.

Maximum fruit diameter was obtained in T4 but it decreased rapidly. On the other hand, T6 with 4.55 cm diameter at DAT 2 showed less loss in diameter (3.81 cm) at DAT 11. T1 showed initially 4.33 cm of polar diameter at DAT 2 which became 2.87 cm only at DAT 11 of storage (Table 4.3). Ajender and Chawla (2019) got similar findings and reported that calcium treated fruit retained higher fruit length than control fruits in apple due to less moisture loss and less shrinkage.

In all variety and treatment combinations, polar diameter decreases gradually. V3T2 showed maximum polar diameter (5.78 cm) at DAT 2 which decreased to 4.48 cm at DAT 11. On DAT 11, V1T1 showed lowest polar diameter (2.33 cm) (Table 4.4). Decrease in fruit diameter was more pronounced in ambient storage than in refrigerated storage due to moisture loss and shrinkage. Ganai et al. (2018) used calcium chloride, hydro-cooling and wax in apple and got similar result.

Table 4.2. Varietal difference in respect of polar diameter (cm) of strawberry during storage

Varieties	Polar diameter (cm) at DAT			
	2	5	8	11
V1	4.18 B	3.93 C	3.59 DE	3.27 G
V2	4.20 B	3.91 C	3.54 EF	3.32 FG
V3	4.48 A	4.31 AB	3.8 CD	3.37 EFG
LSD (0.05)	0.23			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.3. Effect of treatments on polar diameter (cm) of strawberry during storage

Treatments	Polar diameter (cm) at DAT			
	2	5	8	11
T1	4.33 BC	3.83 E-H	3.24 IJ	2.87 K
T2	4.37 BC	4.18 CD	3.85 DEF	3.53 F-I
T3	3.85 EFG	3.67 E-H	3.15 JK	2.89 K
T4	4.82 A	4.49 BC	3.88 DE	3.5 HI
T5	3.82 E-H	3.68 E-H	3.53 GHI	3.32 IJ
T6	4.55 AB	4.45 BC	4.22 C	3.81 E-H
LSD (0.05)	0.32			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at
V3: Festival	T3: Paper box packaging + CoolBot	5% level of probability
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.4. Combined effect of varieties and treatments on polar diameter (cm) of strawberry during storage

Variety x Treatments	Polar diameter (cm) at DAT			
	2	5	8	11
V1T1	3.09 Y-h	2.83 ghi	2.73 hi	2.33 i
V1T2	3.89 L-S	3.57 P-ab	3.24 U-h	3.19 V-h
V1T3	3.68 N-X	3.45 R-d	2.88 d-i	2.86 f-i
V1T4	5.34 AB	5.02 BCD	4.48 D-K	3.62 O-a
V1T5	4.14 G-O	3.97 J-R	3.85 M-T	3.42 R-f
V1T6	4.96 B-E	4.73 C-F	4.44 E-L	4.18 F-O
V2T1	5.22 ABC	4.03 I-Q	3.26 U-h	3.15 W-h
V2T2	3.44 R-e	3.29 T-h	2.99 c-h	2.88 e-i
V2T3	3.81 N-U	3.65 N-Y	3.04 b-h	2.73 hi
V2T4	4.58 D-I	4.48 D-K	4.08 H-Q	3.83 N-T
V2T5	3.69 N-W	3.54 Q-abc	3.44 R-e	3.41 R-f
V2T6	4.49 D-J	4.47 D-K	4.41 E-M	3.90 L-S
V3T1	4.68 C-G	4.63 D-H	3.73 N-V	3.13 W-h
V3T2	5.78 A	5.68 A	5.39 AB	4.48 D-K
V3T3	4.06 I-Q	3.92 K-S	3.52 Q-abc	3.07 Z-h
V3T4	4.55 D-I	3.97 J-R	3.07 a-h	3.07 a-h
V3T5	3.64 O-Z	3.54 Q-abc	3.29 T-h	3.12 X-h
V3T6	4.22 F-N	4.10 G-P	3.81 N-U	3.36 S-g
LSD (0.05)	0.57			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.1.3 Equatorial diameter (cm)

On DAT 2, V2 was higher in equatorial fruit diameter (4.16 cm) followed by V3 (3.71 cm) and V1 (3.41 cm) (Table 4.5). All three varieties showed decreasing trend from DAT 2 to DAT 11 (Table 4.5). Finally, the lowest equatorial diameter (3.10 cm) was found in V1. Ahsan et al. (2014) found similarly significant differences in fruit diameter among Festival, RABI-3 and Camarosa varieties of strawberry. The findings from Dhakal et al. (2022) also supports the present study.

In the treatment T1 showed significant loss in equatorial diameter from 3.67 cm at DAT 2 to 3.00 cm at DAT 11. Maximum equatorial diameter was in T4 at DAT 2 (4.08 cm). All the treatments showed decreasing trend in case of equatorial diameter (Table 4.6). Ajender and Chawla (2019) got similar result. Calcium treated fruit retained higher fruit length than control fruits in apple due to less moisture loss and less shrinkage.

In Combined effect of varieties and treatments, highest fruit equatorial diameter was found in V2T4 (4.96 cm) at DAT 2 which gradually decreased to 3.87 cm at DAT 11. Lowest equatorial diameter was found in V3T1 (2.90 cm) at DAT 11 (Table 4.7). Calcium chloride, hydro-cooling and wax were used in apple in an experiment by Ganai et al. (2018) and they observed that control fruit diameter decreased faster than treated fruit.

Table 4.5. Varietal difference in respect of equatorial diameter (cm) of strawberry during storage

Varieties	Equatorial diameter (cm) at (DAT)			
	2	5	8	11
V1	3.41 EF	3.33 FGH	3.2 HI	3.1 I
V2	4.16 A	3.89 B	3.53 DE	3.38 FG
V3	3.71 C	3.59 CD	3.4 F	3.26 GH
LSD (0.05)	0.13			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.6. Effect of treatments on equatorial diameter (cm) of strawberry during storage

Treatments	Equatorial diameter (cm) at DAT			
	2	5	8	11
T1	3.67 CDE	3.51 EF	3.18 IJK	3.00 L
T2	3.61 DE	3.55 DEF	3.28 HIJ	3.05 KL
T3	3.49 EFG	3.31 GHI	3.17 I-L	3.11 JKL
T4	4.08 A	3.89 B	3.56 DEF	3.43 FGH
T5	3.9 AB	3.62 CDE	3.5 EFG	3.39 FGH
T6	3.8 BC	3.72 BCD	3.57 DEF	3.49 EFG
LSD (0.05)	0.18			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	



Table 4.7. Combined effect of varieties and treatments on equatorial diameter (cm) of strawberry during storage

Variety x Treatments	Equatorial diameter (cm) at DAT			
	2	5	8	11
V1T1	3.41 L-Y	3.34 N-a	3.27 R-d	3.02 a-f
V1T2	3.22 T-e	3.17 W-f	3.07 Z-f	2.93 ef
V1T3	3.41 L-X	3.19 U-f	3.05 Z-f	2.99 def
V1T4	3.65 H-N	3.58 H-R	3.37 M-Z	3.22 U-f
V1T5	3.62 H-P	3.54 J-T	3.44 K-W	3.41 L-X
V1T6	3.18 V-f	3.10 X-f	3.01 b-f	3.00 c-f
V2T1	4.29 BCD	4.08 CDE	3.33 N-ab	3.07 Z-f
V2T2	3.61 H-Q	3.41 L-X	3.14 W-f	3.07 Z-f
V2T3	3.54 I-S	3.36 M-Z	3.15 W-f	3.09 Y-f
V2T4	4.96 A	4.51 B	4.03 D-G	3.87 E-H
V2T5	4.20 BCD	3.59 H-R	3.34 N-a	3.12 W-f
V2T6	4.40 B	4.38 BC	4.22 BCD	4.07 C-F
V3T1	3.32 O-abc	3.12 X-f	2.95 ef	2.90 f
V3T2	4.07 CDE	3.64 H-O	3.36 M-Z	3.16 W-f
V3T3	3.51 K-U	3.40 L-Y	3.31 P-d	3.24 S-e
V3T4	3.63 H-O	3.58 H-R	3.29 Q-d	3.20 U-f
V3T5	3.86 E-I	3.75 F-K	3.72 G-L	3.65 H-N
V3T6	3.85 E-J	3.67 H-M	3.49 K-V	3.40 L-Y
LSD (0.05)	0.32			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.1.4 Fruit firmness (N)

On DAT 2, V3 showed highest fruit firmness which was 2.28 and 1.17 times higher than V1 and V2 respectively. On DAT 11, significant firmness loss was observed in V2 and V3 whereas less firmness loss was occurred in V1 (Table 4.8). Similarly Sturzeanu (2020) did not get significant difference in case of fruit firmness among seven strawberry varieties but the firmness loss of fruit during storage was found to be significant.

On DAT 2, all of the treatments showed almost similar firmness and continued to show decreasing trend on DAT 5, DAT 8 and DAT 11 (Table 4.9). On DAT 11, highest fruit firmness (12.15 N) was found in T6 where severe firmness loss was observed in T1 (control) fruits (1.95 times lower than T6). T4 and T5 also showed less firmness loss than untreated fruits in CoolBot (T2 and T3). Higher firmness and best superficial appearance of strawberry induced by calcium dips and modified atmosphere packaging as reported by Guan et al. (2016). They added that calcium dipping and packaging could result in more effective preservation than individual treatment. Wan Mahfuzah et al. (2012) and Sati and Qubbaj (2021) also supports the results from the current study.

The interaction effect of variety and treatment on fruit firmness was found to be significant. Highest fruit firmness (18.21 N) was observed in V3T6 at DAT 2. On DAT 11, it decreases to 15.11 N. However, all the combination showed decreasing trend in case of fruit firmness (Table 4.10). Lowest fruit firmness was observed in V1T1 (4.93 N) at DAT 11. The calcium treated fruits of V3 (T4, T5 and T6) was found to be best in respect of retaining firmness. Bola et al. (2017) used calcium chloride, carboxymethyl cellulose and chitosan to extend shelf life of strawberry and found similar decreasing trend of firmness where coated fruits showed less decrease than control fruits.

Table 4.8. Varietal difference in respect of firmness of strawberry during storage

Varieties	Firmness (N) at DAT			
	2	5	8	11
V1	7.59 G	7.35 GH	7.02 H	6.56 I
V2	14.78 C	13.41 D	11.41 E	10.25 F
V3	17.35 A	16.45 B	14.42 C	11.94 E
LSD (0.05)	0.45			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.9. Effect of treatments on firmness of strawberry during storage

Treatments	Firmness (N) at DAT			
	2	5	8	11
T1	13.07 BCD	11.92 FGH	9.3 J	6.23 L
T2	12.42 EF	11.5 GH	10.67 I	8.56 K
T3	12.91 CDE	12.07 FGH	10.18 IJK	8.93 JK
T4	13.61 AB	13.1 BCD	12.11 FG	10.82 I
T5	12.98 CDE	12.31 EF	11.46 H	10.81 I
T6	13.93 A	13.51 ABC	12.83 DE	12.15 F
LSD (0.05)	0.63			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at
V3: Festival	T3: Paper box packaging + CoolBot	5% level of probability
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.10. Combined effect of varieties and treatments on firmness of strawberry during storage

Variety x Treatments	Firmness (N) at DAT			
	2	5	8	11
V1T1	7.45 W-c	6.79 Y-d	5.99 def	4.93 f
V1T2	6.56 a-d	6.48 cd	6.50 abc	6.19 de
V1T3	8.15 VWX	8.00 VWX	7.81 WXY	7.77 W-Z
V1T4	7.59 W-b	7.53 W-c	7.08 X-d	6.76 Y-d
V1T5	7.96 VWX	7.76 W-Z	7.66 W-a	7.06 X-d
V1T6	7.81 WXY	7.52 W-c	7.09 X-d	6.69 Z-d
V2T1	13.79 K-O	11.81 QR	8.98 UV	5.28 ef
V2T2	13.25 M-P	11.63 QRS	10.89 RST	8.34 VW
V2T3	14.01 I-N	13.03 M-P	10.08 TU	8.48 VW
V2T4	15.21 D-G	14.42 G-L	12.72 OPQ	11.79 QR
V2T5	14.76 E-K	14.01 I-N	13.39 L-P	12.98 M-P
V2T6	15.78 CDE	15.55 C-F	14.97 D-J	15.64 F-K
V3T1	17.97 A	17.15 AB	12.94 NOP	8.49 VW
V3T2	17.44 AB	16.40 BC	14.63 F-K	11.16 RST
V3T3	16.51 BC	15.18 D-G	12.66 PQ	10.56 ST
V3T4	18.04 A	17.36 AB	16.54 BC	13.91 J-N
V3T5	15.93 CD	15.14 D-H	14.33 L-P	12.40 PQ
V3T6	18.21 A	17.47 AB	16.44 BC	15.11 D-I
LSD (0.05)	1.10			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.2. Colorimetric parameters (L^* , a^* , b^* and h°)

4.2.1 Color L^*

Color L^* value decreased in all three varieties from DAT 3 to DAT 11. However V2 and V3 showed higher color L^* value than V1 (Table 4.11). A gradual decrease in color L^* means dark color with ripening of fruits and beginning to spoil as reported by Ngo et al. (2021).

The treatments are significant in case of color L^* value. There was an increase in color L^* value in T4 and T6 from DAT 7 to DAT 11. Other treatments showed decreasing trend (Table 4.12). An increase in color L^* refers to a slow color change occurred in calcium treated fruit. Ngo et al. (2021) got similar effect in mango induced by pectin/Nano-chitosan based coatings.

The maximum color L^* was obtained in V2T5 (41.81) at DAT 3 and lowest in V1T1 at DAT 11. In most treatments, decreasing trend was seen (Table 4.13). Pelayo et al. (2002) got similar decreasing trend in strawberry by using cold storage and CO_2 in combination.

Table 4.11. Varietal difference in respect of color L* of strawberry during storage

Varieties	Color L* at DAT		
	3	7	11
V1	38.43 AB	37.5 BC	33.29 E
V2	39.14 A	36.92 C	34.72 d
V3	39.11 A	35.66 D	34.98 D
LSD (0.05)	1.17		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.12. Effect of treatments on color L* of strawberry during storage

Treatments	Color L* at DAT		
	3	7	11
T1	38.98 B	38.04 BCD	33.62 IJ
T2	38.58 BC	37.38 B-E	32.03 J
T3	39.36 B	36.7 DG	32.45 J
T4	37.21 C-F	35.54 GH	36.33 E-H
T5	41.29 A	36.46 DG	34.7 HI
T6	37.93 B-E	35.58 FGH	36.85 D-G
LSD (0.05)	0.84		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.13. Combined effect of varieties and treatments on color L* of strawberry during storage

Variety x Treatments	Color L* at DAT		
	3	7	11
V1T1	38.58 B-F	40.83 AB	30.12 P
V1T2	38.29 B-G	37.81 C-H	32.72 L-P
V1T3	39.22 A-E	38.81 B-E	30.37 NOP
V1T4	34.96 H-M	32.31 M-P	33.90 J-M
V1T5	40.88 AB	40.81 AB	37.10 D-I
V1T6	38.6 4B-F	34.44 I-M	35.55 G-L
V2T1	39.09 A-E	37.80 C-H	33.76 J-M
V2T2	38.32 B-G	35.77 F-K	33.17 K-N
V2T3	38.63 B-F	35.50 G-L	33.10 K-O
V2T4	38.51 B-F	39.90 A-D	34.99 H-M
V2T5	41.81 A	35.76 F-K	33.12 K-N
V2T6	38.52 B-F	36.81 E-I	40.20 ABC
V3T1	39.23 A-E	35.50 G-L	36.99 E-I
V3T2	39.15 A-E	39.91 A-D	30.22 OP
V3T3	40.54 ABC	35.81 F-K	33.90 J-M
V3T4	38.16 B-G	34.43 I-M	40.11 ABC
V3T5	40.93 AB	32.81 L-P	33.90 J-M
V3T6	36.63 E-J	35.51 G-L	34.81 I-M
LSD (0.05)	2.87		
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).			
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability

4.2.2 Color a*

Color a* value was highest in V3 and lowest in V1 at DAT 3 and all of three varieties showed decreasing trend in this regard (Table 4.14). Koyuncu (2004) observed varietal difference on color a* and decreasing trend as well among Camarosa, Cavendish and Chandler variety of strawberry.

Significant increase in color a* from DAT 3 to DAT 11 was found in T2 where other treatments showed decreasing trend. However, T1 and T4 was highest in color a* value and it was lowest in T5 (Table 4.15). The result is not similar to Ngo et al. (2021) as they described slower decrease in color a* value for coated fruits than uncoated fruits. It might be due to varietal differences and variation in storage condition.

Initial color a* value at DAT 3 was increased to DAT 7 for several variety and treatment combinations and then started to decrease again at DAT 11 (Table 4.16). Pelayo et al. (2002) got similar decreasing trend in strawberry using by cold storage and CO₂ combinedly.

Table 4.14. Varietal difference in respect of color a* of strawberry during storage

Varieties	Color a* at (DAT)		
	3	7	11
V1	13.96 BC	13.77 BC	13.03 CD
V2	14.86 AB	14.38 B	12.93 CD
V3	15.78 A	14.35 B	12.08 D
LSD (0.05)	1.09		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.15. Effect of treatments on color a* of strawberry during storage

Treatments	Color a* at DAT		
	3	7	11
T1	16.95 A	14.42 BC	12.54 EF
T2	13.96	15.79 AB	12.63 DEF
T3	13.97 CDE	13.98 CDE	11.98 F
T4	16.94 AB	13.47 C-F	12.62 DEF
T5	13.51 CDE	13.2 C-F	13.29 C-F
T6	14.48 BC	14.13 CD	13.01 C-F
LSD (0.05)	1.54		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at
V3: Festival	T3: Paper box packaging + CoolBot	5% level of probability
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.16. Combined effect of varieties and treatments on color a* of strawberry during storage

Variety x Treatments	Color a* at DAT		
	3	7	11
V1T1	15.61 B-I	16.16 A-G	11.40 LMN
V1T2	12.76 J-N	16.55 A-E	13.23 I-N
V1T3	11.19 MN	15.51 B-I	11.39 LMN
V1T4	17.83 AB	12.81 J-N	13.44 H-N
V1T5	12.10 L-N	10.81 N	14.80 C-J
V1T6	14.28 D-K	10.81 N	13.92 E-L
V2T1	16.51 A-E	13.31 I-N	13.12 I-N
V2T2	12.30 J-N	13.73 G-M	12.76 J-N
V2T3	13.49 G-M	13.32 I-N	12.34 J-N
V2T4	14.36 D-K	14.81 C-J	13.21 I-N
V2T5	16.42 A-F	13.30 I-N	13.18 I-N
V2T6	16.10 A-H	17.81 AB	12.99 I-N
V3T1	18.27 A	13.81 F-M	13.12 I-N
V3T2	16.83 A-D	17.10 ABC	11.91 K-N
V3T3	17.22 ABC	13.12 I-N	12.22 J-N
V3T4	15.64 B-I	12.81 J-N	11.21 MN
V3T5	13.21 I-N	15.51 B-I	11.91 K-N
V3T6	13.05 I-N	13.77 F-M	12.12 K-N
LSD (0.05)	2.67		
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).			
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl2 1% + paper box packaging + CoolBot T5: CaCl2 2% + paper box packaging + CoolBot T6: CaCl2 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability

4.2.3 Color b*

There was an increase found in V1 and V2 in color b* value where V3 showed slight decrease (Table 4.17). Koyuncu (2004) observed varietal difference on color b* and decreasing trend as well among Camarosa, Cavendish and Chandler variety of strawberry. The result from the current study is different as the increase in b* value indicated a decrease toward darker chroma (Ngo et al., 2021).

Except T4, T6 and T3, all treatments showed an increasing pattern of b* value at DAT 3 to DAT 7 and then decreased again at DAT 11 (Table 4.18). T4 obtained highest value at DAT 11. The result is not similar to Ngo et al. (2021) as they described slower decrease in color b* value for coated fruits than uncoated fruits. This might be due to the differences in the applied treatments in the applied treatments in our study than the study conducted by Ngo et al. (2021).

The combined effect of varieties and treatments did not follow any trending pattern. There was slight increase in color b* value from DAT 3 to DAT 7 and then decreased or increased again (Table 4.19). Holcroft and Kader (1999) got only decreasing trend in strawberry using controlled atmosphere as they did not use any combined treatment of cold storage and packaging materials.

Table 4.17. Varietal difference in respect of color b* of strawberry during storage

Varieties	Color b* at (DAT)		
	3	7	11
V1	14.36 AB	13.36 CDE	14.12 ABC
V2	12.91 EF	14.78 A	12.31 F
V3	14.06 A-D	13.68 B-E	13.14 DEF
LSD (0.05)	0.97		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.18. Effect of treatments on color b* of strawberry during storage

Treatments	Color b* at DAT		
	3	7	11
T1	13.42 C-G	14.69 ABC	12.53 E-H
T2	13.86 B-F	14.88 AB	11.91 H
T3	13.04 D-H	12.67 E-H	12.57 E-H
T4	14.83 AB	13.92 B-E	15.4 A
T5	14.65 ABC	14.97 AB	14.33 A-D
T6	12.86 E-H	12.53 FGH	12.4 GH
LSD (0.05)	1.38		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.19. Combined effect of varieties and treatments on color b* of strawberry during storage

Variety x Treatments		Color b* at DAT		
		3	7	11
V1T1		13.76 D-L	17.81 A	13.47 G-M
V1T2		14.05 C-L	13.31 G-O	10.49 Q
V1T3		14.13 C-L	13.12 G-P	13.70 E-L
V1T4		14.68 B-J	12.32 J-Q	16.12 A-D
V1T5		15.99 A-E	12.72 I-Q	15.98 A-F
V1T6		13.58 F-M	10.92 OPQ	14.98 B-I
V2T1		13.24 G-P	12.18 K-Q	10.90 PQ
V2T2		12.33 J-Q	15.18 B-H	11.93 L-Q
V2T3		12.76 I-Q	12.81 H-Q	11.93 L-@
V2T4		12.88 G-Q	16.32 ABV	13.11 G-P
V2T5		14.40 C-K	16.10 A-D	14.80 B-I
V2T6		11.86 L-Q	16.12 A-D	11.23 M-Q
V3T1		13.27 G-P	14.10 C-L	13.23 G-P
V3T2		15.21 B-G	16.15 A-D	13.32 G-N
V3T3		12.25 K-Q	12.10 K-Q	12.10 K-Q
V3T4		16.93 AB	13.12 G-P	16.98 AB
V3T5		13.58 F-M	16.10 A-D	12.21 K-Q
V3T6		13.14 G-P	10.56 Q	11.01 N-Q
LSD (0.05)		2.39		
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.2.4 Hue angle (h°)

Maximum hue angle (h°) was observed in V1 at DAT 3 and lowest in V1 at DAT 7. However, all the varieties showed increasing trend from DAT 7 to DAT 11 (Table 4.20). Varietal difference on hue angle (h°) was also reported by Koyuncu (2004).

All six treatments showed significant decrease in h° from DAT 3 to DAT 7 and increase from DAT 7 to DAT 11 (Table 4.21). An increase in h° value refers to color retention which was found in all treatments. The result is not similar to Holcraft and Kader (1999) where they found a decreasing trend in h° value of stored fruit. This difference might be the result of differences in selection of variety and treatment.

Maximum hue angle (h°) value was observed in V1T3 at DAT 3 and lowest in V1T4 at DAT 11. However, hue angle (h°) value change did not follow any particular pattern for all combinations (Table 4.22). However, Pérez and Sanz (2001) expressed a decreasing pattern using oxygen and carbon-di-oxide combinedly on strawberry which is not similar to the current study.

Table 4.20. Varietal difference in respect of hue angle (h°) of strawberry during storage

Varieties	Hue angle (h°) at DAT		
	3	7	11
V1	42.62 A	32.79 D	33.63 CD
V2	38.68 B	33.94 CD	37.41 B
V3	34.17 C	32.85 D	33.75 CD
LSD (0.05)	1.3		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.21. Effect of treatments on hue angle (h°) of strawberry during storage

Treatments	Hue angle (h°) at DAT		
	3	7	11
T1	38.11 AB	34.05 CDE	34.41 CDE
T2	38.48 AB	34.75 CDE	35.45 C
T3	38.92 AB	33.04 E	34.16 CDE
T4	36.68 A	32.97 E	33.06 E
T5	38.56 AB	31.08 F	35.11 CD
T6	37.4 B	33.27 DE	37.4 B
LSD (0.05)	1.84		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.22. Combined effect of varieties and treatments on hue angle (h°) of strawberry during storage

Variety x Treatments	Hue angle (h°) at DAT		
	3	7	11
V1T1	41.81 B-E	34.55 M-S	32.12 R-W
V1T2	42.65 A-D	31.52 S-W	37.67 G-M
V1T3	45.65 A	31.52 S-W	35.85 I-P
V1T4	44.43 AB	35.55 J-P	29.15 W
V1T5	40.16 D-G	30.81 T-W	33.12 P-V
V1T6	41.05 C-F	32.82 P-V	33.90 O-T
V2T1	38.71 E-J	35.51 K-P	35.56 J-P
V2T2	38.85 E-I	37.20 G-N	33.13 P-V
V2T3	37.82 G-L	35.81 I-P	33.54 O-U
V2T4	39.24 E-H	32.80 P-V	37.92 F-L
V2T5	38.53 F-K	30.12 VW	40.22 D-G
V2T6	38.94 E-I	32.20 Q-W	44.11 ABC
V3T1	33.81 O-T	32.10 R-W	35.56 J-P
V3T2	33.94 O-T	35.55 J-P	35.55 J-P
V3T3	33.29 O-V	31.81 R-W	33.10 P-V
V3T4	35.37 K-Q	30.56 UVW	32.11 R-W
V3T5	36.40 H-O	32.31 Q-W	32.01 R-W
V3T6	32.22 Q-W	34.81 L-R	34.20 N-S
LSD (0.05)	3.19		
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).			
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability

4.3 Chemical characteristics

4.3.1 TSS (%)

On DAT 2, maximum TSS (%) was found in V3 which was 1.55 times higher than V1. A decreasing pattern was observed in V2 and V3. On the other hand, there was a slight increase of TSS on DAT 5 in V1 and then decreased again (Table 4.23). Ahsan et al. (2014) also found significant difference on TSS among three strawberry varieties where Festival variety contains 12.6% TSS. Aziz et al. (2018) also reported variations in TSS content from variety to variety.

All the treatments have significant effect on TSS (%) of strawberry. Non-treated fruits (T1, T2 and T3) showed gradual increase in TSS content from DAT 2 to DAT 8. However, calcium treated fruits (T4, T5 and T6) showed a decreasing trend during this storage period (Table 4.24). The increase in TSS of untreated fruits was probably due to hydrolysis of polysaccharides and concentrated juice content as a result of dehydration with the passage of storage time (Akhtar et al., 2010). Calcium chloride treatments formed a thin layer on the surface of fruit which slowed down degradation of TSS (Sohail et al., 2015).

In combined effect of varieties and treatments, highest TSS content (9.16%) was found in V3T3 on DAT 5 and lowest (4.96%) in V1T5 on DAT 11. Non treated fruits (T1, T2 and T3) showed slight increase in TSS on DAT 3 and DAT 5. On the other hand, Calcium treatments (T4, T5 and T6) blocked the increase in TSS in all varieties (Table 4.25). The interaction effect of varieties and treatments on TSS was significant. However, Varieties differ from each other in fruit TSS. Also, high concentration of calcium chloride application increased the metabolic actions which eventually decreased the TSS of the apple fruits as reported by Sajid et al. (2019).

Table 4.23. Varietal difference in respect of TSS (%) of strawberry during storage

Varieties	TSS (%) at DAT			
	2	5	8	11
V1	5.68 F	5.9 E	5.73 EF	5.19 G
V2	8.04 B	7.95 B	7.47 C	7.13 D
V3	8.86 A	8.82 A	8.69 A	8.04 B
LSD (0.05)	0.18			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.24. Effect of treatments on TSS (%) of strawberry during storage

Treatments	TSS (%) at DAT			
	2	5	8	11
T1	7.14 F	7.43 DE	7.46 DE	6.72 G
T2	7.26 EF	7.61 BCD	7.37 DEF	6.84 G
T3	7.4 DEF	7.88 A	7.51 CDE	6.68 G
T4	7.83 AB	7.6 BCD	7.15 F	6.85 G
T5	7.77 AB	7.44 DE	7.15 F	6.78 G
T6	7.76 ABC	7.38 DEF	7.15 F	6.85 G
LSD (0.05)	0.26			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at
V3: Festival	T3: Paper box packaging + CoolBot	5% level of probability
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.25. Combined effect of varieties and treatments on TSS (%) of strawberry during storage

Variety x Treatments	TSS (%) at DAT			
	2	5	8	11
V1T1	5.56 d-g	6.03 Y-c	6.36 XYZ	5.43 e-h
V1T2	5.26 f-i	5.93 Z-d	5.83 b-e	5.13 ghi
V1T3	5.33 f-i	6.40 XY	6.33 YZa	5.33 f-i
V1T4	5.90 a-d	5.63 c-f	5.10 hi	5.03 hi
V1T5	5.93 Z-d	5.56 d-g	5.16 ghi	4.96 i
V1T6	6.10 Y-b	5.86 b-e	5.53 c-f	5.26 f-i
V2T1	7.33 R-V	7.53 O-T	7.20 T-W	6.80 WX
V2T2	7.83 L-P	8.00 J-N	7.53 O-T	7.20 T-W
V2T3	7.76 L-R	8.10 I-M	7.36 Q-V	6.93 VW
V2T4	8.53 C-I	8.40 F-J	7.66 M-S	7.40 P-U
V2T5	8.46 D-I	8.10 I-M	7.86 L-O	7.53 O-T
V2T6	8.33 G-K	7.60 N-T	7.23 S-W	6.96 UVW
V3T1	8.53 C-I	8.73 A-G	8.83 A-F	7.93 K-O
V3T2	8.70 B-G	8.90 A-D	8.76 A-G	8.20 H-L
V3T3	9.10 AB	9.16 A	8.83 A-F	7.80 L-Q
V3T4	9.06 AB	8.76 A-G	8.70 B-G	8.13 I-L
V3T5	8.93 ABC	8.66 B-G	8.43 E-J	7.86 L-O
V3T6	8.86 A-E	8.70 B-G	8.60 C-H	8.33 G-K
LSD (0.05)	0.46			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.3.2 p^H

The differences were observed during DAT 2 to DAT 11 for all of the three varieties. p^H values fluctuated without any trend (Table 4.26). Koyuncu (2004) did not find any significant differences on p^H among three strawberry varieties during storage.

In case of treatments, p^H values fluctuated from DAT 2 to DAT 11 without any trend (Table 4.27). Turmanidze et al. (2016) and Wan Mahfuzah et al. (2012) support the findings from the current study.

The combined effect of varieties and treatments during storage did not follow any certain pattern of changing p^H from DAT 2 to DAT 11 (Table 4.28). Combined effect of packing system, calcium chloride and chlorine on strawberry p^H was not statistically significant as reported by Mozhdehi et al. (2012).

Table 4.26. Varietal difference in respect of p^H of strawberry during storage

Varieties	p^H at DAT			
	2	5	8	11
V1	3.54 ABC	3.51 ABC	3.41 CD	3.38 CD
V2	3.61 AB	3.43 BCD	3.29 D	3.41 CD
V3	3.64 A	3.69 A	3.56 ABC	3.38 CD
LSD (0.05)	0.19			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.27. Effect of treatments on p^H of strawberry during storage

Treatments	p^H at DAT			
	2	5	8	11
T1	3.53 A-D	3.38 CDE	3.34 DE	3.38 CDE
T2	3.74 A	3.5 A-D	3.44 B-E	3.32 DE
T3	3.64 ABC	3.64 ABC	3.35 DE	3.21 E
T4	3.44 B-E	3.55 A-D	3.48 A-E	3.44 B-E
T5	3.58 A-D	3.51 A-D	3.45 B-E	3.63 ABC
T6	3.64 ABC	3.68 AB	3.45 B-E	3.37 CDE
LSD (0.05)	0.27			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl_2 1% + paper box packaging + CoolBot	
	T5: CaCl_2 2% + paper box packaging + CoolBot	
	T6: CaCl_2 3% + paper box packaging + CoolBot	

Table 4.28. Combined effect of varieties and treatments on p^H of strawberry during storage

Variety x Treatments	p ^H at DAT			
	2	5	8	11
V1T1	3.39 B-K	3.35 B-K	3.18 JK	3.35 C-K
V1T2	3.74 A-F	3.54 B-K	3.77 A-D	3.40 B-K
V1T3	3.56 B-K	3.49 B-K	3.57 B-K	3.26 G-K
V1T4	3.47 B-K	3.68 A-I	3.37 B-K	3.42 B-K
V1T5	3.65 A-J	3.37 B-K	3.36 B-K	3.48 B-K
V1T6	3.45 B-K	3.62 A-J	3.24 H-K	3.35 C-K
V2T1	3.48 B-K	3.28 E-K	3.35 C-K	3.54 B-K
V2T2	3.76 A-E	3.43 B-K	3.24 H-K	3.20 IJK
V2T3	3.67 A-I	3.66 A-I	3.32 D-K	3.12 K
V2T4	3.42 B-K	3.40 B-K	3.24 H-K	3.60 A-J
V2T5	3.67 A-I	3.47 B-K	3.28 E-K	3.64 A-J
V2T6	3.67 A-I	3.35 C-K	3.31 D-K	3.38 B-K
V3T1	3.73 A-G	3.52 B-K	3.49 B-K	3.24 H-K
V3T2	3.73 A-F	3.54 B-K	3.33 D-K	3.36 B-K
V3T3	3.71 A-H	3.77 A-D	3.18 JK	3.27 F-K
V3T4	3.44 B-K	3.57 B-K	3.83 AB	3.29 E-K
V3T5	3.43 B-K	3.70 A-H	3.72 A-G	3.77 A-D
V3T6	3.81 ABC	4.06 A	3.82 ABC	3.38 B-K
LSD (0.05)	0.48			
Note: Treatments mean which represent same letter are statistically non-significant (<i>P</i> ≤ 0.05).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	



4.3.3 Titratable acidity (TA) (%)

On DAT 2, highest titratable acidity (0.68%) was observed in both V2 and V3 and lowest (0.66%) in V1. The varieties under study showed decreasing trend from DAT 2 to DAT 11 (Table 4.29). However, Aziz et al. (2018) reported a 0.91% TA in Chandler variety of strawberry. Koyunch (2014) got a decreasing trend of TA from DAT 0 to DAT 10 for three strawberry varieties (Camarosa, Cavendish and Chandler) and this finding supports the finding of present study. Garcia et al. (1998) stated that acidity decrease demonstrates maturation development.

On DAT 2, highest titratable acidity was found in T4 treated fruits followed by the fruits treated with T6 and T5 (Table 30). All six treatments showed decreasing trend where severe loss of titratable acidity was observed in T2. Turmanidze et al. (2016) used calcium chloride (0, 1% and 2%) on strawberry and got decreasing trend which is similar to the present result.

In V1T4 treated fruits, the TA was 0.73% on DAT 2 which was maximum. All the combinations showed slow decrease in TA (%). Lowest TA was found in V1T2 at DAT 4 (Table 4.31). Mozhdehi et al. (2012) did not find any significant difference on TA it was present in the current study as there is variation in fruit acidity and calcium treated fruits also retain some acidity by blocking maturation during storage as reported by Koyuncu (2004) and Garcia et al. (1998).

Table 4.29. Varietal difference in respect of titratable acidity of strawberry during storage

Varieties	Titratable acidity (%) at DAT			
	2	5	8	11
V1	0.66 C	0.65 D	0.63 E	0.62 F
V2	0.68 A	0.66 B	0.64 D	0.62 F
V3	0.68 A	0.67 B	0.64 D	0.62 F
LSD (0.05)	0.01			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.30. Effect of treatments on titratable acidity of strawberry during storage

Treatments	Titratable acidity (%) at DAT			
	2	5	8	11
T1	0.65 FG	0.64 HI	0.64 JK	0.62 M
T2	0.65 GH	0.64 KL	0.62 M	0.60 N
T3	0.67 D	0.65 EFG	0.64 IJ	0.63 L
T4	0.71 A	0.70 B	0.68 C	0.67 D
T5	0.68 C	0.66 DE	0.64 KL	0.62 M
T6	0.70 B	0.68 C	0.66 DEF	0.62 M
LSD (0.05)	0.01			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment LSD (0.05): Significant at 5% level of probability
V2: BARI Strawberry-3	T2: No packaging + CoolBot	
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.31. Combined effect of varieties and treatments on titratable acidity of strawberry during storage

Variety x Treatments	Titratable acidity (%) at DAT			
	2	5	8	11
V1T1	0.65 K-N	0.65 L-O	0.63 PQ	0.61 ST
V1T2	0.58 X	0.56 Y	0.55 Z	0.53 A
V1T3	0.61 ST	0.60 TU	0.59 WX	0.58 X
V1T4	0.73 A	0.71 BC	0.70 CD	0.69 DE
V1T5	0.68 EF	0.67 GH	0.66 H-K	0.65 L-O
V1T6	0.70 CD	0.69 DE	0.68 FG	0.65 L-O
V2T1	0.66 HIJ	0.65 J-M	0.65 L-O	0.64 M-P
V2T2	0.66 H-K	0.64 M-P	0.60 TU	0.60 T-W
V2T3	0.68 EF	0.67 GHI	0.66 HIJ	0.64 M-P
V2T4	0.69 DE	0.68 EF	0.67 GH	0.65 L-O
V2T5	0.68 EF	0.65 J-M	0.64 OPQ	0.62 RS
V2T6	0.71 B	0.69 DE	0.66 I-L	0.60 T-W
V3T1	0.64 NOP	0.63 QR	0.62 R	0.59 UVW
V3T2	0.71 BC	0.69 DE	0.68 EF	0.65 K-N
V3T3	0.70 CD	0.69 DE	0.67 GH	0.65 J-M
V3T4	0.70 CD	0.69 DE	0.66 HIJ	0.65 L-O
V3T5	0.68 FG	0.66 I-L	0.60 TUV	0.59 WX
V3T6	0.67 GHI	0.66 I-L	0.64 NOP	0.59 VWX
LSD (0.05)	0.0121			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.3.4 Ascorbic acid (mg/100 g)

Maximum ascorbic acid (44.25 mg/ 100 g) was found in both V2 and V3 where V1 contained 43.34 mg/ 100 gm of ascorbic acid at DAT 2. All three varieties showed decreasing trend from DAT 2 to DAT 11. On DAT 11, V3 showed 37.85 m/ 100 gm of ascorbic acid which was lowest (Table 4.32). The findings from the present study is similar to the findings reported by Akter et al. (2018) and Singh et al. (2008). They got varietal difference on ascorbic acid content of strawberry cultivars.

Good retention of ascorbic acid was found in the fruits treated by both T5 and T6 followed by T4 (Calcium treated fruits) from DAT 2 to DAT 11. Untreated fruits expressed significant loss in ascorbic acid where T1 contained lowest ascorbic acid (32.3 mg/100 g) (Table 4.33). Calcium chloride treated fruits retained more ascorbic acid after 15 days of storage compared to untreated fruits as reported by Shahzad et al. (2020). This might be because higher concentrations of calcium chloride delayed the rapid oxidation of ascorbic acid in the samples.

Significant loss was observed in all combinations where the fruits of all three varieties with Calcium chloride treatment (T4, T5 and T6) retain more ascorbic acid than the varieties with T1, T2 and T3 from DAT 2 to DAT 11 (Table 4.34). Mozhdehi et al. (2012) also reported that the combined effect of packing system, calcium chloride and chlorine retains more ascorbic acid content than unpacked and untreated fruits of strawberry.

Table 4.32. Varietal difference in respect of ascorbic acid of strawberry during storage

Varieties	Ascorbic acid (mg/100 g) at DAT			
	2	5	8	11
V1	43.34 B	41.6 D	40.05 F	38.27 H
V2	44.31 A	42.71 C	40.76 E	39 G
V3	44.25 A	41.78 D	39.42 G	37.85 H
LSD (0.05)	0.58			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.33. Effect of treatments on ascorbic acid of strawberry during storage

Treatments	Ascorbic acid (mg/100 gm) at DAT			
	2	5	8	11
T1	44.15 B-E	38.55 K	34.45 N	32.3 O
T2	44.51 A-D	42.31 GH	40.29 I	37.45 L
T3	41.54 H	39.24 JK	36.03 M	34.23 N
T4	43.71 DE	42.78 FG	41.81 H	39.95 IJ
T5	45.19 A	44.87 AB	43.97 CDE	42.84 FG
T6	44.69 ABC	44.43 A-D	43.92 CDE	43.47 EF
LSD (0.05)	0.82			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.34. Combined effect of varieties and treatments on ascorbic acid of strawberry during storage

Variety x Treatments	Ascorbic acid (mg/100 g) at DAT			
	2	5	8	11
V1T1	42.83 I-O	38.38 a-d	34.39 gh	32.32 ij
V1T2	43.14 G-M	41.47 O-V	40.11 V-Y	37.64 b-e
V1T3	40.43 U-X	38.49 Z-d	37.26 de	35.74 fg
V1T4	44.95 A-E	44.03 D-J	43.29 F-M	41.21 Q-W
V1T5	46.18 A	45.32 A-D	44.00 D-J	42.10 L-S
V1T6	42.49 K-Q	41.89 M-T	41.25 Q-W	40.66 T-X
V2T1	44.24 D-I	38.91 Y-c	35.54 fg	33.70 hi
V2T2	44.62 B-F	42.33 L-R	40.93 R-X	38.04 b-e
V2T3	43.21 F-M	41.71 N-U	37.32 de	35.23 g
V2T4	43.10 H-N	42.68 J-P	41.39 P-V	39.00 Y-b
V2T5	44.96 A-E	44.86 A-E	44.06 D-J	43.07 H-N
V2T6	45.84 AB	45.69 ABC	45.34 A-D	44.96 A-E
V3T1	45.37 A-D	38.35 a-d	33.42 hi	30.89 k
V3T2	45.78 AB	43.14 G-M	39.83 W-Z	36.68 ef
V3T3	40.98 R-X	37.51 cde	33.50 hi	31.73 jk
V3T4	43.09 H-N	41.62 O-U	40.75 S-X	39.64 X-a
V3T5	44.53 B-G	44.34 C-H	43.84 E-K	43.35 F-L
V3T6	45.74 ABC	45.71 ABC	45.17 A-E	44.81 A-E
LSD (0.05)	1.42			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.3.5 Total carbohydrates (g/ 100 g)

On DAT 2, V1 contained 7.99 g/100 g carbohydrate while V2 contained 7.49 g/100 g (Table 4.35). The decreasing trend is almost similar to all three varieties. There is variation present between in respect of total carbohydrates as reported by Saied et al. (2005). Ahmed et al. (2018) found more carbohydrate content (6.81%) in camarosa variety of strawberry.

The T6 treated fruits expressed highest carbohydrate content with good retention followed by T5. Fruits treated with T4 was also moderately good compared to untreated fruits (T1, T2 and T3) (Table 4.36). Calcium chloride treated fruits retained more total carbohydrates than control in guava as it was observed by Chawla et al. (2018).

Significant differences were present between combined effect of varieties and treatments. V1T3 at DAT 2 showed highest total carbohydrate content (8.46 g/100 g) and lowest in V2T3 (6.52 g/100 g) at DAT 11. All the combinations showed decreasing trend while varieties treated with T4, T5 and T6 retained more carbohydrates than T1, T2 and T3 from DAT 2 to DAT 11 (Table 4.37). The research conducted by Mozhdehi et al. (2012) expressed similar result in case of total carbohydrates.

Table 4.35. Varietal difference in respect of total carbohydrates of strawberry during storage

Varieties	Total carbohydrates (g/ 100 g) at DAT			
	2	5	8	11
V1	7.99 A	7.84 B	7.63 D	7.45 E-F
V2	7.49 E	7.38 F	7.27 G	7.14 H
V3	7.73 C	7.59 D	7.41 EF	7.29 G
LSD (0.05)	0.08			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.36. Effect of treatments on total carbohydrates of strawberry during storage

Treatments	Total carbohydrates (g/ 100 g) at DAT			
	2	5	8	11
T1	7.55 FG	7.47 GH	7.09 KL	6.85 M
T2	7.8 CD	7.56 FG	7.41 HI	7.19 JK
T3	7.63 EF	7.31 IJ	7.04 L	6.82 M
T4	7.64 EF	7.56 FG	7.49 GH	7.39 HI
T5	7.84 BC	7.79 CD	7.69 DE	7.65 EF
T6	7.98 A	7.94 AB	7.91 ABC	7.87 ABC
LSD (0.05)	0.12			

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at 5% level of probability
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.37. Combined effect of varieties and treatments on total carbohydrates of strawberry during storage

Variety x Treatments	Total carbohydrates (g/ 100 gm) at DAT			
	2	5	8	11
V1T1	7.62 M-Q	7.58 N-S	7.12 Y-b	6.79 ef
V1T2	8.05 D-G	7.85 G-L	7.72 J-N	7.48 O-T
V1T3	8.46 A	7.95 F-I	7.47 O-U	7.12 Y-ab
V1T4	7.44 P-V	7.40 R-W	7.27 T-Z	7.18 X-a
V1T5	8.38 AB	8.29 ABC	8.26 A-D	8.22 B-E
V1T6	7.99 FGH	7.97 F-I	7.95 F-I	7.92 G-J
V2T1	7.58 N-S	7.40 R-W	7.14 Y-ab	6.89 c-f
V2T2	7.59 N-R	7.26 U-Z	7.10 Z-c	6.88 def
V2T3	6.80 ef	6.73 f	6.70 fg	6.52 g
V2T4	7.33 T-X	7.28 T-Z	7.21 W-a	7.16 X-b
V2T5	7.77 I-N	7.76 I-N	7.66 K-O	7.64 L-P
V2T6	7.89 G-J	7.87 G-K	7.81 H-M	7.77 I-N
V3T1	7.45 O-V	7.43 P-V	7.00 a-e	6.87 def
V3T2	7.76 I-N	7.59 N-R	7.42 Q-W	7.21 W-a
V3T3	7.64 L-Q	7.25 V-Z	6.96 b-e	6.81 ef
V3T4	8.14 C-F	8.01 E-H	7.97 F-I	7.82 H-M
V3T5	7.37 S-X	7.32 T-Y	7.15 Y-b	7.08 Z-d
V3T6	8.05 D-G	7.98 F-I	7.97 F-I	7.93 F-J
LSD (0.05)	0.22			
Note: Treatments mean which represent same letter are statistically non-significant ($P\leq 0.05$).				
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability	

4.3.6 Anthocyanin (mg/100 g)

The variety V1 expressed highest anthocyanin content followed by V2 at DAT 3. There was a slight increase in anthocyanin content in V1 and V2 on DAT 7 from DAT 3. But it decreased rapidly on Day 7 to DAT 11 (Table 4.38). Singh et al. (2008) confirmed the varietal difference in anthocyanin content in strawberry fruit which is similar to the findings from present study.

The T4, T5 and T6 treated fruits retained anthocyanin content as only a small increase in observed in DAT 7. Untreated fruits (T1, T2 and T3) showed low anthocyanin value with similar decreasing trend from DAT 3 to DAT 11 (Table 4.39). The result from this study is similar to the findings of Kumar et al. (2020). Calcium treatment has been found to increase color formation of strawberry fruits by affecting phenylalanine ammonia lyase and tyrosine ammonia lyase activities (Kumar et al., 2020).

In case of interaction effect of variety and treatment on anthocyanin content, all three varieties with T6 treatment showed higher anthocyanin content than other treatments followed by T5 and T4. Untreated fruits (T1, T2 and T3) of all varieties expressed less anthocyanin content from DAT 3 to DAT 11 (Table 4.40). Rahimi et al. (2018) found similar effect from combined interaction of chitosan and calcium chloride on anthocyanin content of strawberry.

Table 4.38. Varietal difference in respect of anthocyanin of strawberry during storage

Varieties	Anthocyanin (mg/100 g) at DAT		
	3	7	11
V1	38.57 AB	38.68 A	37.33 E
V2	37.79 D	37.88 D	36.15 G
V3	38.29 BC	38.05 CD	36.9 F
LSD (0.05)	0.32		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

Table 4.39. Effect of treatments on anthocyanin of strawberry during storage

Treatments	Anthocyanin (mg/100 g) at DAT		
	3	7	11
T1	37.51 GH	37.65 FGH	35.18 K
T2	37.78 FG	37.21 HI	35.92 J
T3	38.21 DE	37.58 FGH	35.55 JK
T4	38.48 CD	38.86 C	37.88 EFG
T5	37.67 FG	38.01 EF	36.79 I
T6	39.69 AB	39.92 A	39.45 B
LSD (0.05)	0.45		

Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).

V1: RABI-3	T1: Control- Ambient condition	DAT: Days after treatment
V2: BARI Strawberry-3	T2: No packaging + CoolBot	LSD (0.05): Significant at
V3: Festival	T3: Paper box packaging + CoolBot	5% level of probability
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.40. Combined effect of varieties and treatments on anthocyanin of strawberry during storage

Variety x Treatments	Anthocyanin (mg/100 g) at DAT		
	3	7	11
V1T1	37.69 I-Q	38.097 F-L	35.62 V-Y
V1T2	38.63 E-G	37.40 L-Q	36.41 S-V
V1T3	37.66 J-Q	37.72 I-P	35.90 U-X
V1T4	39.43 CD	40.03 ABC	38.42 E-J
V1T5	37.99 G-M	38.25 E-K	37.33 L-R
V1T6	40.04 ABC	40.62 A	40.33 AB
V2T1	37.02 O-T	37.07 N-T	34.47 Z
V2T2	37.34 L-R	37.32 L-R	34.99 YZ
V2T3	38.55 E-H	37.70 I-Q	35.14 XYZ
V2T4	38.68 D-G	38.84 DEF	38.22 E-K
V2T5	36.56 R-U	37.47 K-Q	35.87 U-X
V2T6	38.58 E-H	38.90 DE	38.23 E-K
V3T1	37.83 H-N	37.79 H-O	35.47 XY
V3T2	37.25 M-R	36.92 Q-T	36.35 T-W
V3T3	38.43 E-J	37.32 L-R	35.62 WXY
V3T4	37.34 L-R	37.72 I-P	36.99 P-T
V3T5	38.47 E-I	38.30 E-J	37.18 N-S
V3T6	40.44 AB	40.25 AB	39.79 BC
LSD (0.05)	0.79		
Note: Treatments mean which represent same letter are statistically non-significant (P≤ 0.05).			
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot		DAT: Days after treatment LSD (0.05): Significant at 5% level of probability

4.4 Fruit spoilage (%)

Maximum fruit spoilage (%) was obtained in V1 (21.01%) followed by V2 (Fig. 4.3) after 11 days of storage. V3 showed less fruit spoilage (18.35%) after 11 days of storage (Fig 4.3). Spoilage of strawberry fruit is a varietal characteristics and varies among varieties. Das et al. (2015) got Festival variety (V3) as superior in respect of high disease resistance. Nes (1996) also reported that Elsanta variety of strawberry is resistant to spoilage than other varieties.

The treatments T4 and T5 performed best at showing less fruit spoilage (Fig. 4.4). The T1 treated fruit showed maximum fruit spoilage (36.71%). Amal et al. (2020), Guan et al. (2006), Zhao et al. (2013), Kumar et al. (2021), Garcia et al. (1996) and Cheour et al. (1991) supports the present result as they got minimum strawberry fruit spoilage in calcium treated fruits compared to untreated fruits. Calcium chloride forms an edible coating that induces defense capability for fungal attack in strawberry fruit (Zhao et al., 2013). Surprisingly higher concentration of calcium chloride 3% (T6) showed significant fruit spoilage (%). Higher concentrations of calcium chloride may cause fruit rotting and core rot in apple as reported by Ullah et al. (2007).

The combined effect of varieties and treatments on fruit spoilage (%) was found to be significant at the end of storage. All three varieties with T1 showed maximum spoiled fruits where T4 and T5 treated fruit showed minimum spoilage (Table 4.41). The combined effect of calcium chloride and salicylic acid may be act as synthetic fungicide for controlling fruit decay in strawberry (Shahzad et al., 2020). Combined effect of calcium chloride and chitosan also reduced strawberry fruit spoilage as reported by Rahimi et al. (2018).

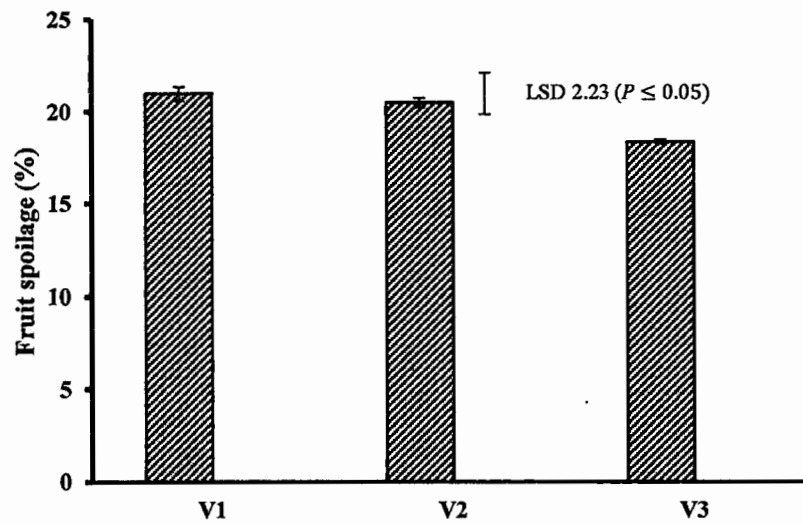


Fig. 4.3. Varietal difference in respect of fruit spoilage (%) of strawberry

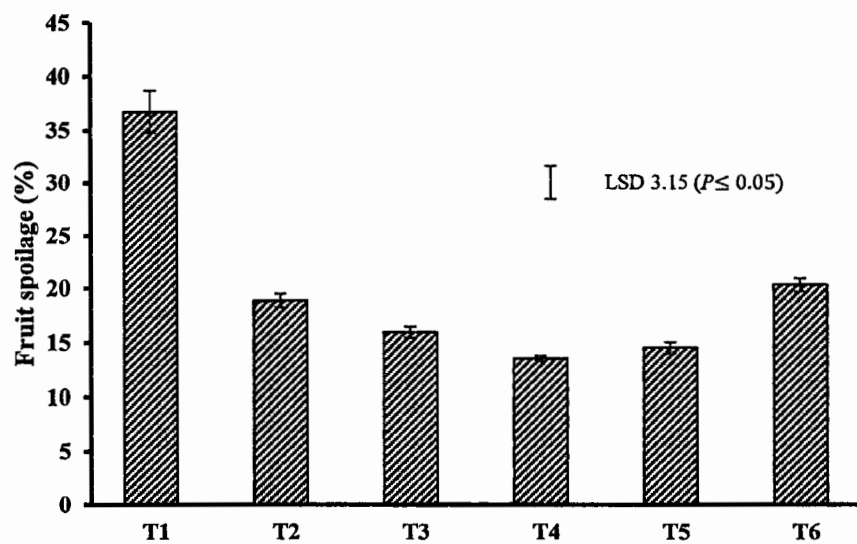


Fig. 4.4. Effect of treatments on fruit spoilage (%) of strawberry

V1: RABI-3	T1: Control- Ambient condition	LSD (0.05): Significant at 5% level of probability
V2: BARI Strawberry-3	T2: No packaging + CoolBot	
	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
V3: Festival	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

Table 4.41. Combined effect of varieties and treatments on fruit spoilage (%) and shelf life (days) of strawberry

Variety x Treatments	Fruit spoilage (%)	Shelf life (days)
V1T1	49.27 A	5.16 K
V1T2	17.39 DEF	6.75 HI
V1T3	15.94 EFG	7.16 GH
V1T4	14.49 EFG	8.25 F
V1T5	11.59 G	9.00 DE
V1T6	17.39 DEF	9.41 CD
V2T1	36.23 B	5.75 J
V2T2	17.39 DEF	6.5 I
V2T3	17.39 DEF	6.67 I
V2T4	13.04 FG	8.57 EF
V2T5	14.49 EFG	9.50 C
V2T6	24.64 C	9.50 C
V3T1	24.64 C	6.41 I
V3T2	21.74 CD	7.25 G
V3T3	14.49 EFG	7.25 G
V3T4	13.04 FG	9.75 C
V3T5	17.39 DEF	10.16 AB
V3T6	18.84 DE	10.50 A
LSD (0.05)	5.45	0.46
Note: Treatments mean which represent same letter are statistically non-significant ($P \leq 0.05$).		
V1: RABI-3 V2: BARI Strawberry-3 V3: Festival	T1: Control- Ambient condition T2: No packaging + CoolBot T3: Paper box packaging + CoolBot T4: CaCl ₂ 1% + paper box packaging + CoolBot T5: CaCl ₂ 2% + paper box packaging + CoolBot T6: CaCl ₂ 3% + paper box packaging + CoolBot	LSD (0.05): Significant at 5% level of probability

4.5 Shelf life (days)

Maximum shelf life (8.55 days) was obtained from the V3. The variety V1 and V2 showed almost similar shelf life (days) (Fig. 4.5). Shelf life of fruit varies from variety to variety as reported by Akter et al. (2018) and Nes (1996).

T6 showed 1.69 times extended shelf life compared to T1 (Control). The T5 treated fruits also showed 1.65 times longer shelf life than T1. Untreated fruits in Coolbot storage (T2 and T3) expressed almost similar shelf life (Fig. 4.6). Maximum shelf life (days) of strawberry is exhibited in calcium treated fruits rather than untreated fruits due to less weight loss (%), less decay (%), good color retention and high fruit firmness (Wan Mahfuzah et al., 2012).

The combined effect of varieties and treatments on shelf life are found to be significant. V3T6 expressed maximum shelf life (10.50 days) which is minimum in V1T1 (5.16 days). All three varieties with T1 showed lowest shelf life of strawberry (Table 4.41). Mozhdchi et al. (2012) reported that combined effect of packing system, calcium chloride and chlorine is best for strawberry fruit survival compared to non-packed, untreated fruits.

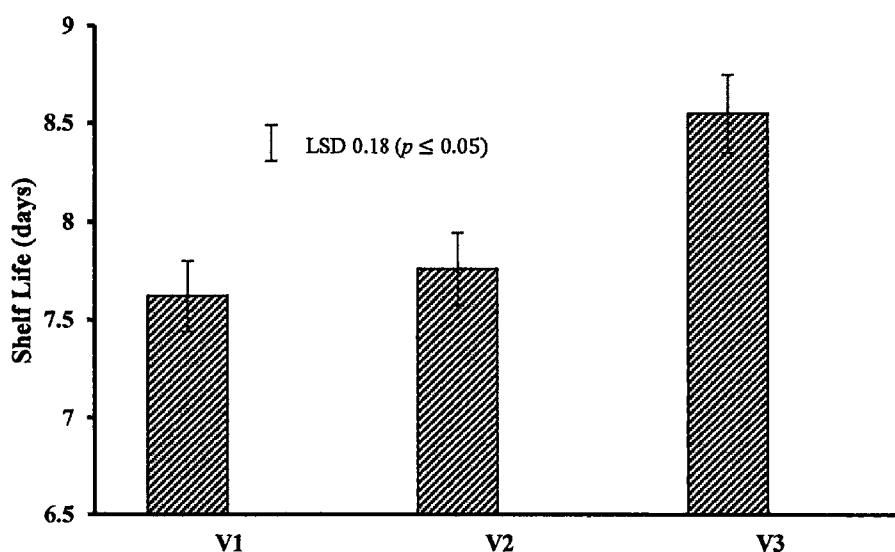


Fig. 4.5. Varietal difference in respect of shelf life (days) of strawberry

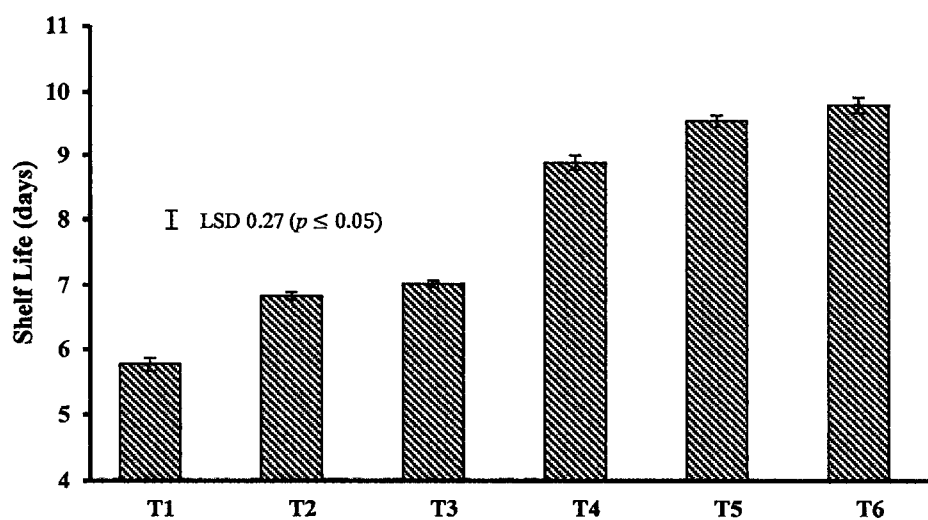


Fig. 4.6. Effect of treatments on shelf life (days) of strawberry

V1: RABI-3	T1: Control- Ambient condition	LSD (0.05): Significant at 5% level of probability
V2: BARI Strawberry-3	T2: No packaging + CoolBot	
V3: Festival	T3: Paper box packaging + CoolBot	
	T4: CaCl ₂ 1% + paper box packaging + CoolBot	
	T5: CaCl ₂ 2% + paper box packaging + CoolBot	
	T6: CaCl ₂ 3% + paper box packaging + CoolBot	

CHAPTER V

**SUMMARY, CONCLUSION AND
RECOMMENDATION**

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The present experiment was conducted on the effect of calcium chloride and packaging on postharvest quality of strawberry. The main objective was to find an effective control measure to minimize the postharvest losses of strawberry. The study was conducted at Horticulture Laboratory, Agrotechnology discipline, Khulna University, Khulna during the period from 30th March to 12th April, 2021. A CoolBot storage room was developed to store the treated and untreated fruits. It generally takes less than 2 hours to reach the lower limit of room temperature ($6\pm 2^{\circ}\text{C}$). The relative humidity (RH) of the CoolBot room is 90-95%. Moreover, CoolBot is cost efficient compared to traditional cold storage.

The experiment was laid out in factorial completely randomized design (CRD) with three replications for the treatments. Here the factors were considered as the strawberry varieties, postharvest treatments and days after treatment (DAT). For each replication of a treatment, approximately 250 gm of freshly harvested fruits were used. There were three varieties of strawberry viz. RABI-3 (V1), BARI strawberry-3 (V2) and Festival (V3) and six treatments viz. Control- Ambient condition (T1), No packaging + CoolBot (T2), Paper box packaging + CoolBot (T3), Calcium chloride 1% + paper box packaging + CoolBot (T4), Calcium chloride 2% + paper box packaging + CoolBot (T5) and Calcium chloride 3% + paper box packaging + CoolBot (T6) were used in the study.

Changes in physico-chemical characteristics as weight loss (%), polar and equatorial diameter (cm), firmness (N), colorimetric parameters (L^* , a^* , b^* and h°), p^H , TSS (%), TA (%), ascorbic acid (mg/100 g), anthocyanin (mg/100 gm), total carbohydrates (gm/100 gm), fruit spoilage (%) and shelf life (days) of fruits were observed during storage.

Significant variation was observed among the varieties for physico-chemical characteristics, fruit spoilage (%) and shelf life. Festival (V3) performed best during the study period through minimum change in fruit weight (16.63%), polar diameter (3.99 cm), firmness (15.04 N), p^H

(3.56), TSS (8.60%), least fruit spoilage (18.35%) and longer shelf life (8.55 days). BARI strawberry-3 (V2) showed maximum equatorial diameter (3.74 cm) and ascorbic acid (41.69 mg/ 100 g). RABI-3 was best for total carbohydrates (7.72 g/100 g), TA (0.65%) and anthocyanin (38.19 mg/100 g). Color values did not differ among the three varieties during the study period. No single variety was found to be superior in case of all fruit quality parameters.

In case of treatment, the T6 (Calcium chloride 3% + paper box packaging + CoolBot) resulted best with minimum loss of weight (6.33%), firmness (13.10 N), total carbohydrates (7.92 g/100 g), TA (0.66%), polar diameter (4.25 cm), anthocyanin (39.68 mg/100 g) and longer shelf life (9.81 days). T5 (Calcium chloride 2% + paper box packaging + CoolBot) treated fruits expressed highest ascorbic acid (44.21 mg/100 g) and p^H (3.54). Fruits treated with T4 (Calcium chloride 1% + paper box packaging + CoolBot) showed best result for equatorial diameter (4.08 cm) and lowest fruit spoilage (13.52%) while T3 (CoolBot + paper box packaging) was higher in TSS (7.36%). Color values were almost similar to treatments applied to strawberry. T1 (Control- Ambient condition) was found to be inferior in respect of fruit quality parameters and shelf life.

5.2 Conclusion and Recommendation

The findings on the combined effect of variety and treatment indicate that Festival (V3) and T6 (Calcium chloride 3% + paper box packaging + CoolBot) might be able to delay the deterioration process and retain maximum fruit quality for longer period. It could be recommended that combination of Festival (V3) and T6 (Calcium chloride 3% + paper box packaging + CoolBot) might be an effective postharvest approach for maintaining physico-chemical properties and extending the shelf life of strawberry during storage. In this regard, further research could be conducted with other strawberry varieties by considering other concentrations of calcium chloride as well as other chemicals with different types of packaging materials.

CHAPTER VI

REFERENCES



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REFERENCES

- Aday, M. S., and Caner, C. (2014). Individual and combined effects of ultrasound, ozone and chlorine dioxide on strawberry storage life. *LWT-Food Science and Technology*, 57(1), 344-351.
- Afrisal, H., Faris, M., Grezelda, L., and Soesanti, I. (2013). Portable smart sorting and grading machine for fruits using computer vision. In 2013 International Conference on Computer, Control, Informatics and Its Applications (IC3INA) (pp. 71-75). IEEE.
- Ahmad, M., Banday, F. A., Bhat, M. Y., Sharma, M. K., Dar, M. A., Khalil, A., and Nazir, N. (2018). Performance of exotic strawberry varieties under temperate conditions of north-western Himalayas. *Indian Journal of Horticulture*, 75(4), 698-702.
- Ahsan, M. K., Mehraj, H., Hussain, M. S., Rahman, M. M., and Jamal Uddin, A. F. M. (2014). Study on growth and yield of three promising strawberry cultivars in Bangladesh. *International Journal of Business, Social and Scientific Research*, 1(3), 205-208.
- Ahsan, M.K., Mehraj, H., Hussain, M.S., Rahmann, M.M., and Uddin. A.F.M. (2014). Study on growth and yield of three promising strawberry cultivars in Bangladesh. *Inter. J. of Business, Social and Scientific Res.* 1(3):205-208.
- Ajender, T. B., and Chawla, W. (2019). Effect of calcium chloride on growth, fruit quality and production of apple. *J. Pharmacog. Phytochem*, 1, 588-593.
- Akhtar, A., Abbasi, N. A., and Hussain, A. Z. H. A. R. (2010). Effect of calcium chloride treatments on quality characteristics of loquat fruit during storage. *Pakistan Journal of Botany*, 42(1), 181-188.
- Akter, M. M., Hossain, M. M., Hoque, M. A., Ivy, N. A., and Roni, M. S. (2018). Evaluating Nutritional Quality and Shelf Life of Strawberry Genotypes under Field Condition.

- Alharaty, G., and Ramaswamy, H. S. (2020). The effect of sodium alginate-calcium chloride coating on the quality parameters and shelf life of strawberry cut fruits. *Journal of Composites Science*, 4(3), 123.
- Amal, S. A., El-Mogy, M. M., Aboul-Anean, H. E., and Alsanius, B. W. (2010). Improving strawberry fruit storability by edible coating as a carrier of thymol or calcium chloride. *Journal of Horticultural Science and Ornamental Plants*, 2(3), 88-97.
- Ara, T., Karim, R., Islam, R., and Hossain, M. (2013). Yield potential study of three genotypes (RABI-3, JP-3 and Camarosa) of strawberry (*Fragaria x ananassa* Duch.) in Bangladesh. *Journal of Genetic and Environmental Resources Conservation*, 1(3), 170-176.
- Asrey, R. and Singh, R. Evaluation of strawberry varieties under semi-arid irrigation region of Punjab. *Indian J of Hort.* 2004; 61:122-124.
- Astuti, N. K., Maghfoer, M. D., and Soelistyono, R. (2013). Calcium chloride applications to improve fruit quality on bruised and diseased of pineapple (*Ananas comosus* (L) Merr). *Applied Chemistry*, 5, 30-34.
- Atri, M., Golami, M., and Karami, F. (2008). The effect of calcium chloride foliar application on shelf life of strawberry cv.'kurdistan'.
- Awang, Y., Ghani, M. A. A., Sijam, K., and Mohamad, R. B. (2011). Effect of calcium chloride on anthracnose disease and postharvest quality of red-flesh dragon fruit (*Hylocereus polyrhizus*). *African Journal of Microbiology Research*, 5(29), 5250-5259.
- Azam, M., Ejaz, S., Rehman, R. N. U., Khan, M., and Qadri, R. (2019). Postharvest quality management of strawberries. *Strawberry-Pre-and Post-Harvest Management Techniques for Higher Fruit Quality*.

- Aziz, M. M., Alvi, A., Rashid, S., Abbas, M. M., and Riaz, S. (2018). Evaluation of strawberry (*Fragaria* × *ananassa* Duch.) Cultivars for morphological and physico-chemical parameters in subtropical climate: Horticultural Research Institute, AARI, Jhang Road, Faisalabad, Pakistan. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, 34(2), 126-129.
- Bagheri, M., Esna-Ashari, M., and Ershadi, A. (2015). Effect of postharvest calcium chloride treatment on the storage life and quality of persimmon fruits (*Diospyros kaki* Thunb.) cv. 'Karaj'. *International Journal of Horticultural Science and Technology*, 2(1), 15-26.
- Bola, P.K., Jain S.K., and Anupama. (2017). Efficacy of calcium chloride, carboxymethyl cellulose and chitosan on the shelf-life of strawberry (*Fragaria* × *ananassa* D.). *Green Farming* Vol. 8 (4): 995-998; July-August, 2017.
- Bowling, B.L. (2000). *The berry grower's Companion*. Timber Press Inc., Portland, Oregon, USA.
- Chandel, J. S., and Badiyala, S. D. (1996). Performance of some strawberry cultivars in foothills of Himachal Pradesh. *Ann. Agric. Res*, 17(4), 375-378.
- Chandler, C. K., Legard, D. E., and Sims, C. A. (1997). 'Rosa Linda' strawberry. *HortScience: a publication of the American Society for Horticultural Science* (USA).
- Chandler, C. K., Legard, D. E., Dunigan, D. D., Crocker, T. E., and Sims, C. A. (2000). Strawberry festival' strawberry. *HortScience*, 35(7), 1366-1367.
- Chawla, S., Devi, R., and Jain, V. (2018). Changes in physicochemical characteristics of guava fruits due to chitosan and calcium chloride treatments during storage. *Journal of Pharmacognosy and Phytochemistry*, 7(3), 1035-1044.
- Cheour, F., Willemot, C., Arul, J., Makhoul, J., and Desjardins, Y. (1991). Postharvest response of two strawberry cultivars to foliar application of CaCl_2 . *HortScience*, 26(9), 1186-1188.

- Chowhan, S., Roni, M. S., Ahmed, S. S., Uddin, H., and Hasan, M. M. (2016). Evaluation of nutritive value and shelf life of strawberry genotypes. *Asian Journal of Medical and Biological Research*, 2(1), 19-26.
- Coombey (1976). The development of fruits. *Ann. Rev. Plant Physiol.*, 27: 507-512.
- Darnell, R.L., Cantliffe, D.J., Kirschbaum, D.S., and Chandler, C.K. (2003). The physiology of flowering in strawberry. *Hort. Rev.* 28 (6): 325-332.
- Das, A. K., Singh, K. P., Prasad, B., and Kumar, R. (2015). Evaluation of Cultivars of Strawberry, a Temperate Fruit for its Adaptability as well as Productivity in Sub-Tropical Agro-Climatic Condition of Supaul District in Bihar. *The Asian Journal of Horticulture*, 10(2), 278-281.
- Das, S., and Samtani, J. (2021). Strawberry Variety Evaluation, Opportunities, and Challenges of High Tunnel Production.
- Dhakal, S., Devkota, S., and Shrestha, B. (2022). Evaluation of Low Chilling Strawberry (*Fragaria ananassa*) Varieties with Respect to Yield and Quality in Eastern Nepal. *American Journal of Life Science and Innovation*, 1(1), 6-14.
- Dukani, H. A. I., and najmaldeen Kakahy, A. N. (2018). Effect of Rosemary Plant Extract and Calcium Chloride Sprays on the Some Fruit Quality and Storability of Strawberry (*Fragaria X Ananassa* Duch) Grown under Plastic House Conditions. *Euphrates Journal of Agriculture Science*, 10(3).
- Ganai, S. A., Ahsan, H., Tak, A., Mir, M. A., Rather, A. H., and Wani, S. M. (2018). Effect of maturity stages and postharvest treatments on physical properties of apple during storage. *Journal of the Saudi Society of Agricultural Sciences*, 17(3), 310-316.
- García, J. M., Herrera, S., and Morilla, A. (1996). Effects of postharvest dips in calcium chloride on strawberry. *Journal of Agricultural and Food Chemistry*, 44(1), 30-33.
- García, M. A., Martino, M. N., and Zaritzky, N. E. (1998). Plasticized starch-based coatings to improve strawberry (*Fragaria × ananassa*) quality and stability. *Journal of Agricultural and Food Chemistry*, 46(9), 3758-3767.

- García, M. A., Martino, M. N., and Zaritzky, N. E. (1998). Starch-based coatings: effect on refrigerated strawberry (*Fragaria ananassa*) quality. *Journal of the Science of Food and Agriculture*, 76(3), 411-420.
- Giacalone, G., and Chiabrando, V. (2017). Active packaging to improve the shelf-life and nutritional quality of strawberries. In VI International Conference Postharvest Unlimited 1256 (pp. 379-386).
- Godana E. A., Alemnew A., Eshetu S., and Awoke M. (2018). Effect of Packaging Materials and Postharvest Treatments on Postharvest Quality and Shelf Life of Banana Fruits (*Musa Spp*). *Annans. Of Food Science and Technology*, 19(2): 292-299.
- Gomez, K. A., and Gomez, A. A. (1984). Statistical procedures for agricultural research. John wiley and sons.
- Guan, J., Park, H. W., Kim, Y. H., Kim, S. H., and Park, H. R. (2006). Effects on quality of strawberry fruit by dipping of calcium solution and MA packaging. *Korean Journal of Food Preservation*, 13(1), 13-17.
- Hernández-Muñoz, P., Almenar, E., Ocio, M. J., and Gavara, R. (2006). Effect of calcium dips and chitosan coatings on postharvest life of strawberries (*Fragaria x ananassa*). *Postharvest Biology and Technology*, 39(3), 247-253.
- Holcroft, D. M., and Kader, A. A. (1999). Controlled atmosphere-induced changes in pH and organic acid metabolism may affect color of stored strawberry fruit. *Postharvest Biology and Technology*, 17(1), 19-32.
- Hossain, A., Begum, P., Zannat, M. S., Rahman, M. H., Ahsan, M., and Islam, S. N. (2016). Nutrient composition of strawberry genotypes cultivated in a horticulture farm. *Food Chemistry*, 199, 648-652.
- Jannati, M., and Abdoosi, V. (2014). Evaluation of effect of calcium chloride and some essential oils on postharvest of strawberry fruit.
- Jun, W. A. N. G., Feng, M. I. A. O., and Rui, Z. H. O. U. (2020). Effect of Different Processing Methods on Storage Quality of Strawberries. *Asian Agricultural Research*, 12(1812-2021-681), 47-50.

- Jun, W. A. N. G., Feng, M. I. A. O., and Rui, Z. H. O. U. (2020). Effect of Different Processing Methods on Storage Quality of Strawberries. *Asian Agricultural Research*, 12(1812-2021-681), 47-50.
- Kader, A. A. (2002). Quality parameters of fresh-cut fruit and vegetable products. Fresh-cut fruits and vegetables. *Science, technology and market*, 11-20.
- Karithi, E. M. (2016). Evaluation of the efficacy of coolbot™ cold storage technology to preserve quality and extend shelf life of mango fruits (Doctoral dissertation, University of Nairobi).
- Khalid, S., Majeed, M., Ullah, M. I., Shahid, M., Riasat, A. R., Abbas, T., and Farooq, A. (2020). Effect of storage conditions and packaging material on postharvest quality attributes of strawberry. *Journal of Horticulture and Postharvest Research*, 3(2-September 2020), 195-208.
- Khreba, A. H., Hassan, A. H., Emam, M. S., and Atala, S. A. (2014). Effect of some pre and post-harvest treatments on quality and storability of strawberry fruits. *The Journal of American Science*, 10(11), 239-248.
- Kim, D. Y., Kim, S. Y., Huh, Y. C., Yoon, M. K., Lee, S. Y., Moon, J. H., and Kim, D. H. (2018). 'Arihyang', a Strawberry Variety with Highly Firm and Large-Sized Fruit for Forcing Culture. *Korean Society of Breeding Science*, 50(4), 497-503.
- Kirmani, S. N., Wani, G. M., Wani, M. S., Ghani, M. Y., Abid, M., Muzamil, S., and Malik, A. R. (2013). Effect of preharvest application of calcium chloride (CaCl_2), Gibberlic acid (GA3) and Naphthelenic acetic acid (NAA) on storage of Plum (*Prunus salicina* L.) cv. Santa Rosa under ambient storage conditions. *African Journal of Agricultural Research*, 8(9), 812-818.
- Koyuncu, M. A. (2004). Quality changes of three strawberry cultivars during the cold storage. *European Journal of Horticultural Science*, 69(5).

- Kumar, A., Karuna, K., Mankar, A., Mandal, S. K., and Kumari, N. (2020). Pre-harvest spray of chitosan, calcium chloride and low temperature storage (7 °C) effect on biochemical attributes of strawberry cv. Camarosa. *Journal of Pharmacognosy and Phytochemistry*, 9(3), 1097-1102.
- Kumar, J., Thakur, D., Thakur, M., and Babita, B. (2016). Performance of strawberry cultivars in mid hill region of Kullu valley of Himachal Pradesh. *Journal of Applied and Natural Science*, 8(2), 967-970.
- Kumar, R., Antil, R. S., and Ali, A. (2021). Effect of packaging material and postharvest calcium treatment on weight loss, decay and biochemical quality of strawberry fruits during storage. *Journal of Applied and Natural Science*, 13(4), 1158-1165.
- Kumari, S., Sankhyani, S., and Kumar, A. (2020). Yield and quality characters of different strawberry (*Fragaria x ananassa* Duch.) cultivars growing under mid hill conditions of Himachal Pradesh.
- Langer, S. E., Marina, M., Burgos, J. L., Martínez, G. A., Civello, P. M., and Villarreal, N. M. (2019). Calcium chloride treatment modifies cell wall metabolism and activates defense responses in strawberry fruit (*Fragaria x ananassa*, Duch). *Journal of the Science of Food and Agriculture*, 99(8), 4003-4010.
- Leak, C., Buntong, B., Acedo, A. L., Easdown, W., Hughes, J. A., and Keatinge, J. D. H. (2015, August). Effects of chitosan coating on quality and shelf life of tomato during CoolBot cold storage. In III Southeast Asia Symposium on Quality Management in Postharvest Systems 1179 (pp. 107-110).
- Lee, S. H., Lee, M. S., Lee, Y. W., Sun, N. K., and Song, K. B. (2003). Effect of Packaging Method on the Quality of Strawberry, Tomato, and plum during Storage. In *Proceedings of the Korean Society of Postharvest Science and Technology of Agricultural Products Conference* (pp. 187-187). The Korean Society of Food Preservation.

- Lester, G. E., and Grusak, M. A. (1999). Postharvest application of calcium and magnesium to honeydew and netted muskmelons: effects on tissue ion concentrations, quality, and senescence. *Journal of the American Society for Horticultural Science*, 124(5), 545-552.
- Luna-Guzmán, I., and Barrett, D. M. (2000). Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. *Postharvest Biology and technology*, 19(1), 61-72.
- Lurie, S. (2009). Stress physiology and latent damage. *Postharvest handling: A systems approach*, 2, 443-459.
- Maas, J.L. (1998). Compendium of strawberry diseases. American Phytopathological Society. St. Paul, MN. p.138.
- Mahmud, T. M. M., Al Eryani-Raqeeb, A., Omar, S. S., Zaki, A. M., and Abdul-Rahman, A. E. (2008). Effects of different concentrations and applications of calcium on storage life and physicochemical characteristics of papaya (*Carica papaya* L.). *American Journal of Agricultural and Biological Science*.
- Matar, C., Gaucel, S., Gontard, N., Guilbert, S., and Guillard, V. (2018). A global visual method for measuring the deterioration of strawberries in MAP. *MethodsX*, 5, 944-949.
- Mazumdar, D. B. C. and Majumdar, K. 2001. Methods of physico-chemical analysis of fruits. Daya Publishing House, India. pp. 112-115.
- McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, 27(12), 1254-1255.
- Mia, M. A. B. 2022. Digital Herbarium of Crop Plants, Department of Crop Botany, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. (Available from: <http://dhcrop.bsmrau.net/bari-straw-berry-3>) (Searched on 20.05.2022).
- Minh, N. P. (2022). Effectiveness of CaCl₂ treatment on quality attributes of banana fruit during storage. *Plant Science Today*, 9(1), 206-214.

- Mootoo, A. (1991). Effect of post-harvest calcium chloride dips on ripening changes in Julie mangoes. *Tropical science*, 31(3), 243-248.
- Moradinezhad, F., Ghesmati, M., and Khayyat, M. (2019). Postharvest calcium salt treatment of fresh jujube fruit and its effects on biochemical characteristics and quality after cold storage. *Journal of Horticultural Research*, 27(2).
- Mozhdehi, F., Abdossi, V., and Kalatejari, S. (2012). Effect of Packing System, Calcium Chloride and Chlorine on the Storage Life of Strawberry Fruits (*Fragaria ananassa* cv. Kordistan). *Journal of Basic and Applied Sciences*, 8(2), 393-398.
- Nagre, P. K., Garad, B. V., Bulbule, A. V., Patil, V. S., and Mote, P. U. (2005). Varietal performance of strawberry under Igatpuri conditions of Western Ghat Zone. *Journal-Maharashtra Agricultural Universities*, 30(1), 120.
- Neetu, S. P. S., and Verma, G. (2020). Varietal screening of strawberry (*Fragaria x ananassa* Duch.) under open field condition for fruit quality and yield in plain region of Chhattisgarh, India. *Journal of Pharmacognosy and Phytochemistry*, 9(1), 405-407.
- Neetu, S. S. (2018). Evaluation of Strawberry Cultivars for Growth and Yield Characteristics in plain Region of Chattisgrah India. *Int. J Curr. Microbiol. App. Sci*, 7(02), 2835-2840.
- Nes, A. (1996, April) Evaluation of strawberry cultivars in Norway. In III International Strawberry Symposium 439 (pp. 275-280).
- Ngo, T. M. P., Nguyen, T. H., Dang, T. M. Q., Do, T. V. T., Reungsang, A., Chaiwong, N., and Rachtanapun, P. (2021). Effect of pectin/nanochitosan-based coatings and storage temperature on shelf-life extension of "Elephant" Mango (*Mangifera indica* L.) Fruit. *Polymers*, 13(19), 3430.
- Nguyen, V. T., Nguyen, D. H., and Nguyen, H. V. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (*Fragaria x ananassa* Duch.). *Postharvest Biology and Technology*, 162, 111103.

- Nunes, M. C. N., Brecht, J. K., Sargent, S. A., and Morais, A. M. M. B. (1995). Effects of delays to cooling and wrapping on strawberry quality (cv. Sweet Charlie). *Food Control*, 6(6), 323-328.
- Panda, A. K., Goyal, R. K., Godara, A. K., and Sharma, V. K. (2016). Effect of packaging materials on the shelf-life of strawberry cv. Sweet Charlie under room temperature storage. *Journal of Applied and Natural Science*, 8(3), 1290-1294.
- Peano, C., Giuggioli, N. R., and Girgenti, V. (2014). Effect of different packaging materials on postharvest quality of cv. Envie2 strawberry. *International Food Research Journal*, 21(3).
- Pelayo, C., Ebeler, S. E., and Kader, A. A. (2003). Postharvest life and flavor quality of three strawberry cultivars kept at 5°C in air or air+ 20 kPa CO₂. *Postharvest Biology and Technology*, 27(2), 171-183.
- Peoun, P., Buntong, B., Yim, S., Vat, S., Acedo, A. L., Easdown, W., and Keatinge, J. D. H. (2015). Modified atmosphere packaging of leaf mustard during evaporative cooling and CoolBot cold storage. In *III Southeast Asia Symposium on Quality Management in Postharvest Systems 1179* (pp. 173-176).
- Pérez, A. G., and Sanz, C. (2001). Effect of high-oxygen and high-carbon-dioxide atmospheres on strawberry flavor and other quality traits. *Journal of Agricultural and Food Chemistry*, 49(5), 2370-2375.
- Poudel, S., Gautam, I. P., Ghimire, D., Pandey, S., Dhakal, M., and Regmi, R. (2021). Modified atmosphere packaging of capsicum for extending shelf life under coolbot condition. *Journal of Agriculture and Natural Resources*, 4(1), 120-129.
- Rahimi, B. A., Shankarappa, T. H., Krishna, H. C., Mushrif, S. K., Vasudeva, K. R., Sadananda, G. K., and Masoumi, A. (2018). Chitosan and CaCl₂ coatings on physicochemical and shelf life of strawberry fruits (*Fragaria x ananassa* Duch.). *Int. J. Curr. Microbiol. App. Sci*, 7(7), 3293-3300.

- Rahman, M. M., Rahman, M. M., Hossain, M. M., Khaliq, Q. A., and Moniruzzaman, M. (2014). Effect of planting time and genotypes growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.). *Scientia Horticulturae*, 167, 56-62.
- Rahman, M. U., Sajid, M., Rab, A., Ali, S., Shahid, M. O., Alam, A., and Ahmad, I. (2016). Impact of calcium chloride concentrations and storage duration on quality attributes of peach (*Prunus persica*). *Russian agricultural sciences*, 42(2), 130-136.
- Ram, R. B., and Yadav, A. K. (2006). Introduction and evaluation of some strawberry (*Fragaria ananassa* Duch; Rosaceae) cultivars under Lucknow conditions. *Plant Archives*, 6(2), 529-531.
- Reyes-Medina, A. J., Pinzón, E. H., and Álvarez-Herrera, J. G. (2017). Effect of calcium chloride and refrigeration on the quality and organoleptic characteristics of cape gooseberry (*Physalis peruviana* L.). *Acta Agronómica*, 66(1), 15-20.
- Rolle, R. S. (2006). Improving postharvest management and marketing in the Asia-Pacific region: issues and challenges. *Postharvest management of fruit and vegetables in the Asia-Pacific region*, 1(1), 23-31.
- Saied, A. S., Keutgen, A. J., and Noga, G. (2005). The influence of NaCl salinity on growth, yield and fruit quality of strawberry cvs. 'Elsanta' and 'Korona'. *Scientia Horticulturae*, 103(3), 289-303.
- Saini, R. S., Sharma, K. D., Dhankhar, O. P. and Kaushik, R.A. 2006. Laboratory manuals for analytical techniques in horticulture. AgrobiosPublishing Co. Ltd., India. pp. 5-16.
- Sajid, M., Basit, A., Ullah, I., Tareen, J., Asif, M., Khan, S., and Nawaz, M. K. (2019). 13. Efficiency of calcium chloride (CaCl₂) treatment on post-harvest performance of pear (*Pyrus communis* L.). *Pure and Applied Biology (PAB)*, 8(2), 1111-1125.
- Sati, F., and Qubbaj, T. (2021). Effect of calcium chloride postharvest treatment in combination with plant natural substance coating on fruit quality and storability of tomato (*Solanum lycopersicum*) fruits during cold storage. *Journal of Applied Botany and Food Quality*, 94, 100-107.

- Shahzad, S., Ahmad, S., Anwar, R., and Ahmad, R. (2020). Pre-storage application of calcium chloride and salicylic acid maintain the quality and extend the shelf life of strawberry. *Pakistan Journal of Agricultural Sciences*, 57(2).
- Sharma, G. I. R. I. S. H., and Thakur, M. S. (2008). Evaluation of different strawberry cultivars for yield and quality characters in Himachal Pradesh. *Agricultural Science Digest*, 28(3), 213-215.
- Singh, A., Patel, R. K., De, L. C., and Pereira, L. S. (2008). Performance of strawberry (*Fragaria ananassa*) cultivars under sub-tropics of Meghalaya. *Indian Journal of Agricultural Sciences*, 78(7), 575.
- Sohail, M., Ayub, M., Khalil, S. A., Zeb, A., Ullah, F., Afridi, S. R., and Ullah, R. (2015). Effect of calcium chloride treatment on postharvest quality of peach fruit during cold storage. *International Food Research Journal*, 22(6).
- Sturzeanu, M. (2020). Postharvest quality of strawberry fruits grown in conventional system.
- Sunil, S., Neeru, D., Vigya, M., Dwivedi, S. K., and Raman, N. L. M. (2013). Evaluation of coolbot cool room as a low cost storage system for marginal farmers. *Progressive Horticulture*, 45(1), 115-121.
- Suutarinen, J., Heiska, K., Moss, P., and Autio, K. (2000). The effects of calcium chloride and sucrose prefreezing treatments on the structure of strawberry tissues. *LWT-Food Science and Technology*, 33(2), 89-102.
- Tabassum, P., Khan, S. A. K. U., Siddiqua, M., and Sultana, S. (2018). Effect of guava leaf and lemon extracts on postharvest quality and shelf life of banana cv. Sabri (*Musa sapientum* L.): Effect of plant extract on banana shelf life. *Journal of the Bangladesh Agricultural University*, 16(3), 337-342.
- Tac-an, M. I. A., Lubaton, C. D. S., Lacap, A. T., and Bayogan, E. R. V. (2019). Postharvest quality of mangosteen (*Garcinia mangostana* L.) at two fruit maturities under ambient and coolbot storage conditions. *Philippine Journal of Crop Science (Philippines)*.

- Temocico, G. E. O. R. G. E. T. A., Sturzeanu, M. O. N. I. C. A., Ion, V., and Cristea, S. (2019). Evaluation of strawberry fruit quality for new selections and cultivars. *RomBiotechnolLett*, 24(4), 742-748.
- Turmanidze, T., Gulua, L., Jgenti, M., and Wicker, L. (2016). Effect of calcium chloride treatments on quality characteristics of blackberry, raspberry and strawberry fruits after cold storage. *Turkish Journal of Agriculture-Food Science and Technology*, 4(12), 1127-1133.
- Uddin, A. J., Ahsan, M. K., Hussain, M. S., Mahmud, M. F., and Mehraj, H. (2016). Evaluation of Strawberry Germplasm at Sher-E-Bangla Agricultural University, Bangladesh. *World Applied Sciences Journal*, 34(1), 78-83.
- Ullah, J., Alam, S., Ahmad, T., and Qazi, I. M. (2007). Effect of CaCl_2 coating on the sensory quality and storage disorders of apple cv. kingstar stored at ambient conditions. *Sarhad Journal of Agriculture*, 23(3), 775.
- Ullah, M. H. (2007). Effect of postharvest treatments on the prolongation of shelf life of banana. Master's Thesis, Bangladesh Agricultural University, Mymensingh, Bangladesh.
- Voth, V., and Bringhurst, R. S. (1989). Strawberry plant called 'Oso Grande'. Plant patent- United States Patent and Trademark Office (USA). no. 6578.
- Wan Mahfuzah, W. I., Zulkifli, M. S., Latifah, M. N., and Fauziah, O. (2012). Evaluations for effectiveness of calcium chloride treatment on the postharvest quality of strawberry. In VII International Postharvest Symposium 1012 (pp. 515-520).
- Wang, Y. S., Tian, S. P., and Xu, Y. (2005). Effects of high oxygen concentration on pro-and anti-oxidant enzymes in peach fruits during postharvest periods. *Food chemistry*, 91(1), 99-104.
- Wills, R. B. H., Warton, M. A., Mussa, D. M. D. N., and Chew, L. P. (2001). Ripening of climacteric fruits initiated at low ethylene levels. *Australian Journal of Experimental Agriculture*, 41(1), 89-92.

APPENDIX

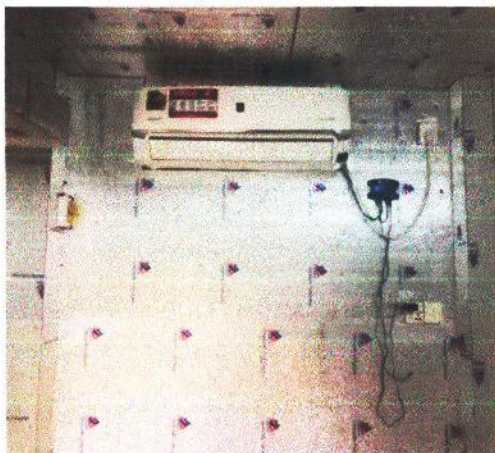


Fig. 1. CoolBot storage

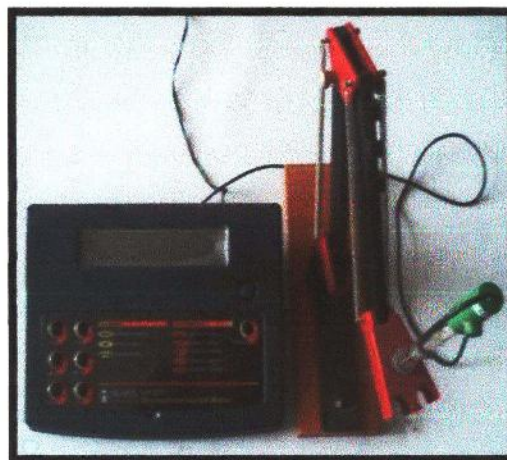


Fig 2. Desktop p^H meter



Fig 3. Electrical balance



Fig. 4. Hand refractometer



Fig 5. Chemical balance



Fig 6. Spectrophotometer (i)



Fig 7. Spectrophotometer (ii)



Fig 8. Hot plate magnetic stirrer

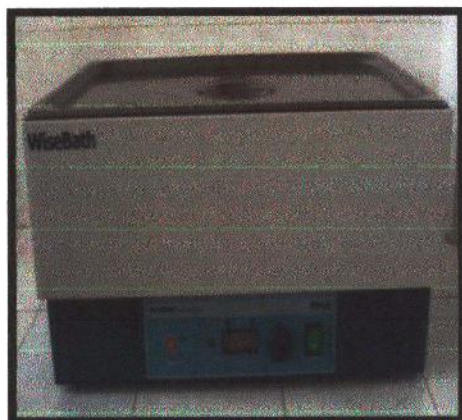


Fig. 9. Outside views of water bath



Fig. 10. Inside views of water bath

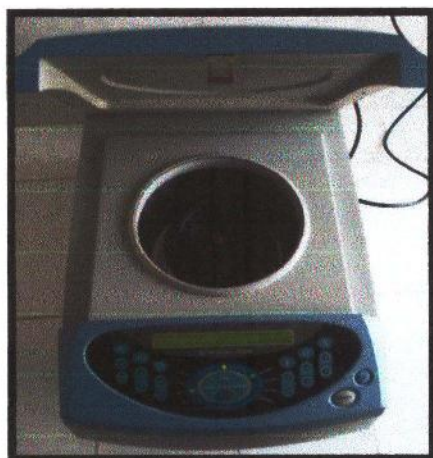


Fig. 11. Outside views of refrigerated centrifuge machine

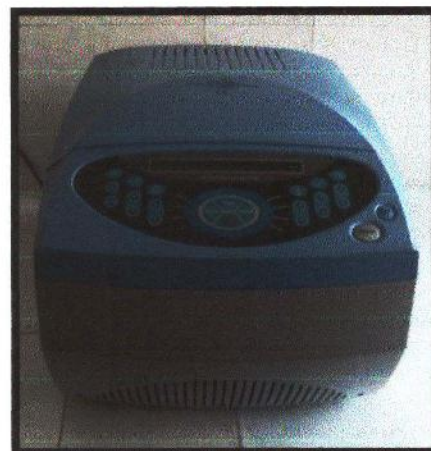


Fig 12. Inside views of refrigerated centrifuge machine



Fig. 13. Incubator (temperature controller)



Fig. 14. Colorimeter

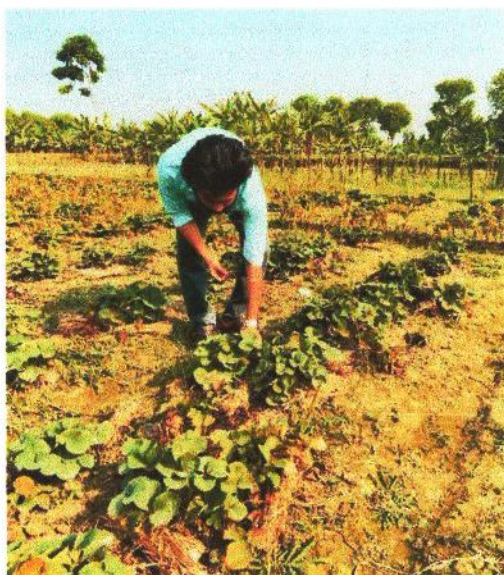


Fig. 15. Fruits collection from field



Fig. 16. Collected fruits from field