Finding out the suitable postharvest treatments for extending shelf life of Jujube

A THESIS

BY

STUDENT ID: MS 230814

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Approved as to style and contents

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DECEMBER, 2024

DEDICATION

To My Beloved Parents and All Teachers.

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ABSTRACT

Jujube is an extremely perishable fruit with a short shelf life and a considerable proportion of harvested jujube get spoiled due to the postharvest decay. Application of calcium chloride and edible chitosan coatings is a key step to reduce the loss of perishable commodities. The study was conducted at Horticulture Laboratory, Agrotechnology Discipline, Khulna University, Khulna during the period from 4th February 2024 to 20th February 2024. jujube was collected from Koya Bazar, Batighata, Khulna. The current study was designed to evaluate the effect of postharvest calcium and chitosan coating on maintaining fruit quality and shelf life of jujube during storage at ambient conditions. The fruit samples were coated with 2% and 4% solution of $CaCl_2$, 1g and 2g of chitosan solution and combined application of $CaCl_2$ and chitosan. Untreated fruits were maintained as the control. The experiment was laid out in a completely randomized design with three replications of the treatments. Changes in different physico-chemical parameters were recorded to evaluate the effectiveness of the treatments in extending fruit shelf life and sustaining postharvest quality of jujube. Results revealed that weight loss of untreated jujube fruits were almost higher than the weight loss of treated fruits. The change in color was faster in untreated jujube, whereas the slower changes in fruit color and texture was recorded in the fruits treated with calcium and chitosan. Application of calcium chloride and chitosan at 0.5% significantly reduced physiological weight loss (%), color change, total soluble solid (°Brix), titratable acidity (%) along with maintained texture, shrinking and shelf life of jujube compared to the untreated control.

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Abbreviated Form	Word
DAT	Days after treatment
TSS	Total Soluble Solid
TA	Titrable Acidity
CRD	Completely Randomized Design
LSD	Least Significance Difference
RH	Relative Humidity
STAR	Statistical Tool for Agricultural Research

CHAPTER 1

INTRODUCTION

Fruit and vegetable are an important part of our daily diet. Fruits are perishable horticulture crops that are wet-based and contain a high percentage (75–90%) of water. A range of nutritionally rich and delicious fruits and vegetables are being grown in Bangladesh due to favorable tropical and sub-tropical climates (Alvarez et al., 2021). Large amounts of vitamins and minerals may be found in fruits. Fruits rich in vitamins A, B, and C include papaya, mango, guava, jujube, jackfruit, pineapple, lemon, and more. Iron, potassium, magnesium, and calcium are also present. Large amounts of phosphorus and amino acids may be found in wood apples, litchi, almonds, etc. (Shahroon et al., 2021). Consuming fruit on a daily basis keeps us healthy (Rahman, 1998).

Jujube (*Ziziphus mauritiana* L.), is a well-liked fruit that is indigenous to China and India. It is a member of the Rhamnales order and Rhamnaceae family. The Arabic term zizyphus lotus, is from where the genus name Ziziphus originates (Bailey,1947). There are 135 to 170 species in the genus Ziziphus. (Islam and Simmons, 2006), with 17 of them indigenous to India (Watt, 1883; Bailey, 1947; Singh et al., 2000). *Z. mauritiana* may be grown in drier regions of the Indian subcontinent (Sebastian and Bhandari, 1990). The Ziziphus species are found in both the hemispheres' tropical, subtropical, and temperate zones. (Rendle, 1959). In tropical and subtropical regions, jujube fruit is the primary fruit crop in dry and semi-arid regions (Liu et al., 2008). Additionally, in several African nations, jujube is grown on marginal terrain (Johnston, 1972). There are small and huge jujube plantations in Afghanistan, Iran, Syria, Mayanmar, Australia, France, the United States, and Russia (Pareek, 2013). Improved jujube cultivars are cultivated on 90,000 hectares of land in India, with an average output of 8.34 t/ha (Awasthi and More, 2009). In Chinese medicine, jujube fruit, which includes flavonoids, vitamins, amino acids, organic acids, polysaccharides, and microelements (Li et al., 2007), is used to treat spleen disorders and replenish blood (Shen et al., 2009). Along with its nutritional content, *Z. mauritiana* fruits contain an energy value of 20.9 kcal per 100 g of pulp. Fruit is an extremely nutrient-dense diet including a lot of proteins, carbohydrates, and several micronutrients like calcium (Ca), potassium (K), sodium (Na), copper (Cu), phosphorus

(P), iron (Fe), zinc (Zn), and potassium (H). In Zimbabwe, consumption of *Z. mauritiana* fruit is highly significant in terms of nutrition throughout its seasonal availability (Shettima et al.,2016). The total sugar content of fruits of the cultivar Umran was 8.1% (Singh et al., 1983). The amino acids asparagine, aspartic acid, arginine, glutamic acid, serine, glycine, threonine, alanine, valine, methionine, leucine, and isoleucine all of them were found in jujube pulp. (Bal, 1981). Typically consumed fresh, jujube fruit is high in ascorbic acid, vital minerals, and carbs. (Pareek, 1983; Abbas et al., 1988; Pareek et al., 2002). The edible portion of the jujube fruit can have either a sour or a sweet taste. The dry weight of jujube's edible portion, which includes both sweet and sour varieties, ranges from 21.1 g to 24.1 g per 100 g. Different proportions of crude fibre (4.9 to 7.3 g), crude proteins (7.9 to 8.7 g), fat (0.8 to 1.5 g), and carbs (79.5 to 83.2 g) make up the edible component's dry weight of 100 g (Kumar et.al.,2024). It includes a variety of bioactive compounds with broad pharmacological effects on humans, including flavonoids, glycosides, volatile oil, triterpenic acid, and saponins (Zhao et al., 2008).

Jujubes are a fruit species whose popularity and production are growing daily because of their precocity, lengthy flowering time, resilience to dry weather, high nutritional content, variety of consumption patterns, and health benefit (Liu et al., 2020). Jujubes are drupes that range in size from globose to ovoid and can measure up to 6 x 4 cm. Their flesh is white, crisp, and juicy, with a subacid to sweet taste that turns mealy when the fruit is completely matured. Their skin smooth or rough, glossy, thin, but resilient, and yellowish to reddish or blackish. The tuberculate seed, which has elliptic, brown kernels that are 6 mm long, has irregularly wrinkled stones (Pareek, 1983; Abbas et al., 1988; Pareek et al., 2002). As the fruit ripens and matures, its colour changes from green to yellow to chocolate brown.

Significant postharvest losses of fruits and vegetables are a serious problem for any nation with an agriculturally based economy. However, practically all emerging nations experience this common occurrence (Thumula, 2006). Sadly, massive postharvest losses mean that a startling portion of the product never makes it to the customers. In Bangladesh, one-third of fruits are wasted because postharvest management is lacking, including storage and preservation facilities and an adequate transportation infrastructure (The Business Post, 2023). The majority of tropical agricultural products do, in fact, experience substantial postharvest losses for a number of reasons, such as inadequate harvesting techniques, pest attacks, product deterioration due to microbiological agents, storage challenges, and a lack of suitable infrastructure (FIRCA, 2013).

The jujube harvesting season peaks from mid-March to mid-April. Jujube fruit is extremely perishable, non-climacteric, and fraught with issues during marketing and storage, including quick senescence at room temperature and in cold storage (Kader et al.,1989). Jujube fruit has a short postharvest life that is characterized by softness and a reduction in soluble solids content. Because of senescence, peel browning, quality degradation, and fungal infections are also remarkable characteristics of this fruits (Jiang et al., 2004; Tian et al., 2005). At room temperature, several types have a shelf life of 2–6 days due to their extreme perishability (Ghosh and Mitra, 2004). The overall quality of jujube fruits (after harvest) is dependent on the storage conditions utilized, and they have a shelf-life of only four to five days at room temperature. Fruit begins to decay quickly, and overripe fruits degrade quickly, as a result of the high temperatures and low relative humidity that are common during harvest (Meena et al., 2009). Extending the fruit's storage life, which usually results in an extension of its shelf life. Jujube fruits are used to make a variety of goods, including candies, jelly, jam, murabba, squash, and many other things. They are also eaten both fresh and dry. The cost-benefit analysis demonstrates how profitable jujube cultivation is (Pareek, 2001). Properly handling and storing perishable fruits is crucial in preserving the quality for a long time after harvest. There are certain methods that have been applied to maintain the quality of fruits after harvest. Waxing, irradiation, fungicidal dips, growth stimulants, hot water and air pre-harvest treatment, film liners, perforated polythene sheets, and sub-atmospheric pressure are the methods of treatments. Several fruits have been shown to have their shelf life extended after harvest (Haritha and Anmol,2022).

Fruit quality maintenance and postharvest loss reduction have been identified as difficult undertakings (Botelho et al., 2016). Researchers have looked into various postharvest methods for fruits in an effort to find methods that preserve quality and increase shelf life. To lessen this spoiling, a variety of preservatives and preservation methods are being applied. Physical treatments such as heat treatments, irradiation, and edible coating are employed worldwide (Ghasemnezhad et al., 2013). Fruits are also preserved using a variety of chemicals, including calcium chloride, nitric oxide, sulphur dioxide, antimicrobials, and anti-browning compounds (El-Ramady et al., 2015). The postharvest preservation of fresh fruit greatly benefits from the use of exogenous ethylene and activated oxygen (Ozone) (Graham, 2000). For human health, however, the majority of them are unclean. In this regard, it is imperative that appropriate preservation methods be created that are safe for the environment and do not harm people. A safe and environmentally friendly solution must be developed in order to reduce postharvest loss of jujube. To enhance appearance, postpone ripening, minimize water loss and deterioration, and prolong shelf life, edible coatings can be put to fruits and vegetables (Ochoa et al., 2011). Edible films and coatings provide additional benefits such as non-toxicity, non-polluting, barrier to gaseous qualities, edibility, biocompatibility, and cheap (Huq et al., 2015). A wonderful solution for fruit and vegetable preservation is the use of biologically produced preservatives in accordance with health and safety laws (Romanazzi et al., 2017). Appropriate postharvest management procedures are necessary to be tuned. Application of various postharvest procedures and treatments to fruit can improve its quality at postharvest and extend shelf life of jujube. Therefore, it is imperative to find out the suitable postharvest treatment and with this goal the current study has been designed with the following objectives.

Objectives

- To find out suitable postharvest treatment for extending shelf life of jujube.
- To observe the change in physio-chemical properties of jujube by using different postharvest treatments.

CHARPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Horticultural products are important to the human diet and health (Elhadi M. Yahia etal.,2019). Fruits are susceptible to decay and spoilage during storage (Pace & Cefola, 2021). There are many different reasons why it is deteriorating. The invasion of microorganisms can be caused by a number of circumstances, including damage to the fruit's surface and extremely high humidity or temperature (Mahanti et al., 2022; Wu, Tang, & Fan, 2024). Some fruits may lose water, dry up, and shrivel while being stored because of a too dry or inadequately ventilated storage environment. Jujube fruits are vulnerable to bruises and other damage during harvesting and other postharvest handling processes, including as packing, transportation, and storage (Gustavsson et al., 2011, Sharma et al., 2021). Oxidation may cause the fruit's skin to become brown, which would alter the fruit's look and taste. This is often brought on by fruit enzyme and free radical reactions (Li & Yu, 2001; Wu, Zhang, & Fan, 2024). Fruits that experience cold or freezing damage due to insufficiently low temperatures may have mushy flesh and black blotches on their skin. Microbial metabolites or chemical changes during storage might result in undesirable odors. Fruit rot in the postharvest phase significantly reduces its shelf life and marketing supply chain. (Gustavsson et al., 2011, Sharma et al., 2021). FAO (2011) reports that microbial degradation is the main cause of the 15% to 50% of fruit and vegetables that are lost after harvest globally. This proportion is much greater in poor countries where proper techniques for keeping fruits and vegetables are not accessible.

Approximately one-third of the fruit is wasted annually before it reaches consumers in the agricultural and post-harvest phases (Zhou et al., 2022). Thus, there is a pressing need to provide an economical and environmentally friendly way to prolong the shelf life of perishable goods (Zhou et al., 2023).

Significantly increasing fruit and vegetable production would not be necessary to satisfy the growing demand if postharvest loss is considerably reduced. It is less expensive to minimize harvest losses than to grow a comparable additional crop of high-quality fruits and vegetables (Pragya Uikey et al.,2023). Minimizing fruit and vegetable loss and waste is the main concerns for food security of world's population. Future sustainable feeding of the world's population requires a reduction in postharvest losses (Gustavsson et al., 2011, Sharma et al., 2021).

Edible coatings have long been used by the fresh fruit industry as a strategy to mitigate the adverse effects. Edible coatings may extend the shelf life of fresh-cut fruits by reducing respiration, oxidative reaction, gas exchange, moisture and solute migration, and physiological disturbances (Baldwin et al., 1996; Park, 1999). Edible coatings can carry active ingredients such as colourants, flavourings, minerals, spices, antimicrobial compounds, and anti-browning agents that can extend product shelf life and reduce the risk of pathogen growth on food surfaces (Pranoto et al., 2005).

However, there have been few attempts to commercialize fresh fruits and even fewer specialized research on them. Much research needs to be done in order to provide safe fresh fruit products with excellent nutritional content and sensory quality. The creation of innovative processing techniques for preserving fresh cut fruit is necessary to overcome some of the obstacles to the effective commercial distribution of such products. Interest in the possible application of natural compounds to prevent microbial proliferation has grown dramatically as a result of consumer awareness regarding the usage of chemically generated food additives.

It has been proposed that Calcium chloride has been employed extensively in the food preservation industry in recent years. It could also help preserve the fresh-cut items' hardness and aesthetic appeal, extending their shelf life. Fruit storage life has been extended by applying calcium compounds before to harvest and dipping in a calcium chloride solution after harvest (Gupta et al. 2011; Mehta et al. 1985). There are many functions for calcium ions in plant physiology., calcium treatment of fruits delay senescence by preserving membrane integrity and enhancing cell wall rigidity (Ishaq et al. 2009; Zhi et al. 2017). Studied on how calcium can extend the shelf life of fruits and vegetables have been conducted for a long time, it has only looked at the physico-chemical and qualitative characteristics of the produce. There is relatively little information available on calcium affects the components of the cell wall and the processes that cause the breakdown during storage (Langer et al. 2019; Zhi et al. 2017).

One of the most widely used edible film materials in recent years is chitosan, a naturally occurring alkaline polysaccharide, because of its exceptional biocompatibility and lack of toxicity. Chitosan is a popular food ingredient treating postharvest fruits and vegetables that works well in place of synthetic fungicides (Romanazzi et al., 2017). Chitin is deacetylated to produce chitosan, a naturally occurring and eco-friendly substance (Khoshgozaran-Abras et al., 2012). Chitosan and its derivatives prevent deterioration, extending the shelf life of fruits and vegetables. The biopolymer's potential for usage as coating materials makes it an interesting application for product preservation (Chien et al., 2007; Devlieghere et al., 2004; Qiuping and Wenshui, 2007; Sabir et al., 2019). Chitosan has antibacterial properties because of its amino groups or the hydrogen bonds it forms with extracellular polymers (Hughes et al., 1994). According to El-Badawy and El-Sally (2011), Hong et al. (2012), and Xing et al. (2011a), chitosan is a biopolymer with exceptional film-forming qualities. On fruit, it can form a semipermeable film that may alter the internal atmosphere, reduce weight loss and shrivelling caused by transpiration, and enhance overall fruit quality.

2.2 Factors affecting Postharvest Loss

Postharvest losses are losses that happen after harvest until the food is consumed, and they include both quality and quantity losses. (Kader, 2002). Fruit and vegetable post-harvest losses are influenced by a variety of variables. These elements include losses brought on by sanitary, mechanical, physiological, and physical circumstances. The primary characteristics of vegetables are their short shelf life and high degree of metabolic activity. Due to these conditions, a significant portion of the food is lost between harvest and eating (Hayatu, 2000: Sani and Alao, 2006). Post-harvest loss of fruits and vegetables is also caused by many reasons, including infections caused by non-infectious pathogens, pathological rots, and insect and mite damage. But the most dangerous of the causes are pathological rots, which are followed by mechanical harm. When mechanical damage is combined with pathological rots, the perishables suffer significant harm. (Mustapha and Yahaya, 2006; Anonymous, 2011; William et al., 1991).

Environmental elements that contribute significantly to damage include temperature, relative humidity, and oxygen balance, particularly while the item is being stored. It is also the result of environmental factors like humidity and temperature that make fruits and vegetables vulnerable to disease. Nonetheless, the loss of fruits and vegetables as a result of biochemical and physiological harm is intimately linked. (Sani and Alao, 2006; William et al., 1991). Post-harvest losses also result in monetary losses due to labor, transportation, and other costs. Losses in quality include those that impact a product's acceptability, edibility, and nutritional/caloric makeup. Developed nations often experience these losses more frequently. (Kader, 2002). Quantity losses are those that cause a product's quantity to decrease. Quantity loss is more prevalent in underdeveloped nations. (Kitinoja and Gorny, 2010).

2.3 **The Main Reasons of Postharvest Losses of Fruits and Vegetables**

There are many reasons for postharvest losses of fruits and vegetables. The primary reasons for postharvest loss of fruits and vegetables are environmental, pathological, physiological, or mechanical and many others issues. (Yahaya, 2005).

2.3.1 Mechanical Factors

The primary challenge is maintaining the freshness of fruits and vegetables while they are being distributed. Due to their high-water content, short shelf life, and susceptibility to spoiling, fresh fruits and vegetables significantly reduce the amount of time needed for shipping and transactions. As a result, they need extremely safe transit and efficient infrastructure. However, mechanical damage throughout the distribution and sales process results in a significant loss of quality because of the underdeveloped distribution infrastructure and equipment. Statistics show that the loss rate of fruits and vegetables can range from 25% to 35%, but in industrialized nations, such as the United States, the loss rates are between 1% and 2% (Fang.2002). The other study report on supermarket fresh logistics distribution centers from the states that the primary causes of fruit and vegetable loss are the shipping, sorting, storage, and transportation operations (Zhang and Deng, 2012).

There was a lot of physical damage from handling. For the most vulnerable crops (for example, leafy greens in Benin, which suffered 34.3±40.3% on-farm, 86.4±35.9% at wholesale, and 73.8±26.0% at retail markets), crops handled in large, unprotected sacks (for example, cabbage in Ghana), and crops handled without any sort of packaging (for example, bananas in Rwanda, which suffered 8.5±12.7% on-farm, 19.0±18.4% at wholesale, and 22.0±14.4% at retail markets). Many crops showed visible symptoms of bruising, fruit harvests showed softening, and leafy greens showed withering as indicators of losses and quality problems (Kitinoja and Al Hassan 2012). In India, perceived quality decreases resulted in average retail market value losses of 18% for litchis, 52% for cucurbits, 31% for okra, 20% for mangoes, and 1% for tomatoes (Kitinoja and Al Hassan, 2012).

2.3.2 Microbial Factors

Some perishable crops, especially in developing countries, destroy over 30% of crop yields, whereas postharvest diseases destroy 10% to 30% of agricultural harvests. Particularly fresh fruits and vegetables are very perishable commodities, and their quality is affected by postharvest handling, transportation, storage, and promotion (Agrios 2005). According to Wilson et al. (1995), inappropriate handling, packaging, storage, and transportation of fruits and vegetables can cause them to degrade and create germs that are triggered by the fruits' and vegetables' changing physiological states. Fungi are the most important and prevalent diseases, affecting a wide range of host plants and resulting in the destruction and financial loss of most fresh fruits and vegetables during storage and transportation. Fruit is particularly vulnerable to pathogenic fungus because of its low pH, greater moisture content, and nutritional composition. These fungi can produce mycotoxins, which can render fruit unsafe for human eating in addition to causing rots. (Moss, 2002). An estimated 36% of vegetable deterioration is attributed to soft rot bacteria. Similarly, fungal rot in tender fruits can cause serious harm. Naturally, vegetables can become infected by the field, surface cleaning water, contact with equipment, and storage conditions. When it comes to fruit and vegetable rots, fungus such as Alternaria, Botrytis, Diplodia, Monilinia, Phomopsis, Rhizopus, Penicillium, Fusarium, and others are the most frequent culprits. Other bacteria that cause serious harm include Ervinia and Pseudomonas. Microorganisms that break down food after harvest thrive in environments with high relative humidity and temperatures. Typically, fungi target more acidic tissue, whereas bacteria prefer fruits and vegetables with a pH of higher than 4.5 (Pasquariello et al., 2013).

2.3.3 Environmental and Others Factors

Environmental factors including temperature, humidity, composition, and the percentage of gases stored in controlled atmospheres all have a major impact on the postharvest loss of fruits and vegetables. The bacteria that flourish at the high temperatures and relative humidity cause significant harm to the crop (Díaz-Mula et al., 2012). It appears that chilling damage most frequently affects tropical and subtropical fruits and vegetables. In the postharvest setting, relative humidity (RH) has an effect that is comparable to that of temperature. Because air's ability to retain moisture varies with temperature, the effects of temperature and relative humidity are mostly similar and related. RH is impacted by the aeration in retail establishments and storage containers, which indirectly impacts when illness manifests. (Duan et al., 2020). For many fruits and vegetables, high relative humidity (RH) only reduces decay losses when the temperature is around zero degrees Celsius. The effects of temperature and high RH on decay are closely related. However, microbial growth cannot occur on fruit and vegetable surfaces when the relative humidity falls below 90% (Danladi, 2000). Horticultural crop production is heavily seasonal, and supply and price are negatively correlated. The items' perishability and inadequate storage facilities exacerbate the dilemma (Emana & Gebremedhin 2007). The major reasons for seasonal differences are that items are more readily available during the main harvest season, forcing them to be sold at prices that are 6–25% lower for other purposes (animal feed) (Parmar et al. 2017).

Fruits and vegetables must be used for another purpose because they cannot be absorbed for storage. Farmers were therefore compelled to sell their goods in local markets or on the farm (Hussen et al. 2013). Poor market access is often a concern throughout the majority of the country (Teshome & Dürr 2016). Other factors that contribute to PHLs of fruits and vegetables include inadequate markets for product absorption, low product prices, a lack of coordination among producers to strengthen their bargaining power, inadequate pricing systems, and a lack of transparency in market information (Emana et al. 2017). The quantity of marketable fruits is also greatly impacted by distance from the market, agricultural expertise, and lack of access to market information (Woldesenbet 2013). Markets for fruits and vegetables are marked by unethical information-sharing and cheating tactics, which have resulted in uncompetitive market behavior nationwide (Teka 2009).

2.4 Methods of Reduce Postharvest Losses and Waste of Fruits and Vegetables

2.4.1 Cultural Practices

Fruits and vegetables should have a healthy cultural operation to guarantee normal development and prolong their shelf life. Maintaining regular watering and mulching is essential when fruits are growing. While a continuous supply of potassium fertilizers improves the quality of fruits and vegetables' storage, heavy nitrogenous fertilizer applications usually cause quicker tissue degeneration. These fruits may degrade dramatically in quality and frequently have a limited shelf life. As a result, it is recommended to meet the requirements for these micronutrients at the right time. Damage from birds in orchards can be reduced by employing certain mechanical devices and providing sufficient, careful supervision (Yadav et al., 2023).

2.4.2 Storage

Storage is the process of preserving agricultural goods' quality and halting deterioration for a certain period of time following their typical shelf life. Reducing the rate of ageing brought on by respiration, moisture loss, and disease degradation is the main objective of storage. Horticultural product is effectively stored using a wide range of storage structures used worldwide (Kiaya, 2014). The ideal temperature for fruit and vegetable storage is the lowest that won't damage fresh food by cooling it. It has been discovered that controlled atmosphere storage (CAS), which involves controlling the gaseous environment in a storage facility in addition to temperature and humidity, improves postharvest quality preservation (Alao 2000).

Storage in a controlled environment might therefore significantly reduce the quantity of postharvest pesticides required to protect fruits and vegetables from insects and bacteria (Thompson, 1998). The most common method for reducing metabolic activity is cold storage. Low-temperature (LT) storage conditions, however, need to be tailored and optimised for every kind of crop. For optimal effects, additional storage parameters including humidity and air composition should also be changed. Determining the ideal storage conditions is therefore essential to extending the shelf life of fruits and vegetables (Adeeko et al., 2020).

2.4.3 Chemical Treatment

Fresh food is preserved by chemical treatments using synthetic or natural pesticides, which are very effective methods of preventing microbial activity and minimizing losses. However, because of potentially hazardous residues and byproducts, this approach may have detrimental effects on both human and environmental health. The public is calling for a decrease in the usage of these chemicals as a result. Additionally, this approach is dubious due to a number of health and environmental issues around the possibility of dangerous food contamination from preharvest pesticide treatment, as demonstrated for cherry tomatoes (Shimshoni et al., 2019). Several compounds, including fungicides, prolong the shelf life of fruits and vegetables by delaying the ripening and senescence processes. It has been established that using postharvest plant hormones can extend the shelf life of vegetables (Ziy and Fallic, 2021). Many fruits retain their green colour when an indole acetic acid solution is applied. Furthermore, pre-harvest maleic hydrazide (MH) sprays stop potatoes and onions from sprouting while being stored (Yadav et al., 2023).

2.4.4 Physicochemical Treatments

"Physicochemical" treatments include inhibition of physiological and pathological deterioration of fresh-harvested produce by a combination of any type of physical, chemical, or environmentally friendly chemical methods (Elazar and Zoran.,2017). Applications of calcium have been widely used to improve the quality of fresh fruit by, for instance, lowering the incidence of mould growth and physiological disorders, postponing the breakdown of membrane lipids, reducing browning caused by polyphenoloxidase (PPO), and increasing texture through cross-linking with middle-lamella and cell wall pectins (Alandes et al., 2009). However, Alandes et al. (2009) found that calcium lactate (Ca-L) offered distinct advantages over calcium chloride ($CaCl_2$), including avoiding the bitterness and off-flavor of the chloride as well as the production of carcinogenic compounds (trihalomethanes and chloramines) that are connected to chlorine use. Prior to soaking papaya (Carica papaya) fruits in a 30°Bx sucrose solution and drying them at 70°C, (Martın-Diana et al., 2007) administered calcium to the fruits at three different concentrations [0.5, 1.5, and 2.5%]. According to Udomkun et al. (2014), $CaCl_2$ at 2.5% (w/v) in particular added an undesirable bitterness to the dried papaya, whereas Ca-L at 2.5% provided the highest acceptance scores.

2.4.5 Edible coatings

Edible Coatings is natural ingredients. Edible coating applications is a safer way to increase the shelf life of perishable products and enhance the look of food (Fawole et al., 2020). Fresh produce coated with edible, semipermeable film can extend fruit life after harvest by lowering respiration, gas exchange, and moisture loss. It can also postpone ripening processes like fruit softening, colour changes, organic acid loss, and the conversion of starches into sugars (Tzortzakis et al., 2019). Thus, in order to increase storage duration and shelf life for fresh agricultural goods, edible coatings are receiving more and more attention as alternative storage techniques. Applying edible coatings based on polysaccharides to plums can stop shriveling, a commercially significant postharvest condition (Fawole et al., 2020). Edible coatings are occasionally used in conjunction with other organic substances that act as antimicrobials to boost a treatment's effectiveness (Tzortzakis et al., 2019). According to Arnon et al. (2014), chitosan bilayer edible coating improved fruit shine to a sufficient degree but did not stop postharvest weight loss. Additionally, the flavor quality of grapefruit and oranges was unaffected, while it was marginally compromised in mandarins (Arnon et al., 2014). To assess the physiological characteristics and preservation quality of Chinese jujube fruits during storage at 4°C for 60 days, Xing et al. (2015) added cinnamon oil to a chitosan coating. They discovered that the chitosan oil coating improved the preservation of the fruits' sensory quality.

2.5 Effect of $CaCl_2$ and chitosan treatment on maintenance of fruit quality and retention of health-promoting compounds

Studies on the potential of calcium to prolong the shelf life of fruits and vegetables have been conducted for some time, but they have only examined the physico-chemical and qualitative aspects of the food. The breakdown of the main cell wall (Giongo et al. 2013), alteration of cellulose microfibrils (Carpita and Gibeaut 1993), alteration of hemicellulose (Brummell and Harpster 2001), and depolymerization of pectin (Rose et al. 1998) are characteristics of fruit softening caused by enzymatic hydrolysis of cell wall components such as cellulose, hemicellulose, pectins, and glycoproteins (Ali et al. 2004). The breakdown of the cellulose-hemicellulose network (Cheng et al. 2009) by the coordinated activity of cell wall hydrolyzing enzymes, the cell wall loses its integrity (Deng et al. 2005). Numerous functions are carried out by calcium ions in plant physiology. Because calcium preserves membrane integrity and increases cell wall rigidity, it may delay senescence in fruits (Ishaq et al. 2009; Zhi et al. 2017). In addition, there is very little information available regarding how calcium affects the components of the cell wall and the processes that cause the disintegration during storage (Langer et al. 2019; Zhi et al. 2017).

Chitosan has no flavour and is not harmful. Sea creature shells, eggshells, and silkworm pupae (Zhu et al., 2018) can all include this macromolecular straight-chain polymer (Hossain & Uddin, 2020). It is widely available, affordable, easy to get, ecologically friendly, and has high biocompatibility. The benefits of chitosan itself include its ability to create films, its antimicrobial qualities, and its biological compatibility. These characteristics can successfully keep fruit from rotting while being stored and preserve its quality (Lee et al., 2023). By reducing oxygen and/or raising carbon dioxide levels, the chitosan coating changes the interior environment of the fruit by forming a semipermeable layer surrounding its surface. This delays the ripening and senescence processes by lowering the fruit's respiration rate and metabolic activity (Olivas and Barbosa-Cánovas, 2005; Romanazzi et al., 2007; 2009; Vargas et al., 2008). There are less soluble solids because of the slower pace at which carbohydrates are broken down into sugars due to a decreased respiration rate. The concentrations of soluble solids in fruit tissues, however, can be influenced by a variety of confounding factors, including the fruit being tested, its maturity stage, the storage conditions, and the thickness of the chitosan coating (Ali et al., 2011; Das et al., 2013). On the other hand, it would be predicted that fruit with limited respiration would have a lower pH and be more acidic since organic acids, such citric and malic acid, are substrates for the enzymatic activities of plant respiration (Yaman and Bayindirli, 2001). The filmogenic properties of the chitosan coating have mostly been employed as a water barrier to lessen fruit weight loss and water loss while it is being stored. All of these physiological alterations have been seen in chitosan-treated fruits and vegetables (Vargas et al., 2008; Bourlieu et al., 2009). Because the pores and skin of these goods are more evenly distributed and homogeneous, nanoemulsions and nanoparticles may help to improve the barrier qualities and functioning of coatings for use in minimally processed fresh fruits (Hassan et al., 2018).

2.5.1 Weight loss

Calcium reduces phosphatidylinositol bisphosphate phosphorylation, which lessens fruit mass loss. Because aquaporin activity is reduced, there is probably less water moving from the cytoplasm to the apoplast. Thus, fruit weight is maintained for a longer duration and evaporation is reduced (Xu et al., 2022). According to Sinha et al. (2019), a pre-harvest spraying of 2% $Ca(NO_3)2$ on plum trees reduced fruit mass loss by around 1% as compared to the control during all post-harvest measurement procedures. Ali and colleagues (2021) sprayed 1% $CaCl_2$ on pre-harvest peach fruits and observed reduced mass losses (ranging from 21.6% to 26.9%) in comparison to the control and other treatments (ranging from 34.66% to 35.16%). In order to decrease the loss of fruit mass after 20 days after harvest (DAH), Thakur et al. (2019) also administered $CaCl_2$ to papaya and melon (Cucumis melo) at the time of harvest. Lemon fruits treated with 0.18 M $CaCl_2$ showed a mass loss of 23.2% at 42 DAH, compared to 28.7% for control fruits (Frempong et al., 2022). When apple fruits were harvested, Xu et al. (2022) submerged them in 2% $CaCl_2$ for 30 minutes. The mass losses for the treated and control fruits ranged from 4.7% to 5.6%. Likewise, it has been demonstrated that calcium supplementation reduces mass loss in blueberries (Lobos, Retamales, Luengo Escobar et al., 2021) and grapes (Shi et al., 2023).

Fruit weight loss is mostly caused by respiration and epidermal moisture loss. Dehydration will cause an increase in fruit with damaged surfaces. In order to avoid dehydration, edible coatings act as barriers that stop water from transferring, shield fruit skin from mechanical harm, and seal minor cuts. In comparison to fruit that was not coated, fruit coated with 1% and 1.5% chitosan, with and without the addition of CaGl, lost weight while being stored at 10°C and 70% relative humidity (Petriccione et al., 2015). Weight loss occurred in every sample during storage. During storage, fruit without a coating lost significantly more weight than fruit with one. In contrast to samples coated with 1% and 1.5% chitosan, which lost 19.6% and 14.2% of their weight, respectively, untreated strawberries lost 28.7% of their weight following storage. The 1.5% chitosan solution's increased viscosity likely results in a thicker coating, further reducing moisture loss. Adding Ca-Glu to the film-forming fluid had no discernible effect on strawberries' capacity to shed weight. In accordance with this, grape weight loss was mostly seen during the first three days of storage and was higher for the control and pure chitosan-coated samples than for the bergamot oil-coated samples, which displayed the least amount of weight loss. Storage time did not result in any discernible, significant changes (Volpe et al., 2019). As chitosan's molecular weight rises, its ability to preserve freshness is observed to improve (Li et al., 2023; Li, Sun, et al., 2023). The increase in its impact, however, becomes less apparent as the molecular weight exceeds a particular threshold. Strawberry was electrostatically coated with chitosan coatings by Jiang et al. with varying average molecular weights (MWs) of around 5, 19, and 61 kDa (Jiang et al., 2020). According to the findings, the 61 kDa chitosan coating was superior at preserving the flavonoid content while delaying the rise in pH and malondialdehyde (MDA) concentration. Zhang, Cao, and Jiang (2022) examined the adhesion characteristics of chitosan to the surfaces of different post-harvest fruits as well as its ability to produce films with varying molecular weights (30, 100, 200, and 300 kDa). It was found that chitosan films with a larger molecular weight had superior mechanical, water-vapor-barrier, and water-resistance qualities.

2.5.2 Colour

Colour is an important quality feature that has a considerable impact on the physical appearance and commercial acceptance of fruits (Sinha et al., 2019). Because calcium preserves the amount of chlorophyll in fruit, it is known to postpone colour changes. Ca slows down the ripening period by lowering ethylene production and respiratory intensity (Souza et al., 2023). Ca, the first enzyme implicated in the breakdown of chlorophyll, is thought to be responsible for this preservation of green pigments by inhibiting enzymes like chlorophyllase (Nassarawa et al., 2024). In line with Amini et al. (2016), who noted a decrease in carotenoid concentration in sweet pepper fruits treated with nano-calcium, Bitange et al. (2021) notice that the application of Ca slows down the breakdown of chlorophyll and the synthesis of pigments. According to Souza et al. (2023), fig fruits with high chromaticity and colour values were retained when plants were sprayed with 1% $CaCl_2$. Similarly, Bitange et al. (2021) found that during the postharvest period, mango fruits treated with $CaCl_2$ had greater colour values than the control. Furthermore, after being treated with $CaCl_2$, the peaches' epidermis showed a greener hue (Maletsika et al., 2023). When compared to the control, Liu et al. (2023) discovered that the values of L*, a*, and b* in pear fruits grew less when Ca lactate was applied. This suggests that postharvest fruits treated with Ca have a delay in colour development, which reduces their perishability.

Numerous studies have shown that the application of chitosan altered the colour of the fruit peel. These changes can be observed visually or via the use of technological tools. The application of chitosan coating to longan fruit postponed the browning of the fruit skin while concurrently decreasing the activity of PPO, the enzyme that causes polyphenol oxidation (Jiang and Li, 2001). Papaya fruit treated with chitosan showed slight changes in peel colour, as seen by the slower rise in brightness and chroma values when compared to uncoated papaya fruit. The papaya fruit treated with 1.0%, 1.5%, and 2.0% chitosan may have delayed colour development due to reduced ethylene production and a slowed respiration rate, which produce delayed fruit ripening and senescence (Ali et al., 2011). The combination of calcium and chitosan also postponed changes in the surface colour of papaya fruit, as evidenced by the lower brightness and chroma values and the greater hue angle value in treated papaya as compared to untreated papaya (Al Eryani et al., 2008).

2.5.3 Texture

Texture is a critical quality parameter in fruit marketing (Huang et al., 2023). Texture is one of the main factors that affects the fruit's quality after harvest (Barrett et al., 2010). Enzymes like polygalacturonase hydrolyze pectin during the biochemical process of fruit softening, which is often associated with the disintegration of the cell wall components (Atkinson et al., 2012). Texture is made up pectin polymers, which are cross-linked to ions, primarily Ca_2, to keep neighbouring chains attached to one another (Fertonani 2006; White and Broadley 2003). When coupled with pectic acid, calcium strengthens the structure of the cell wall, increases cell adhesion, and forms Ca pectate, which increases fruit texture (Zhang & Wang, 2019). Moreover, the build-up of homoga lacturonans and a rise in pectin networks are brought on by the exogenous injection of calcium (Huang et al., 2023). Benavides et al. (2002) founded as storage time increased, the jujube fruit's texture gradually reduced, comparing the $CaCl_2$-treated fruits to the untreated fruits, Casero et al. (2004) in apples, Ishaq et al. (2009) in apricots, and Zhi et al. (2017) in peaches. Findings indicated that post-harvest calcium administration improved fruit texture during storage by reducing softening. Calcium build-up in the cell walls help facilitate the cross-linking of the pectic polymers, which strengthens the walls and promotes cell cohesion, which may explain why calcium-treated apples retain their texture (White and Broadley 2003). The application of $CaCl_2$ decreases the quantity of water-soluble pectins, indicating extended texture in persimmon (Diospyros kaki) fruits, according to Liu et al. (2023). Ali et al. (2021) found that applying $CaCl_2$ by pre-harvest sprays (1%, 2%, and 3%), as opposed to the control, significantly enhanced the hardness of peach fruit by 28%, 13%, and 24%. In general, calcium treatments have been successful in keeping a variety of fruits, including jujube (Ziziphusmauritiana Lamk.) (Jain et al., 2019), papaya, melon, guava (Thakur et al., 2019), apple (Xu et al., 2022), plum (Sinha et al., 2019), grapevine (Shi et al., 2023), blueberry (Lobos, Retamales, Luengo Escobar et al., 2021), lemon (Frempong et al., 2022), and kiwi (Sotiropoulos et al., 2021). Fruit texture is preserved during storage because to the low oxygen and high carbon dioxide levels that limit the activity of these enzymes (Maqbool et al., 2011). Low temperatures and chitosan successfully extended *Ziziphus mauritiana's* life storage by reducing degradation (Abdolali et al., 2021). Chitosan has antimicrobial qualities (Camatari et al., 2018) that could prevent the deterioration of a variety of fruits, including mangoes (Camatari et al., 2018; Chien et al., 2007), jujubes (Wang et al., 2014), strawberries (Romanazzi et al., 2013), sweet cherries, table grapes (Romanazzi, 2010), and apples (Li et al., 2015). Fungal cell walls frequently include chitin. Chitosan inhibits the development of fungi on the fruit by inducing chitinase, a defence enzyme that catalyses the degradation of chitin (El-Ghaouth et al., 1991). According to Qiuping and Wenshui (2007) and Dutta et al. (2009), chitosan coating can reduce microbial development that cause to fruit rotting and provide a protective barrier on the surface of fresh fruit. Chitosan, as an exogenous elicitor, boosts the activities of peroxidase (POD) and polyphenol oxidase (PPO), which in turn promotes resistance to subsequent pathogen infections (Li et al., 2015). According to Devlieghere et al. (2004), a number of variables, including chitosan, storage temperature, and food ingredients, will affect its antibacterial effectiveness.

2.5.4 Total Soluble Solid

TSS, or total soluble solids, one of the most powerful aspects of fruits on the market is taste, mostly dictated by the quantity of TSS. During ripening and storage, the starch in fruits progressively changes into sugars. On the other hand, calcium slows down metabolism and respiration, which delays the breakdown of polysaccharides to monosaccharides. These delays ripening and lowers the TSS of fruits after harvest (Dorostkar et al. (2022). Similar to this, Souza et al. (2023) note that the application of $CaCl_2$ lowers the amount of reducing sugars and the concentration of TSS in figs, which is explained by the increased stabilisation of pectin structures that calcium provides. According to Shi et al. (2023), the maximal TSS peak in grapevine fruits was postponed from 14 DAH in the control to 28 DAH in the treated fruits when calcium was applied. According to Shiri et al. (2015), as calcium content rises, TSS in papaya fruits falls. Additionally, after 20 days of storage, the application of $CaCl_2$ reduces the quantity of TSS in papaya, melon, and guava fruits by 20%, 12.6%, and 9.34%, respectively, in comparison to the control (Thakur et al., 2019). However, in certain fruits, such apples (Fallahi & Mahdavi, 2020), blueberries (Lobos, Retamales et al., 2021), and cape gooseberries (Álvarez-Herrera et al., 2022), the addition of calcium had no effect on the TSS concentration.

By using chitosan and other polysaccharide-based coverings, the weight loss, titratable acidity, and carbon dioxide evolution of banana fruit were all reduced. Furthermore, compared to the untreated fruit, the coated fruit had lower levels of reducing sugar and total soluble solids, suggesting that the coated fruit's decreased metabolism was the reason for the slower rate of reducing sugar synthesis (Kittur et al., 2001). Jujube fruits are categorised as climacteric fruits, meaning that their total soluble solids content rises as they mature while being stored (Taain et al., 2015). Moreover, the accumulation of total soluble solids was brought on by the fruits' declining water content during longer storage periods since the quantity of total soluble solids in fruits is inversely connected with its water content (Burton, 1982). In terms of the correlation between chitosan treatment and storage duration, the same data showed that the untreated fruits had the highest percentage of total soluble solids (25.12%) during the course of four weeks of storage. After a week of storage, fruits treated with 2% chitosan had the lowest percentage of total soluble solids (17.45%) (Eman and Taain, 2021).

2.5.5 Titrable Acidity

The application timing, storage duration, concentration, and species assessed all affect how Ca affects TA in fruits (Souza et al., 2023). According to Ali et al. (2021), the use of calcium reduces the activity of oxidative enzymes, including polyphenol oxidase, ascorbate oxidase, peroxidase, oxidase, and catalase, which reduce the quantity of organic acids during storage (Shi et al., 2023). This suggests that high TA levels are maintained when fruits are treated with calcium (Dorostkar et al., 2022). When Ranjbar et al. (2020) added $CaCl_2$ and nano-calcium to apple fruits before harvest, they discovered that TA rose at harvest time. This was explained by a drop-in respiratory activity, which in turn led to a decrease in the hydrolysis of organic acids. According to Ali et al. (2021), fruits treated with 1% $CaCl_2$ retain high TA values during storage because the respiratory intensity decreases, not allowing the number of acids employed as a respiratory substrate to diminish (Saltveit et al., 2019). According to Liu et al. (2023), applying calcium to pear fruits results in greater TA values throughout the postharvest period, which is in line with what was seen in apricot (Dorostkar et al., 2022). On the other hand, Maletsika et al. (2023) discover that adding calcium to peach fruits lowers TA and the levels of quinic and citric acids. According to Ribeiro et al. (2020), 4% $CaCl_2$ applied before to harvest reduces TA in guava fruits. In other research, TA values in blueberries (Lobos, Retamales et al., 2021) and goose berry fruits (Álvarez-Herrera et al., 2022) are unaffected by the fertilisation application of calcium.

Chitosan had a major effect on the percentage of total titratable acidity in the jujube fruit variety. In contrast to the other treatments, the fruits of the control treatment exhibited the greatest percentage of total titratable acidity (0.238%) while kept at 4°C. However, the lowest percentage of total titratable acidity (0.171%) was found in fruits treated with 2% chitosan (Eman and Taain, 2021). These results are in line with those of Srinivasa et al. (2002) on mango fruits treated with chitosan. As storage time rose, the total titratable acidity percentage decreased, eventually reaching 0.150% after four weeks. According to the same chart, this might be because the organic acids were either eaten by respiration processes or transformed into sugars (Burton, 1982).

2.5.6 Vitamin-C

Jujube fruits have a low ascorbic acid concentration at first, but it rises until the fruit achieves physiological maturity (Abbas 1997). As the ripening process progressed, the amount of ascorbic acid increased, reaching its highest on the fifteenth day of storage at 200C (559 mg per 100g) (Kader et al. 1984). Bal et al. (1995) also observed that the vitamin-C content of jujube fruit increased with fruit maturity. According to studies by Shokrollahfam et al. (2012) and Veltman et al. (2000), calcium compounds bind to membranes and make them more stable. As a result, they keep free radicals and reactive oxygen species from attaching to membranes and help to keep biological membranes healthy. Furthermore, calcium compounds increase the activity of APX, which delays the quick oxidation of ascorbic acid. According to Ruoyi et al. (2005), peaches' ascorbic acid concentration remained constant after 50 days of storage when 0.5% $CaCl_2$ was applied. According to Pooviah (1979), applications of calcium chloride (4%) before and after harvest enhanced fruit quality, and their usage during harvest period boosted ascorbic acid in fruits. The use of calcium compounds slowed the deterioration of the vitamin C content in plums and jujube fruits, according to Al-Obeed (2012) and Shokrolahfam (2012). Apple and kiwi fruit (Paliyath et al., 2009), apple (Sams et al., 1993), pomegranate "Malas-Yazdi" (Ramezanian et al., 2009), papaya (Selvaraj et al., 1982), strawberry (Shafiee et al., 2010), and tomato (Pila et al., 2010) have all been shown to have similar increases in vitamin C.

According to Zhu et al. (2008), applying edible coatings made of various polysaccharides considerably decreased the amount of vitamin C lost from mangos. The enzymes phenol oxidase and ascorbic acid oxidase cause ascorbic acid to be lost later on during storage. In contrast to the other treatments, the fruits treated with 2% chitosan exhibited the greatest content of vitamin C (164.98 mg. 100 g^{-1} fresh weight). At 154.83 mg/100 g^{1}, the lowest concentration of vitamin C was found in the fruits that were not treated with chitosan; this was not substantially different from the fruits that received 1% chitosan treatment (Eman and Taain, 2021).

2.6 Conclusion

According to some reports, Natural ingredients like chitosan and calcium chloride are used in edible coating applications as a safer way to improve food look and prolong the shelf life of perishable goods (Fawole et al., 2020). Fresh produce coated with edible semipermeable film can extend fruit life after harvest by lowering respiration, gas exchange, and moisture loss. It can also postpone ripening changes like fruit softening, colour changes, organic acid loss, and the conversion of starches into sugars (Tzortzakis et al., 2019). This review covers the latest and relevant studies on the use of chitosan and $CaCl_2$ for fruits and vegetables both before and after harvest. According to recent studies, this biopolymer may effectively maintain the quality of fruits and vegetables while reducing postharvest deterioration throughout storage and shelf life. Edible coatings are therefore becoming more and more popular as alternate techniques for extending the shelf life and storage duration of fresh agricultural products. Edible coatings are sometimes used in conjunction with other natural substances that act as antimicrobials to boost a treatment's effectiveness (Tzortzakis et al., 2019). However, further investigation is necessary to completely comprehend the distinct impacts of various coatings on fruit physiology and postharvest performance.

CHAPTER 3

MATERIALS AND METHODS

The postharvest handling and preservation of jujube in Bangladesh has not yet been standardized though there were many works have been done on different preservatives. In this respect, the present study was conducted to evaluate the shelf life, changes in quality parameters of jujube and the effect of chitosan, $CaCl_2$ and combined effect of chitosan and $CaCl_2$ on jujube. In this chapter, the methodology and materials used followed in the conducted experiments have been described narratively.

3.1 Experimental location and Conditions

The experiment was conducted at the Horticulture laboratory, Agrotechnology Discipline, Khulna University, Khulna. The experiments were conducted at ambient conditions. The maximum and minimum temperatures as well as relative humidity in the storage room were 30.6°C and 25°C and 85 and 79 % respectively. Temperature and relative humidity of the storage room were recorded with a digital Temperature-humidity recorder (Thermo, Germany).

3.2 Experimental Materials

Green matured jujube of 'Appale qul' cultivar (local cultivar) of uniform size, shape and color was used in this study.

Jujube is one of the important fruits in Bangladesh and is cultivated commercially in Khulna region and available during the lack period of jujube fruit in Bangladesh (Dec-Mar). Jujubes are soft, delicious drupes with a diameter of 2.5 cm. However, some varieties can have fruit as large as 6.25 cm in length and 4.5 cm in width. The shape might be circular, oblong, oval, or obovate, while the skin can be shiny, thin, tough, or smooth. Even on the same tree, the ripening seasons of the fruit vary. As they mature, fruits change from their initial green color to yellow. The fully grown fruit has wrinkled skin, is soft, juicy, completely crimson, and smells good. The mature fruit tastes both sour and sweet. It has a flavor and texture similar to apples. The meat is white, crunchy, and has a flavor that ranges from acidic to subacid to sweet when underripe. Overripe fruits are wrinkled, with buff-colored flesh that is mushy, spongy, and musky; fully ripe fruits are less crisp and slightly mealy. The aroma is nice and apple-like at first, but when it gets overripe, it takes on an odd musky scent. Two elliptic, brown seeds, 1/4 in (6mm) long, are contained in a single, rough, hard, oval or oblate center stone.

3.3 Collection and processing of experimental materials

For this study, Fresh Matured jujube were directly collected from local farm in Koya Bazar, Dumuria, Khulna. Jujube were picked up in the morning transported to Horticulture Laboratory, Agrotechnology Discipline, Khulna University, Khulna at an earliest convenience by using an air-cooled vehicle. Adequate care was taken to avoid any injury during transportation. After collection the fruits will be cleaned and kept in shade prior to imposition of treatments. Fruits were selected for freedom from visual defects and uniformity of shape, color, and size.

3.4 Experimental design

The experiments were conducted by following two-factor experiment with Factorial completely randomized design (CRD) comprising of 13 treatments with 3 replications having 500(gm) fruits in each of the replications.

3.4.1 Experimental Treatments

The experiments consist of mainly two factors as follows-

Factor A: Treatments

3.4.1.1 Experiment 1

In experiment 1 details of the treatments are as follows:

T_1- Control

T_2- $CaCl_2$ 2%

T_3- $CaCl_2$ 4%

T_4- Chitosan 4 g/L

T_5- Chitosan 8 g/L

T_6- $CaCl_2$ 2% + Chitosan 4 g/L

T_7- $CaCl_2$ 4%+ Chitosan 4 g/L

T_8- $CaCl_2$ 2%+ Chitosan 8 g/L

T_9- $CaCl_2$ 4%+ Chitosan 8 g/L

3.4.1.2 Experiment 2

In experiment 2 details of the treatments are as follows:

T_1- $CaCl_2$ 0.5%

T_2- $CaCl_2$ 1%

T_3- Chitosan 1 g/L

T_4- Chitosan 2 gm/L

Factor B: Days after treatment (DAT)

3.4.2 Preparation and application of experimental treatments

3.4.2.1 Preparation of working solutions for experiment 1

At first, 2.5g ,5g and 10g of $CaCl_2$ and 0.5g, 1g and 2g of chitosan were weighed using electric balance to prepare the stock solution. To prepare 2 and 4% solution of $CaCl_2$, 5 g and 10 g of $CaCl_2$ was dissolved in 250 ml of distilled water. To have 4 and 8g/L solution of chitosan, the working solution was prepared by adding 1g and 2g of chitosan in 250 ml of vinegar. The combined solution of $CaCl_2$ and Chitosan was prepared by mixing 125 ml of both of the solutions having the desired concentrations for those chemicals.

3.4.2.2 Preparation of working solutions for experiment 2

At first, 1.25g and 2.5g of $CaCl_2$ and 0.25g and 0.5g of chitosan were weighed using electric balance to prepare the stock solution. To prepare 0.5 and 1% solution of $CaCl_2$, 1.25 g and 2.5 g of $CaCl_2$ was dissolved in 250 ml of distilled water. To have 1 and 2g/L solution of chitosan, the working solution was prepared by adding 0.25g and 0.5g of chitosan in 250 ml of vinegar.

3.4.2.3 Application of experimental treatments

Randomly selected matured jujube of uniform size, shape and color were the raw materials in the study. The jujube was cleaned up to prepare them for applying the respective treatments in the experiments. During applying the treatments by spraying, the fruits were kept on newspaper placed on the table in the laboratory at ambient temperature and after drying, they left on another paper until the end of data collection. Jujube fruits without any treatment were considered as control.

3.4.3 Observations Recorded

Observations were recorded on physical, chemical and microbiological parameters as follows

Physical parameters-

- Physiological weight loss (%)
- Changes in color (subjective and objective) (score in a scale of 1-7)
- Changes in Texture (score in a scale of 1-5)
- Shrinking (%)
- Scorch

Chemical parameters-

- Changes in Vit. C
- Changes in TA (Titratable Acidity)
- Changes in TSS (Total Soluble Solids)
- TSS/TA ratio

The measurements were made by using standard procedures which have been described in details in section (3.5.1) Observation on physical characteristics were recorded regularly. However, data on chemical parameters were recorded in every alternate day. Collection of data continued for (14) days in experiment 1 and (14) days for experiment 2 after treating the jujube fruits. The collected data were recorded in writing and also saved in the computer as Excel files for further analysis.

3.5 Methods of studying parameters

The physico-chemical properties and shelf life of jujube fruits were studied using the following techniques.

3.5.1 Methods of studying the physical parameters

3.5.1.1 Fruit color

A. Visual Assessment

The visual assessment of skin color of jujube was recorded daily during the fruit ripening period by following a rating scale (Dang et al., 2008) ranging from 1 to 9 (Plate 3.1) who categorized the fruits from green to full red color.

Plate 3.1: Categorizing ripening jujube on the basis of skin color (Dang et al., 2008)

Table 3.1: Numerical identification of different stages of jujube in respect of changes in color, texture, shrinking% and scratch.

Numerical indicator	Color change (Dadzie and Orchard, 1997)	Texture of jujube (Dang et al., 2008)	Shrinking Percentage	Scratch
1	Green	Hard	0-25%	0-25%
2	Dull green	Semi Hard	25-50%	25-50%
3	Greenish Yellow	Moderately Soft	50-70%	50-70%
4	Yellowish Green	Very soft	70-90%	70-90%
5	Pinkish green	Over very soft	>90%	>90%
6	Yellow			
7	Purple Yellow			
8	Semi Red			
9	Red			

B. Assessing Fruit color by using a Chromameter

The skin color of sample fruit was also recorded on color coordinates as L*, a* and b* from opposite positions of each fruit in Commission International de L'Eclairage (CIE) units using a chromameter (Plate 3.3 and Plate 3.4). Chroma value (C*) and hue angle (h°) were also calculated from the recorded data. Chromaticity L* represents the lightness of the fruit color, which ranges from 0 (black) to 100 (white).

Plate 3.2. Chromameter

Chromaticity a* indicates the redness (+a*) or greenness (-a*), and chromaticity b* indicates the yellow (+b*) or blue (-b*) colour of fruit skin. For colour interpretation, red was at an angle of 0°or 360°, yellow at 90°, green at 180° and blue at 270°. Hue angle (h°) values were calculated as: $h° = \tan^{-1} b*/a*$. Chroma (C*) was defined as the intensity of colour saturation from dull to a vivid color (low-to-high values, respectively) and was calculated as: $C* = (a*^2 + b*^2)^{1/2}$. Hue angle andchroma value were calculated following the formula mentioned earlier by McGuire (1992).

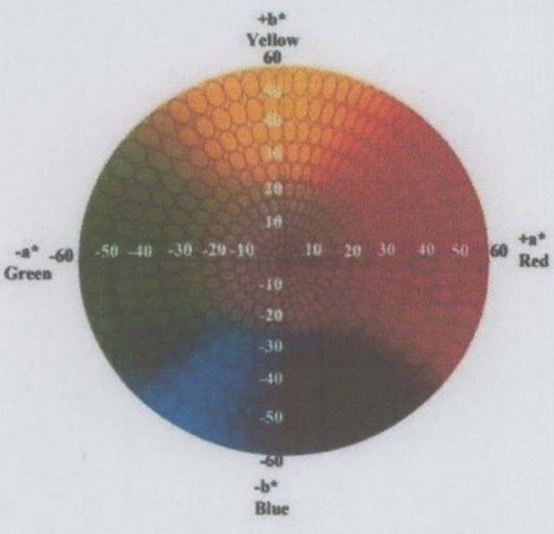

Plate 3.3: Colour chart – Commission International de L'Eclairage (CIE) L*, a* and b*

3.5.1.2 Texture of Jujube

By using numerical rating scale (Table 3.1) from 1 to 5, required days in reaching different stages of texture during postharvest storage was determined. Daily subjective texture of individual jujube fruit in each replication was determined byhand feeling using a numerical rating scale of 1 to 5 (1 = hard, 2 = semi hard, 3 = moderately soft, 4 = Soft, 5 = Very soft, 6 = Over very soft) as described earlier by Dang et al. (2008).

3.5.1.3 Weight Loss (%)

The weight Jujube was measured by using an electrical balance. (Plate 3.4). Percent of total weight loss was calculated by using the following formula (Ahmad et al, 2013)-

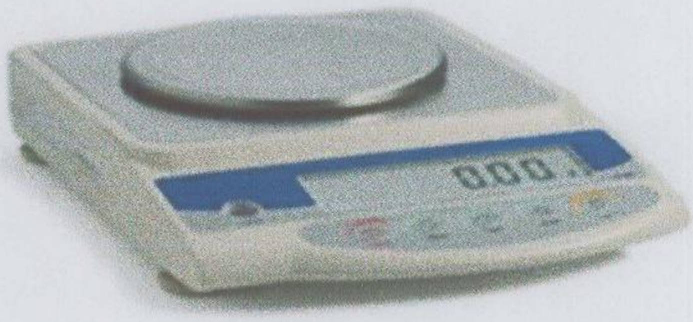

Plate 3.4: Electrical Balance

$$WL\ (\%) = \frac{IW-FW}{IW} X100$$

Here,

WL = Percent of weight loss

IW = Initial fruit weight (g)

FW = Final fruit weight (g)

3.5.2 Methods of studying the Chemical parameters

3.5.2.1 Titratable Acidity (TA) (%)

Both organic and inorganic acids are present in jujube fruits. These acids are vital elements of fruits since they, along with carbohydrates, affect the fruits quality and flavour. When these fruits are harvested, there acid content, along with sugar content or the amounts of soluble solids, are used to determine their maturity stage. TA was calculated by using the following formula as suggested by sugri (2013).

$$\text{Malic acid (\%)} = \frac{0.0067 \text{ X Vol.of NaOH X } 30}{5\text{x}10} \text{X}100$$

Where,

0.0067 = Milli-equivalent weight of malic acid

30 = Total volume (ml)

5 = Extract juice sample (ml)

10 = Volume of aliquot (ml)

The following reagents were used for the determination of titratable acidity.

a. Standard NaOH solution (0.1N)

b. Phenolphthalein solution [approx. 0.5% in 80% ethanol (W/V)]. (Plate 3.5).

Plate 3.5: Chemical Sample

Equipment

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

Procedure:

- A fruit sample of 10 g was taken. This was thoroughly crushed in a blender and extracted using distilled water. After the extract was filtered, distilled water was added to the filtrate to make it up to 100 ml.
- 10 ml fruit juice was taken and 20 ml distilled water was added for dilution. The final volume made up to 30 ml.
- From a 30 ml diluted solution, 5 ml of an aliquot was transferred into a conical flask. This aliquot was given just one or two drops of phenolphthalein solution, and it was thoroughly shaken.
- 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.

3.5.2.2 Total Soluble Solid (TSS)(%Brix)

This was measured using a refractometer (REF 105) and was referred to as the degree of Brix. This tested the concentration of sucrose in fruit extract. It is widely used during fruit and vegetable processing to determine the concentration of sugar in the products. At 20°C of room temperature, the Brix is usually considered equivalent to the percentage of sucrose (sugar) in the solution. A drop of squeezed jujube juice obtained from the fruit pulp was placed on the prism of the refractometer which gave the reading of the TSS percentage directly.

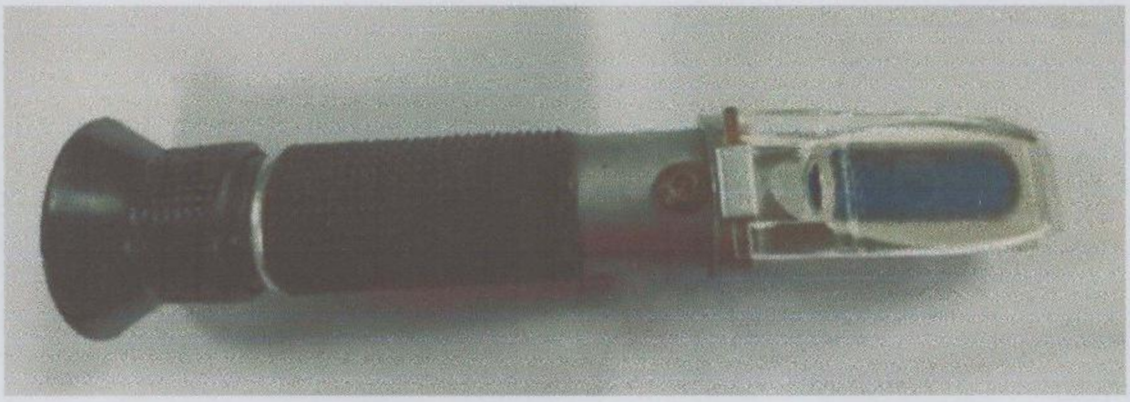

Plate 3.6: Hand refractometer

3.5.2.3 TSS: TA ratio

TSS: TA ratio was calculated by dividing SSC (%) with the corresponding TA (%).

3.5.2.4 Assessment of Vitamin C

Titrimetric estimation of vitamin C was conventionally done by using 2, 6-dichlorophenol indophenols dye solution. This dye is blue in alkaline solution and red in acidic solution. Ascorbic acid reduces the dye to a colourless form. The reaction is quantitative and specific for ascorbic acid at pH 1.0-3.5.

Procedure

- 30 ml juice were taken after juice extraction from fruits by grinding.
- Then separated into 3 parts, each part contained 10 ml juice.
- It was titrated with 2, 6-dichlorophenol indophenol solution.
- Volume of metaphosphoric acid was 5 ml and standard ascorbic acid solution (0.01%)

Formula for determining Vitamin C

$$\text{Vitamin C (mg/100g)} = \frac{e.d.b}{c.a}$$

Here,

a = weight of sample

b = volume made with metaphosphoric acid

c = Volume of aliquot taken foe estimation

d = Dye factor

e = Average burette reading for sample

3.5.3 Shelf Life

During storage, different postharvest treatments influenced the shelf life of jujube fruits. Shelf life was measured by counting the days required the jujube fruits for retaining and eating. The fruits retained in good condition until the score for, colour change retained less than or equal to 5 and texture less than or equal to 3. Loss of 20% weight was also considered to calculate shelf life. The number of average days required to reach at the mentioned level of the considered parameters were recorded for analysing the shelf life of jujube fruits (Tabassum et al., 2018).

3.6 Statistical Analysis

Statistical analysis was conducted on the collected data of various parameters using STAR (Statistical Tool for Agricultural Research) statistical package, version 2.0.1 (IRRI, 2022). The mean values of all the treatments were calculated and analysis of variances (ANOVA) for all the parameters was performed by F-test. According to Gomez and Gomez (1984), the significant difference between the pair of means compared by LSD (Least Significance Difference) test at 5% level of probability.

CHAPTER 4

RESULTS AND DISCUSSION

The result obtained from the study on physico-chemical characteristic of jujube fruits treated with Calcium chloride and synthesized chitosan at different concentration have been presented and discussed in this chapter.

4.1 Effect of Calcium chloride and synthesized chitosan based chemical treatments on physical characteristics of Jujube fruits

Data on cumulative weight loss, color, Texture, shrinking, scratch of jujube fruits treated with different concentrations of Calcium chloride and synthesized chitosan were recorded every day during storage in ambient conditions. The results in this regard have been presented as follows-

4.1.1 Effect of postharvest treatments on cumulative weight loss of Jujube Fruits.

The results obtained from the study indicates that $CaCl_2$ and chitosan coating significantly reduced the weight loss of jujube fruit during storage compared to the controls (Figure 4.1). Irrespective of the treatments the weight loss of T1 (control) treated fruits was 1.04 times higher than the average of the weight loss of the treated fruit on 10 DAT. When the fruits were treated with $CaCl_2$ solely (1% and 4%) or in combination with chitosan (8 g l^{-1}), they showed a lower loss of weight than the loss of weight of the control fruits on 10 DAT.

Lower weight loss was also reported in coated mango fruits (4.0 to 6.6%) as compared to control having higher percent weight loss (9.0%) by Zafrul et al. (2019). Dang et al. (2010) also reported that chitosan formed a coating film on the outside surface of the sweet cherries that effectively retarded the loss of water. In jujube, as the storage time increases, the weight losses in the fruit increase as reported by Chen et al. (2019), and this occurs with the increase of water loss in the fruit as a result of the increase in respiration rate and dehydration (Zhang et al., 2019). Applying calcium is known to reduce mass loss in blueberries (Lobos et al., 2021) and grapes (Shi et al., 2023).

Calcium prolongs fruit weight retention and reduces evaporation (Xu et al., 2022).

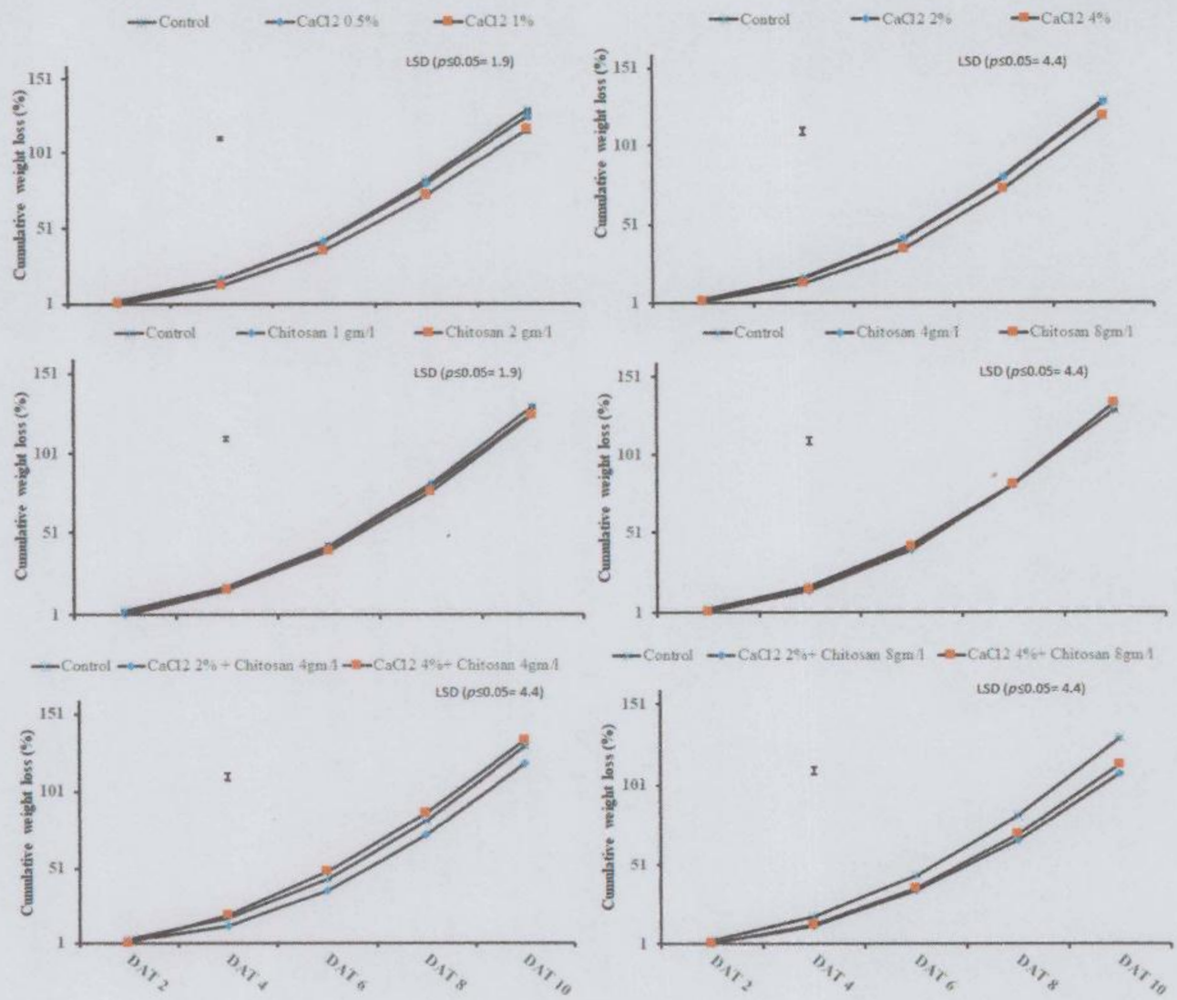

Figure 4.1. Effect of postharvest treatments on cumulative weight loss of Jujube Fruits

4.1.2 Effect of postharvest treatments on Visual color (subjective) of Jujube fruits.

A significant change in color of jujube obtained from this study (Figure 4.2). A slower increase of color score indicated the lower level of de-greening of jujube peel. After 14 days of treatment, the color change of T_1 (control) treated fruits was almost 1.06 times higher than the average of the color change on the day. However, the color change score of Chitosan 2 gm/l treated fruits was almost 0.97 parts lower than the average of the color change score on that day. Kittur et al. (2001) stated that during storage, chitosan coating delayed color changes in banana. Ali et al. (2011) also noticed that the delay of color development in the papaya fruit treated with higher concentrations of chitosan could be attributed to the slow rate of respiration and reduced ethylene production, leading to a delayed fruit ripening and senescence. The result of the present study is also supported by the findings of Robinson (1996). According to Bitange et al. (2021), applying calcium slows down the production of pigments and the breakdown of chlorophyll, which is consistent with Amini et al. (2016), who found that sweet pepper fruits treated with nano-calcium had less carotenoid concentration.

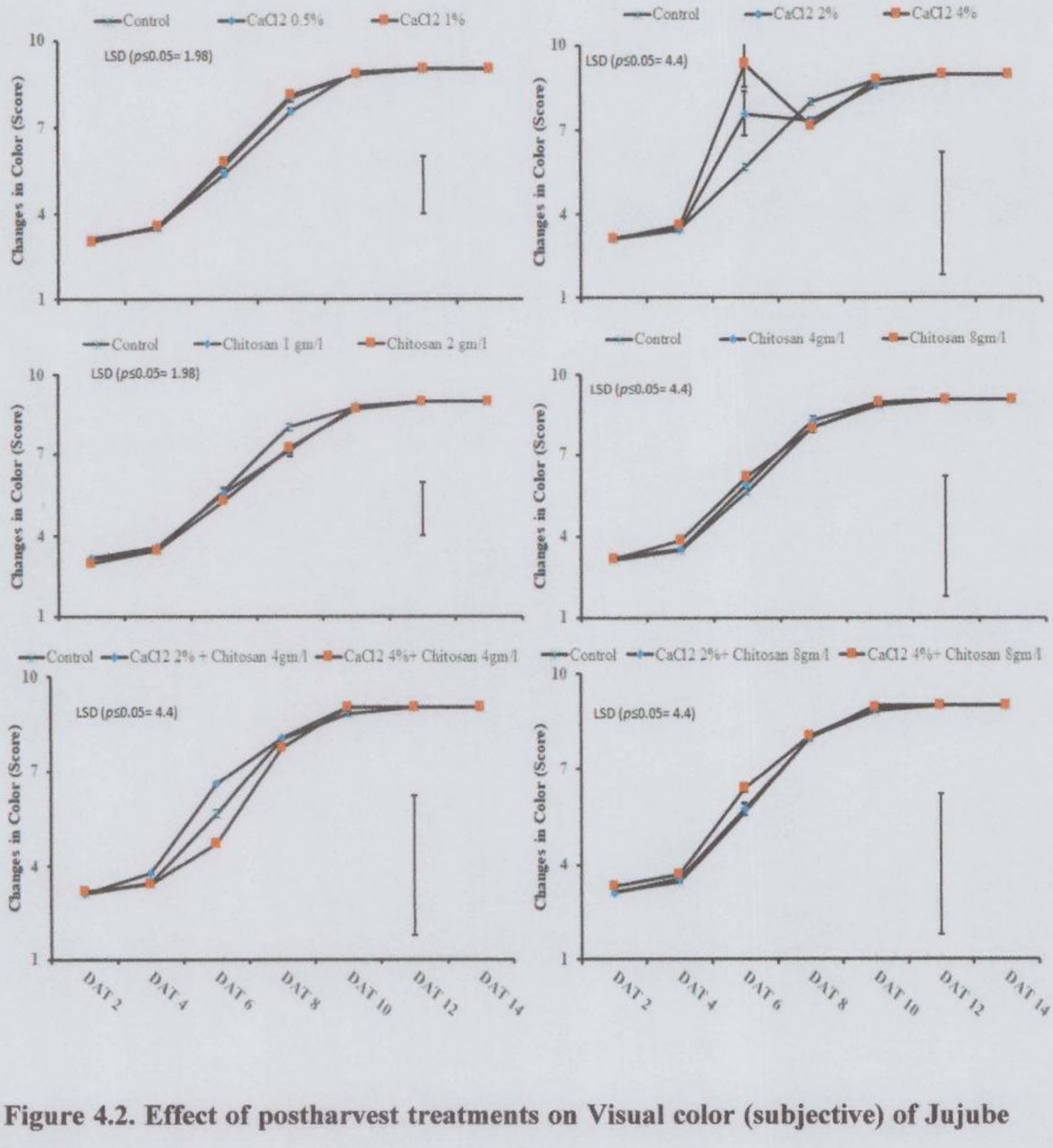

Figure 4.2. Effect of postharvest treatments on Visual color (subjective) of Jujube fruits

4.1.3 Effect of postharvest treatments on color (objective) of Jujube fruits.

4.1.3.1 Effect of postharvest treatments on objective color (L*) of Jujube fruits.

Chromaticity L* represents the lightness of the fruit color, which ranges from 0 (black) to 100 (white). The L* values generally presented a declining trend in this study.In jujube, the changes in color chromaticity L* was faster with untreated control, whereas the changes were slower in $CaCl_2$ and chitosan treated fruit.

The L* value of the control treated fruits was almost 1.05 times higher than the average of the L* value of the treated fruit on 14 DAT. After 14 days of treatment, it was observed that color change of $CaCl_2$ and chitosan treated fruits was almost 0.96 parts lower than the average of the color change (Figure 4.3). These experimental results are in consistent with previous studies conducted by Jiang et al., (2005); Varasteh et al., (2012) where they observed that treatment delayed fruits' color changes. Similar findings were reported in strawberries coated with edible coatings, where a color change in fruit was significantly delayed (Velickova et al., 2013).

4.1.3.2 Effect of postharvest treatments on objective color (a*) jujube fruits

Chromaticity a* indicates the redness (+a*) or greenness (-a*). In jujube, the changes in color chromaticity a* were faster with untreated control, whereas the changes were slower with $CaCl_2$ and chitosan (Figure 4.4). After 14 days of treatment, the redness of T1 (control) treated fruits was almost 1.31 times higher than the average of the color change during storage period. Whereas, the color change of $CaCl_2$ 4% treated fruits was about 0.51 parts lower than the average of the color change on that day. These experimental results are in accordance with the findings from the studies conducted by Zhu et al. (2021) where they observed that coating treatment delayed color changes of fruits. Compared to the control fruits, the chromaticity a* value of chitosan treated fruits remain lower as reported by Mshora et al. (2022). According to Liu et al. (2023), postharvest fruits treated with calcium exhibit a delay in colour development, they also discovered that the values of L*, a*, and b* in pear fruits grew less when calcium was applied.

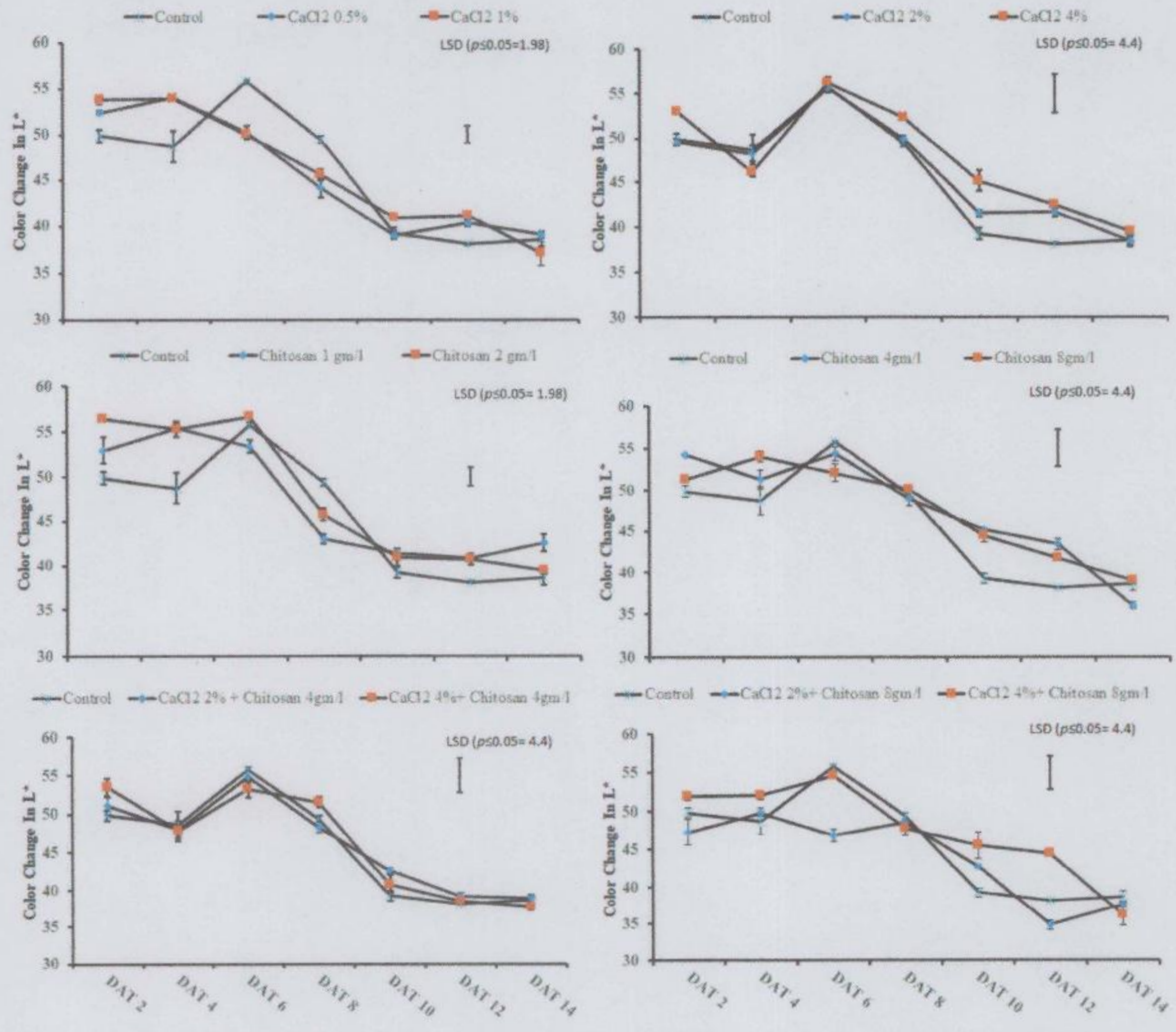

Figure 4.3. Effect of postharvest treatments on objective color (L*) of Jujube fruits.

4.1.3.3 Effect of postharvest treatments on objective color (b*) of jujube fruits

Chromaticity b* indicates the yellow (+b*) or blue (-b*) color of fruit skin. In jujube, the changes in chromaticity b* were faster with untreated control, whereas the changes were slower with $CaCl_2$ and chitosan (Figure4.5). On 14 DAT, the change in color of (control) treated fruits was almost 1.05 times higher than the average of the color change. On the other hand, changes in color as it was observed after 14 days of treatment in $CaCl_2$ 0.5% and 1% treated fruits was almost 0.91 parts lower than the average of the color change during the storage period. Mshora et al. (2022) stated that similar results in case of coated fruits.

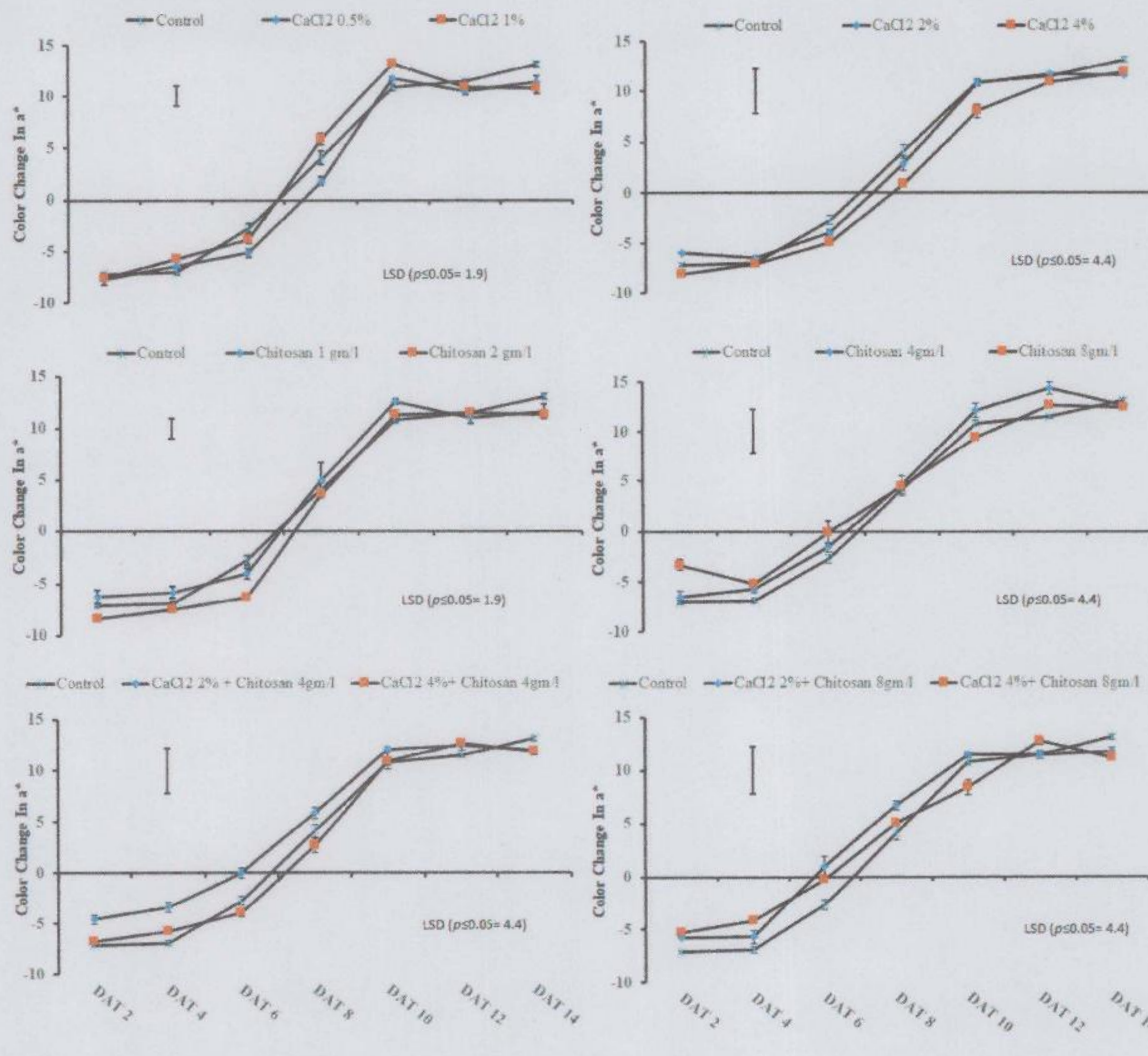

Figure 4.4. Effect of postharvest treatments on objective color (a*) jujube fruits

4.1.3.4 Effect of postharvest treatments on objective color (c*) of jujube fruits

The chroma value of coated as well as uncoated jujube fruits decreased during the study (Figure 4.6). A lower C* value (24.43) was observed in fruits coated with $CaCl_2$ 0.5% as compared to uncoated fruits, where a rapid change in C* value (26.53) was recorded. Similar findings were reported in strawberries coated with edible coatings, where a color change in fruit was significantly delayed (Velickova et al., 2013). According to Souza et al. (2023), fig fruits with high chromaticity and hue values were retained when plants were sprayed with 1% $CaCl_2$.

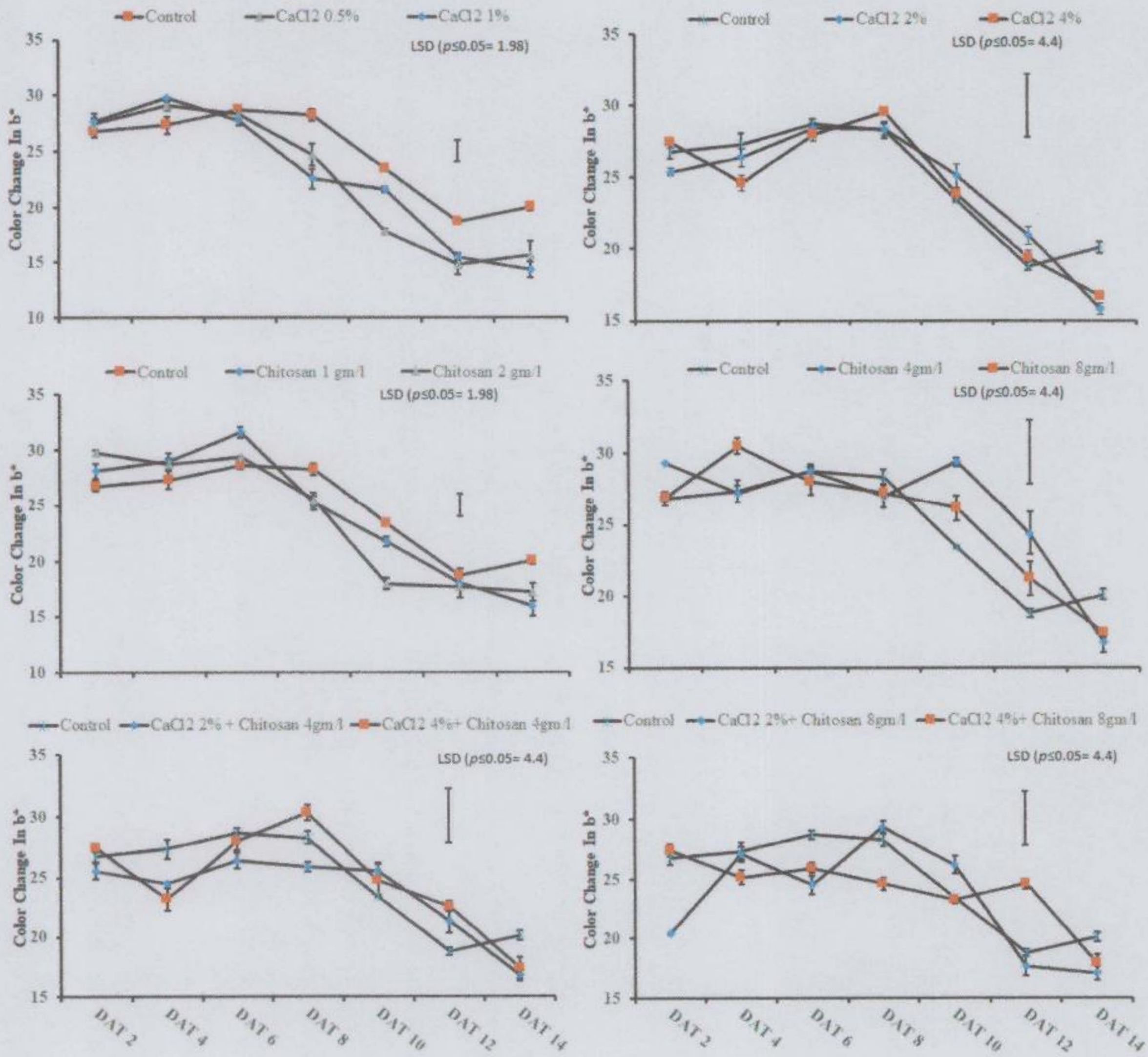

Figure 4.5. Effect of postharvest treatments on objective color (b*) of jujube fruits

4.1.3.5 Effect of postharvest treatments on objective color (h*) of jujube fruits

Hue angle of pulp of all the jujube fruits decreased throughout the storage period irrespective of calcium and chitosan coatings. A comparatively higher (83.98) hue angle was registered in fruits with $CaCl_2$ 4% coatings as compared to control fruits which recorded minimum (80.92) hue angle (Figure 4.7). Coated fruits recorded lesser hue angle (h*) and higher chroma values which may be attributed to the slow pulp color changes and fruit senescence. This indicated that lower storage temperature slowed down the de-greening processes in jujube fruits. These results were in consistent with some previous researches in apricots and peaches (Salunkhe et al., 1991). Coating fruits with

0.5% chitosan maintained the hue values (h*), delaying the color change during the storage period. Bitange et al. (2021) found that during the postharvest period, mango fruits treated with $CaCl_2$ had greater colour values than the control.

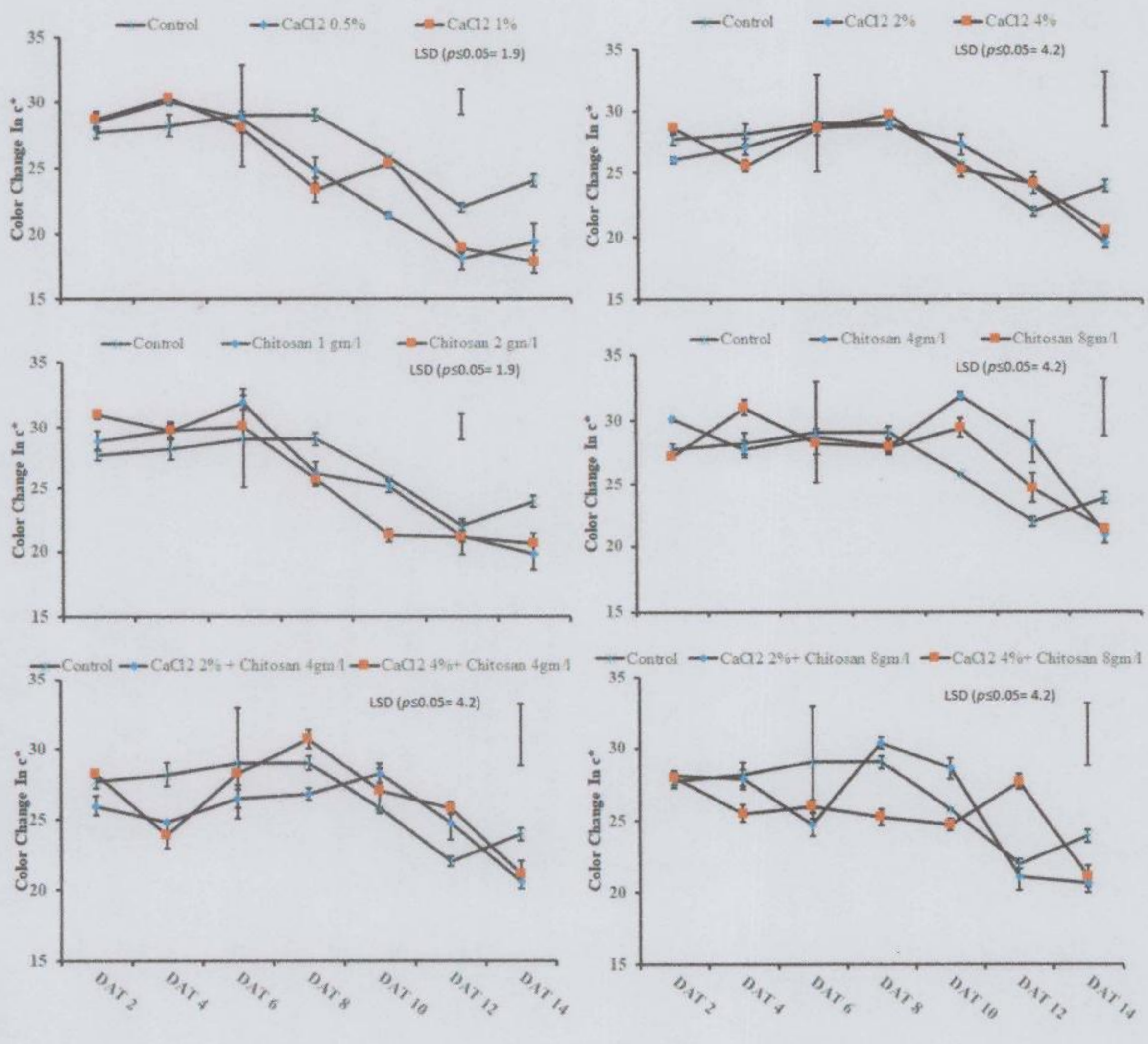

Figure 4.6. Effect of postharvest treatments on objective color (c*) of jujube fruits

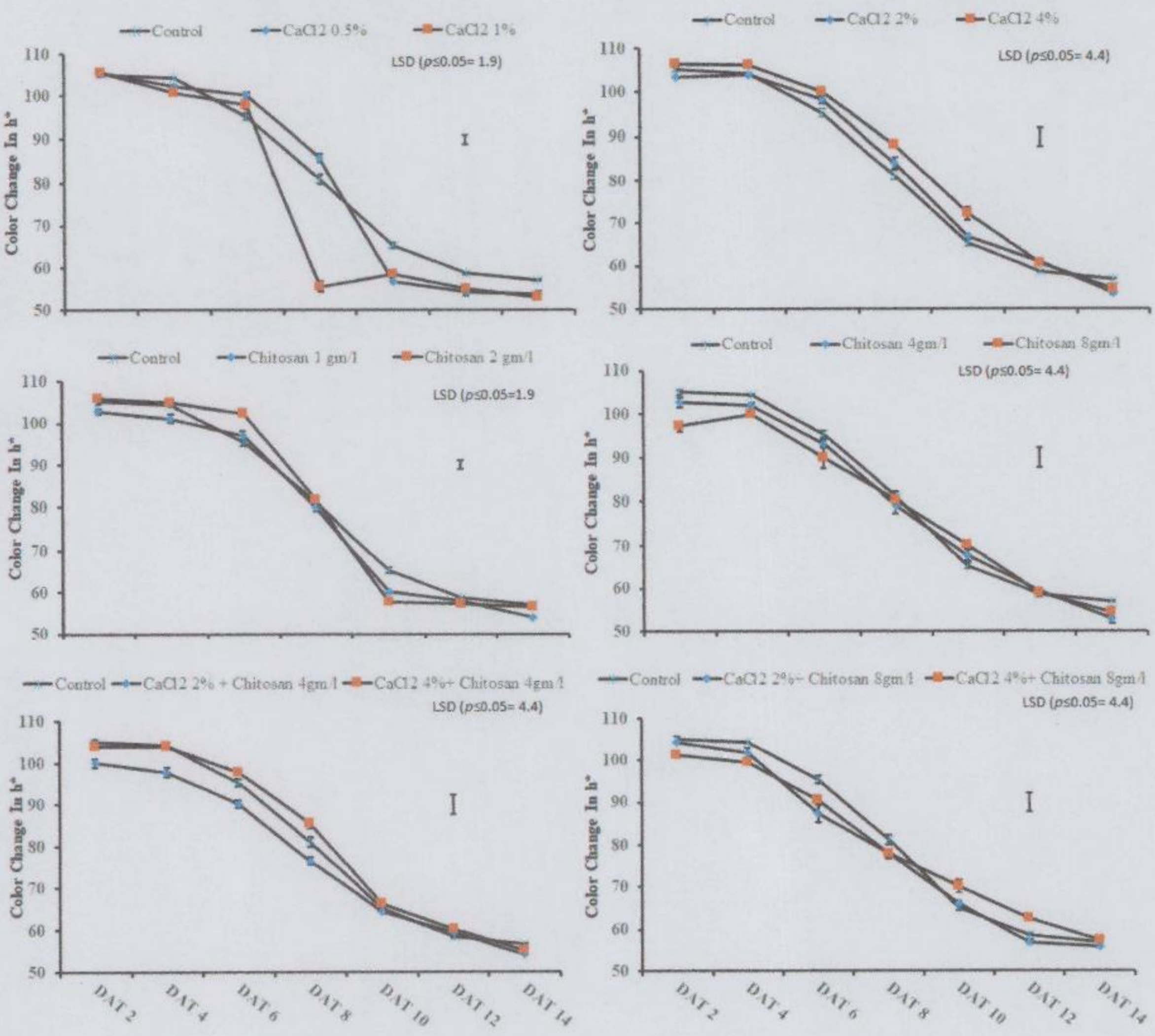

Figure 4.7. Effect of postharvest treatments on objective color (h*) of jujube fruits

4.1.4 Effect of postharvest treatments on Texture of jujube fruits

Texture is an essential sensory feature, indicative of fruit quality and storage life. Statistically highly significant variation was observed in respect of texture of jujube fruits during storage. $CaCl_2$ and chitosan coating delay the maturation by reducing the rate of respiration resulting greater texture. Comparatively better retention of texture in jujube was observed in $CaCl_2$ and chitosan treated fruits 0.7 parts lower than the untreated control fruits on DAT 14 (Figure4.8). On the contrary, the rates of texture changes were slower in jujube that were coated with $CaCl_2$ and chitosan.

Previous studies have reported preventing decrease in fruit texture with chitosan for mango (Jongsri et al., 2016) as well as papaya (Ali et al., 2011), guava (Hong et al., 2012) and grape (Al-Qurashi and Awad, 2015). Applications of calcium have been beneficial in preserving fruit texture for extended periods of time in a variety of fruits, including jujube (*Ziziphus mauritiana* Lamk.) (Jain et al., 2019).

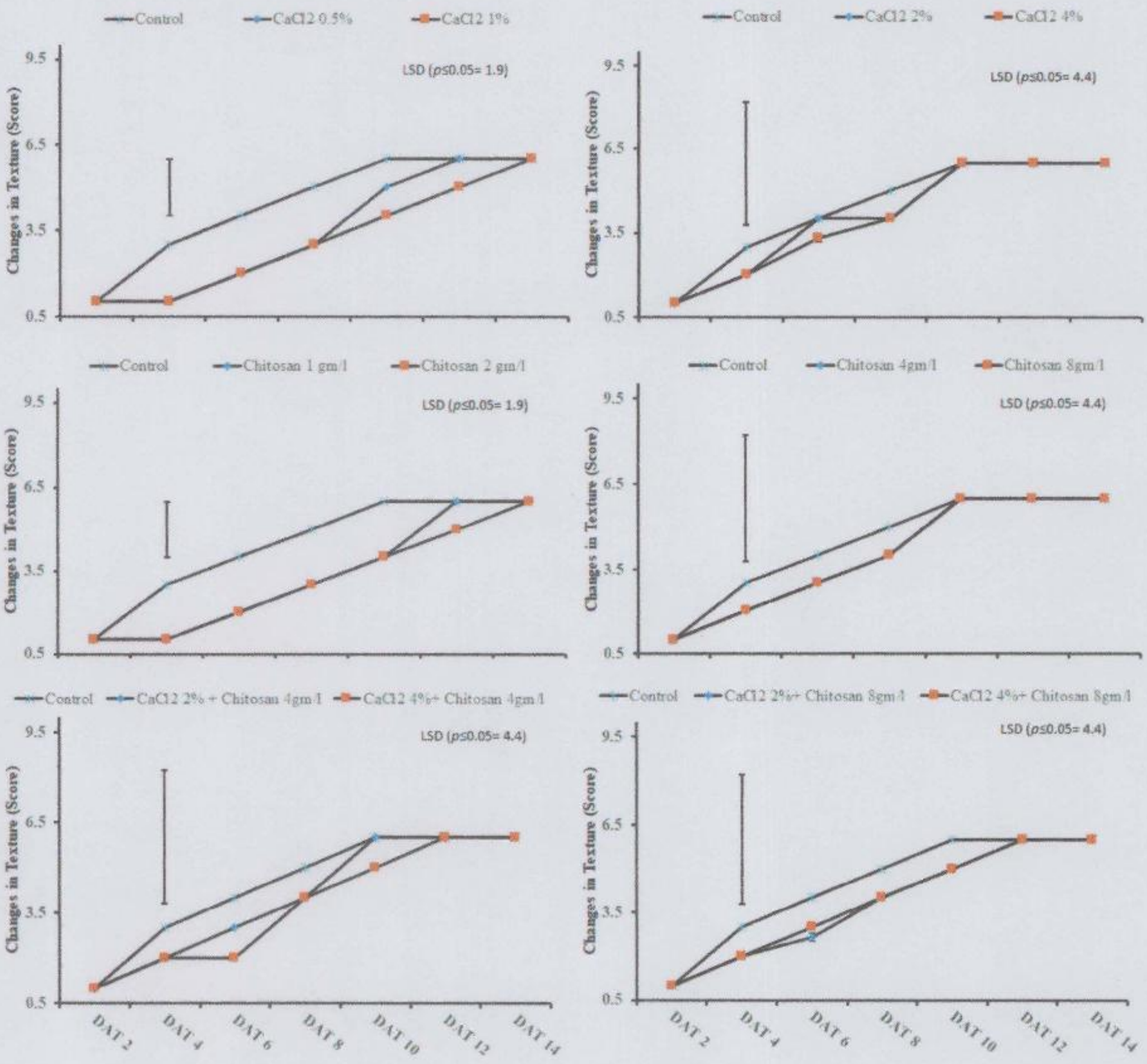

Figure 4.8. Effect of postharvest treatments on Texture of jujube fruits

4.1.5 Effect of postharvest treatments on Shrinking% of jujube fruits

Shrinking is also an essential sensory feature, indicative of fruit quality and storage life. Statistically highly significant variation was observed in respect of shrinking of jujube fruits during storage. $CaCl_2$ and chitosan coating slows the shrinkage by reducing the rate of respiration resulting lower shrinkage. Comparatively better retention of texture in jujube was observed in $CaCl_2$ and chitosan treated fruits 0.7 parts lower than the untreated control fruits on DAT 14 (Figure4.9). On the contrary, the rates of shrinkage changes were slower in jujube that were coated with $CaCl_2$ and chitosan. Previous studies confirmed that indicated coating was effective to maintain quality by reducing the ripening rate also reduce shrinkage percentage in comparison to uncoated ones. Coated fruits had good shelf life (Mani et al. 2017). When 1% $CaCl_2$ was applied to peach trees, the fresh mass, size, and pulp-to-stone ratio increased, producing fruits with a greater diameter and a better profit margin. According to Khalaj et al. (2017), foliar application of calcium enhanced the amount of pectic compounds in the cell walls, which in turn raised the thickness of the pericarp tissue and the fruits' total fresh mass.

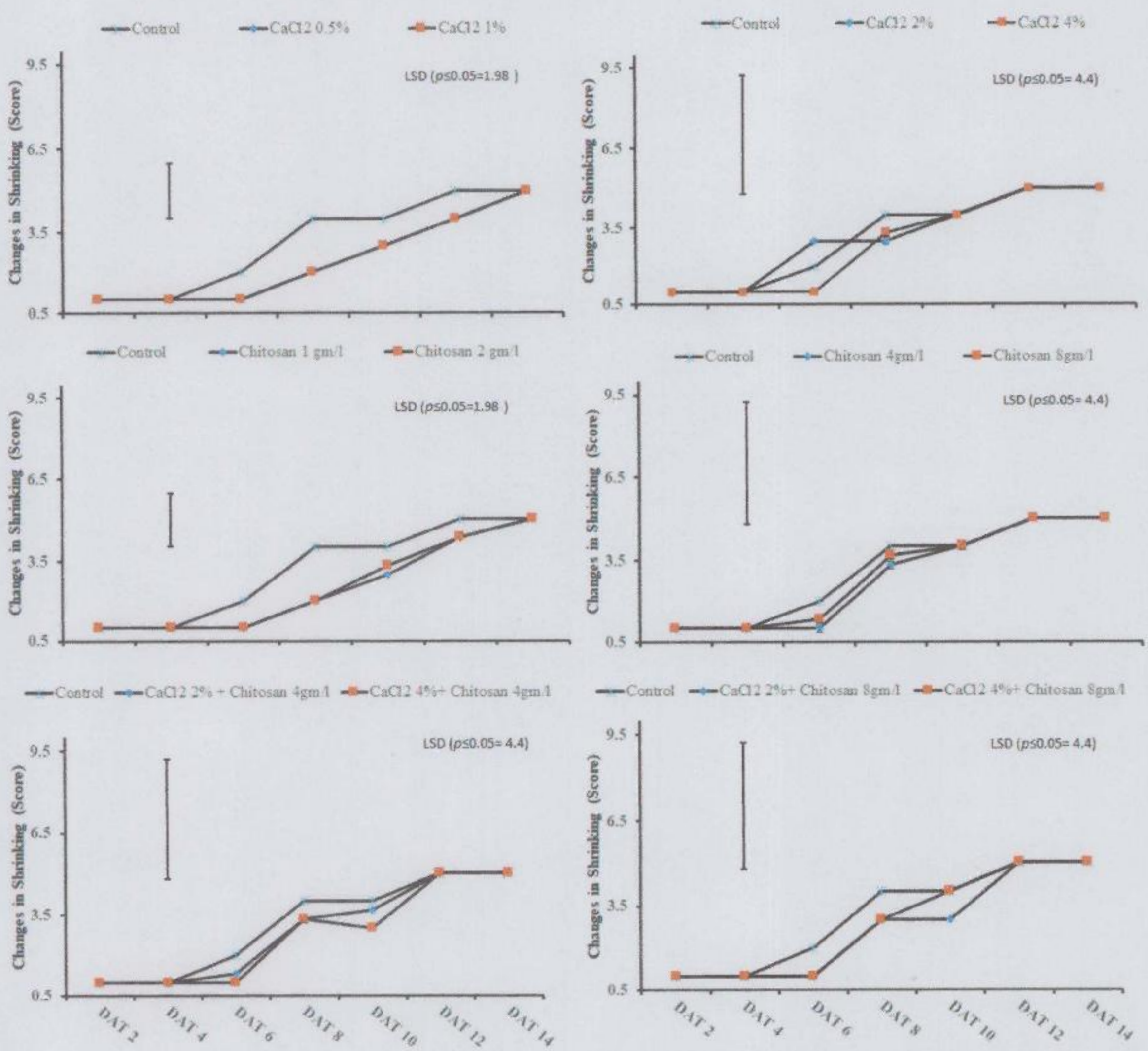

Figure 4.9. Effect of postharvest treatments on Shrinking% of jujube fruits

4.1.6 Effect of postharvest treatments on Scratch of jujube fruits

It was observed of scratching of jujube fruits during storage. $CaCl_2$ 2% and 4% coating show extensive scratch on jujube peel. It almost 30 and 50 percent respectively on DAT 8. Treatment of $CaCl_2$ 4%+ Chitosan 8gm/l show 25% scratch on DAT 8(Figure4.10).

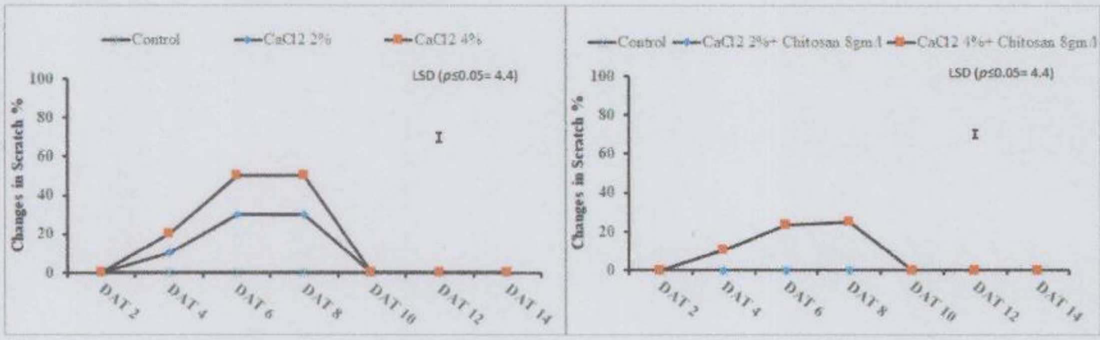

Figure 4.10. Effect of postharvest treatments on Scratch % of jujube fruits

4.1.7 Effect of postharvest treatments on Total soluble solids (TSS) Content of Jujube fruits.

Total soluble solids (°Brix) Data pertaining to total soluble solids are presented in (Figure 4.11) clearly reveals that effect of different post-harvest treatments of calcium chloride and chitosan influenced the total soluble solids during the storage period. The control jujube showed a significant change in TSS at the end of storage However, $CaCl_2$ 0.5% coating treatments significantly delayed jujube TSS rise during storage time. The lowest TSS value were recorded in $CaCl_2$ 2% and the highest TSS value were recorded in $CaCl_2$ 4%+ Chitosan 8gm/l coating treatment.

Chitosan coatings could provide a semipermeable film around the fruit surface, which modifies the internal atmosphere by reducing oxygen and/or elevating carbon dioxide levels, which decrease the fruit respiration level and metabolic activity (Vargas et al., 2008). Similar views were expressed by Ali et al. (2011) who observed that chitosan coating effectively delayed changes in soluble solids concentration of papaya during 5 weeks of storage. The total soluble solids were found highest in the fruits treated with calcium chloride 1.5 percent, followed by calcium chloride 0.5 per cent under ambient conditions, respectively (Singh et al. 2010) Similar rise and fall in total soluble solids was also noticed in guava (Jayachandran et al. 2004) and loquat (Akhtar et al. 2010). It could be probably because of delayed ripening, reduced respiration rate, lowered hydrolytic enzymes and metabolic activities. (Sakhale et al. 2009). According to Souza et al. (2023), the application of $CaCl_2$ lowers the concentration of TSS and the amount of reducing sugars in figs. This is because calcium provides a stronger stabilisation of pectin structures.

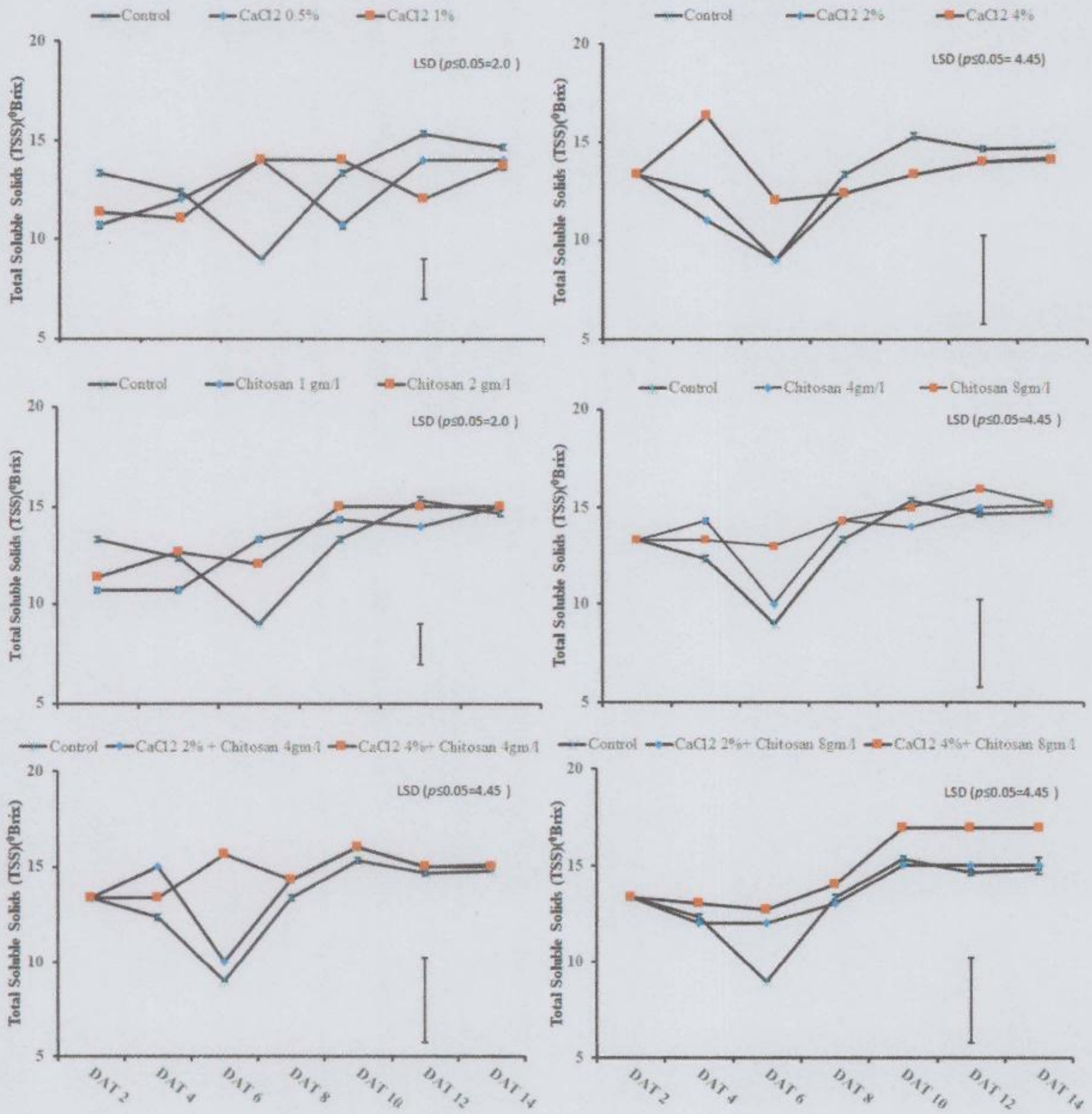

Figure 4.11. Effect of postharvest treatments on Total soluble solids (TSS) Content of Jujube fruits.

4.1.8 Effect of postharvest treatments on Titratable acidity (TA) Content of jujube fruits

Titratable acidity is responsible for the sourness of fruit. TA decreased in all the fruits irrespective of the coatings during the entire storage period (Figure 4.12). After 14 days of treatment, it was observed that, the decline in acidity of uncoated fruits was 1.27 times higher than the average of the titratable acidity during storage period. The decline in acidity of uncoated fruits was higher as compared to TA in the $CaCl_2$ 2%+ chitosan 8 g/L coating treatments, TA was higher than in control and other storage treatments. Results were in harmony with the previous findings in mango as reported by Zhu et al. (2008). Kittur et al. (2001) stated that polysaccharide-based coatings applied on banana fruit displayed reduced carbon dioxide evolution, loss in weight and titratable acidity. The reduction in acidity of Ber fruits was quite slow at cool temperature (Hiwale and Singh, 2003). According to Ali et al. (2021), fruits treated with 1% $CaCl_2$ retain high TA values throughout storage because the amount of acid utilised as a respiratory substrate does not decrease because of a drop in respiratory intensity (Saltveit et al., 2019). According to Liu et al. (2023), applying calcium to pear fruits results in greater TA levels throughout the postharvest period, which is in line with what was seen in apricot (Dorostkar et al., 2022).

4.1.9 Effect of postharvest treatments on Vitamin C (Vit-C) Content of Jujube fruits

Treatment with different concentrations of $CaCl_2$ and chitosan showed significant effects on ascorbic acid content of the jujube fruits (Figure 4.13). The results showed that by increasing the storage period, vitamin C content of fruits decreased. Jujube fruits treated with chitosan 8gm/l expressed the highest ascorbic acid content at 4 DAT. Suseno et al. (2014) reported reduce loss of vitamin C in cavendish banana while they used 2% chitosan edible coating with 80% deacetylation. On the other hand, fruits treated with $CaCl_2$ 4%+ chitosan 8gm/l showed the highest ascorbic acid content at 6 DAT. There was a decreasing trend in relation to vitamin C content of fruit pulp during storage. It was also remarkable that vitamin C contents declined steadily up to the end of the storage period. The findings of Absar et al. (2020) supported the above results of vitamin C.

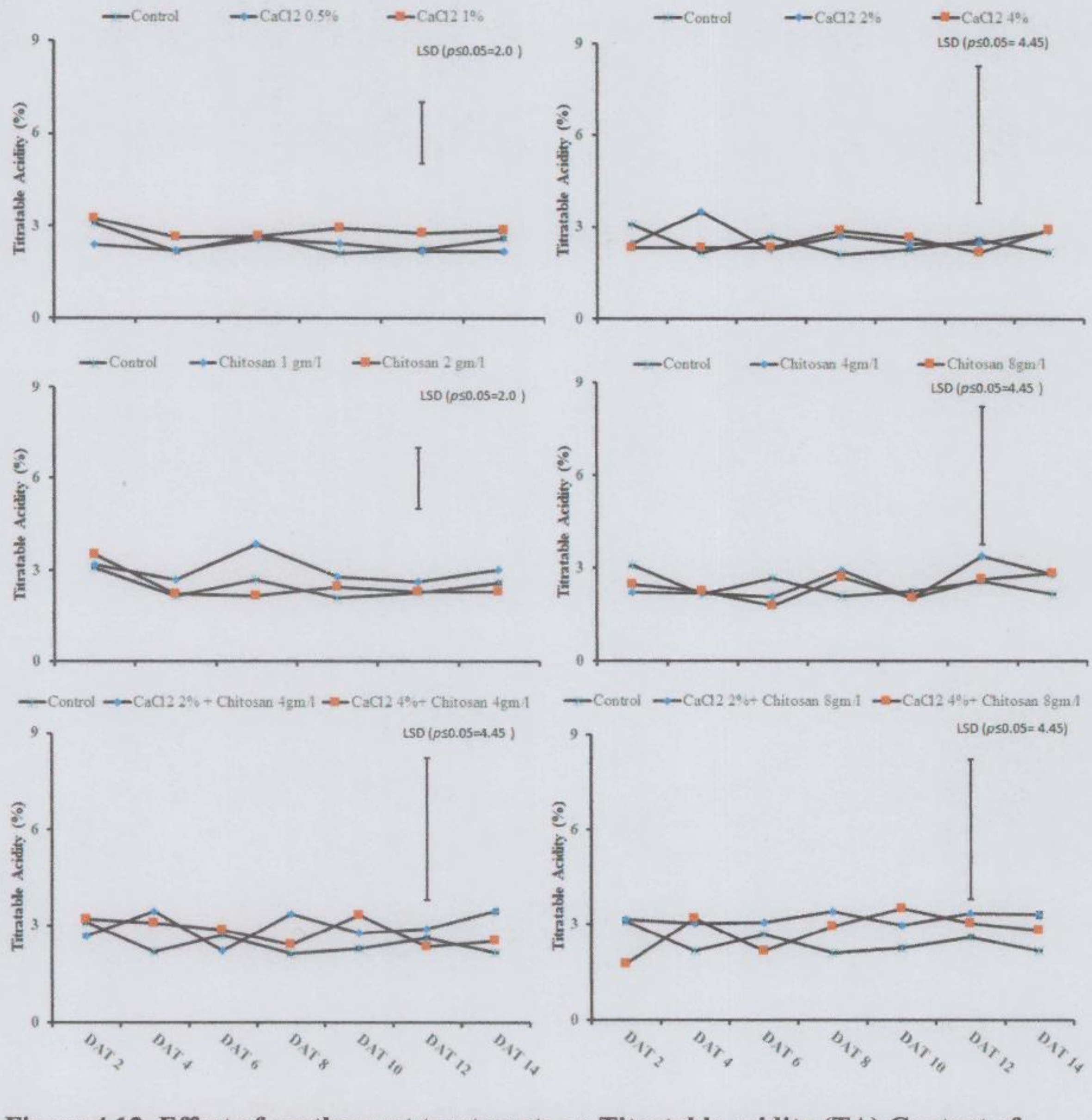

Figure 4.12. Effect of postharvest treatments on Titratable acidity (TA) Content of jujube fruits

4.1.10 Effect of postharvest treatments on shelf life of Jujube fruits

The application of calcium chloride and chitosan could be beneficial in prolonging shelf life and maintaining the quality of jujube fruits by inhibiting the respiration rate in jujube fruits and decreasing postharvest diseases. Calcium chloride and chitosan not only maintains weight loss but also improves the postharvest quality during storage. Shelf life of jujube fruits was significantly affected by the different postharvest treatments of Calcium chloride and chitosan concentration (Figure 4.14). The largest shelf life about 8 days of jujube fruit was recorded in chitosan 1 gm/l treated fruits. Pawan and Jatinde

(2022) observed Jujube with edible chitosan coatings preserved its quality, extended its shelf life, and inhibited microbiological growth in both cold and ambient storage.

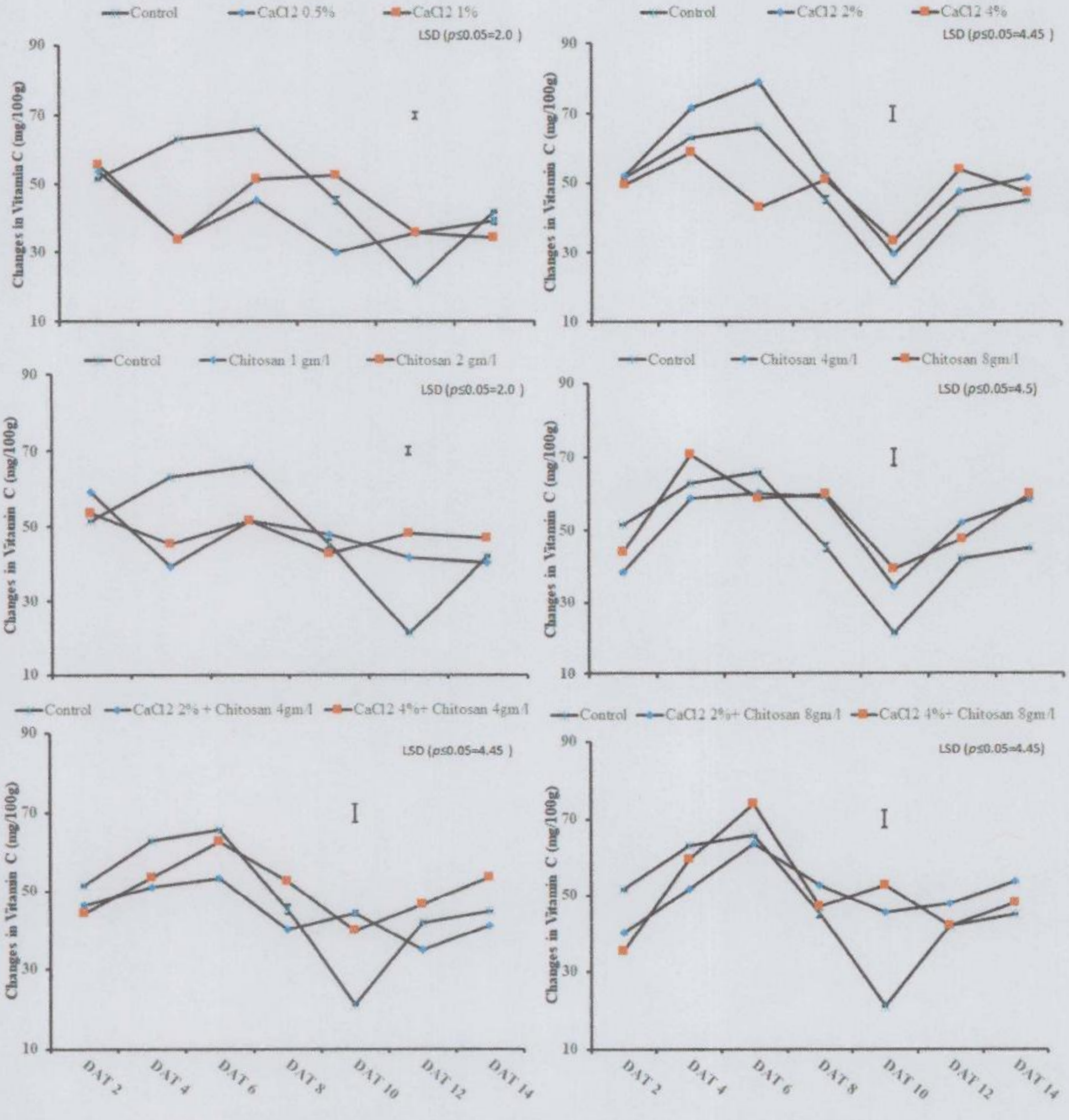

Figure 4.13. Effect of postharvest treatments on Vitamin C (Vit-C) Content of Jujube fruits

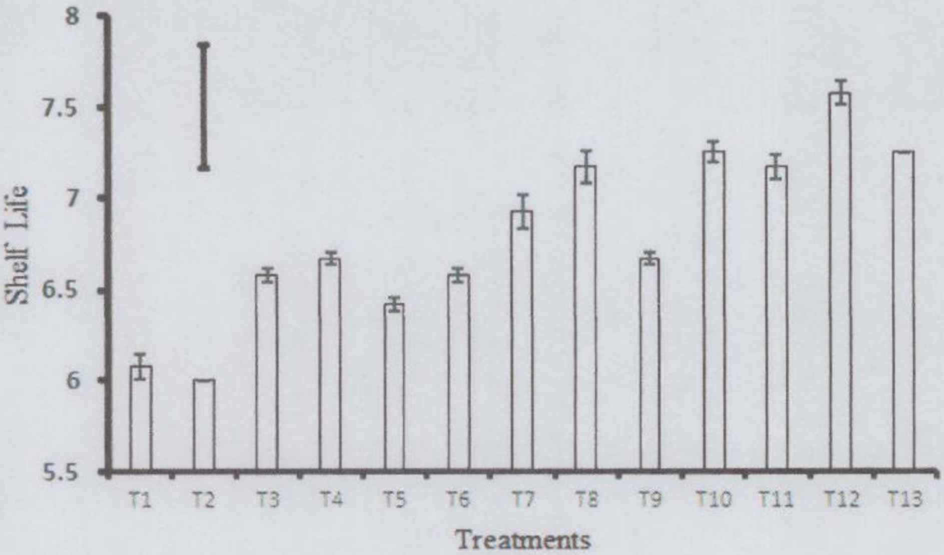

Figure 4.14. Effect of postharvest treatments on shelf life of jujube

CHAPTER 5
SUMMARY, CONCLUSON AND RECOMMENDATION

The current study was conducted on the effect of $CaCl_2$ and synthesized chitosan on physico-chemical properties of jujube fruits in ambient condition. The main objective of the study was to identify suitable eco-friendly postharvest treatment for maintaining quality of jujube. The study was conducted at Horticulture Laboratory, Agrotechnology Discipline, Khulna University, Khulna during the period from 4th February 2024 to 20th February 2024. jujube was collected from Koya Bazar, Batighata, Khulna.

The two-factor experiment was conducted in this study following factorial completely randomized design (CRD) with three replications of treatments containing 500g fruits in each replication. The temperature of horticulture laboratory ranged from 26 °C to 31 °C with relative humidity of 80-90%. The postharvest treatments were applied to randomly selected fruits. Jujube fruits were treated with 2% and 4% solution of $CaCl_2$, 1g and 2g of chitosan solution and combined solution of $CaCl_2$ and chitosan. Untreated fruits were maintained as the control. Both treated and untreated fruits were kept at ambient temperature. Observations were made during the storage period on various physical (weight loss, texture, color [subjective and objective], Shrinking%, scratch and shelf-life) and chemical (TA, TSS, TA: TSS ratio and vitamin C) parameters of jujube fruits. Data of physical parameters were recorded regularly while chemical parameters on every alternate day.

From the experiment jujube, it was observed that chitosan treated fruits performed better than others treated fruits in respect of cumulative weight loss, color (subjective), texture, shrinking, scratch and TA. On the other hand, combination of $CaCl_2$ and chitosan treated fruits showed better results in vit-C content. Another important thing observed that application of higher concentration of $CaCl_2$ (2% and 4%) caused scratched on jujube peel. The longest shelf life of jujube was recorded in chitosan 1 g/L treated fruits It is evident that chitosan might have the capacity to inhibit ripening process and suitable for jujube postharvest.

CHAPTER 6

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Appendix

Picture of the performed study

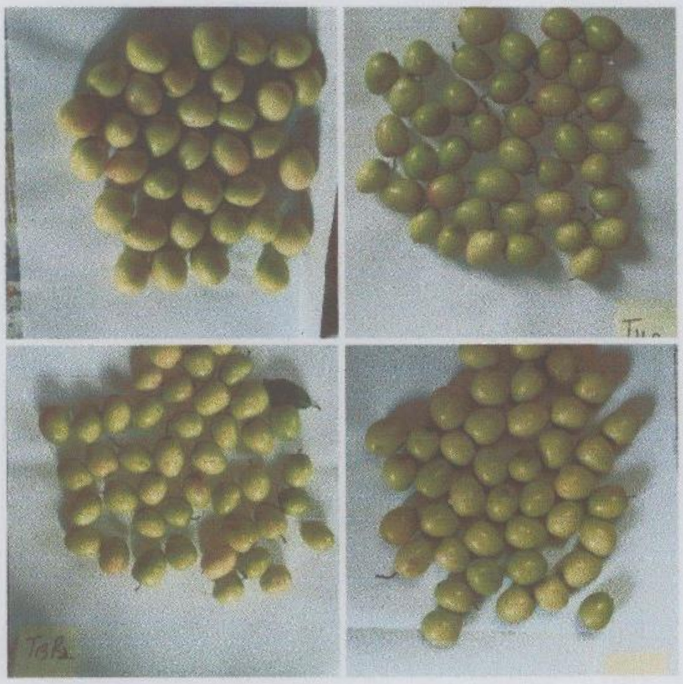

Plate 7.1. Color of jujube on 0 days

Plate 7.2. Changes in color of jujube on DAT 1

Plate 7.3. Changes in color of jujube on DAT 3

Plate 7.4. Changes in color of jujube on DAT 5