

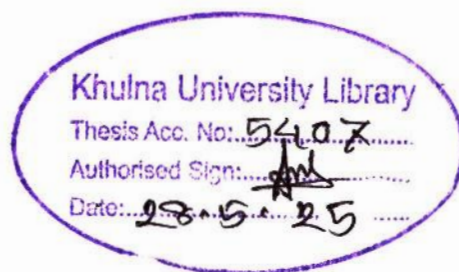
EFFECT OF CHITOSAN COATING ON POSTHARVEST QUALITY AND SHELF LIFE OF JUJUBE (*Ziziphus jujuba* L.) AT AMBIENT CONDITION

A Thesis

By

Student ID: MS-210812

**A Thesis (Course No. HRT - 6315) Submitted to the Agrotechnology Discipline in
Partial Fulfillment of the Requirements for the Degree of Master of Science in
Horticulture**



Agrotechnology Discipline

Khulna University

Khulna-9208

December, 2024

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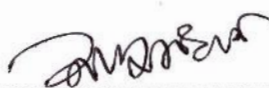
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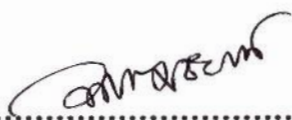
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December, 2024

Dedicated to

My

Beloved Parents



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The Author

ABSTRACT

The study was carried out at the Horticulture Laboratory of Agrotechnology Discipline, Khulna University, Khulna from December 2022 to April 2023 to investigate the effects of chitosan coating in extending the postharvest life of jujube fruits and maintaining their quality. Due to short shelf-life of ber fruits, developing postharvest protocols incorporating chitosan coatings to extend its shelf life and maintain quality is one of the major issues regarding the ber fruit industry. The experiment consisted of four treatments with five varieties of jujube fruits and laid out in a Completely Randomized Design with three replications for the treatments. The treatments were four levels of chitosan solution viz. T_1 = control, T_2 = 0.1%, T_3 = 0.3%, and T_4 = 0.5% concentration, and the five varieties of jujube fruits were V_1 = Ball Sundori Kul, V_2 = Apple Kul and V_3 = Kashmiri Kul, V_4 = Thai Kul and V_5 = Narkeli Kul. At the end of the storage, Ball Sundori Kul coated with 0.5% chitosan showed the highest Vit C (19.62 mg/100g), TSS (15.13%), TA (1.40%), while uncoated Narkeli Kul expressed the lowest highest pH (4.11) of uncoated Ball Sundori Kul whereas the Apple Kul contain the lowest pH with 0.3% chitosan. Again Ball Sundori Kul coated with 0.5% chitosan coating maintained the highest total flavonoid (0.90 mg/100g) and total anthocyanin (35.25 mg/100g), while uncoated Thai Kul showed the lowest. The lowest disease incidence (55.00%) was recorded from Ball Sundori Kul coated with 0.5% chitosan as uncoated Narkeli Kul and Thai Kul was the highest. However, the minimum weight loss (14.33%), maximum length (52.57cm) and breadth (40.99cm) were recorded from Ball Sundori Kul coated with 0.5% chitosan. Colorimeter values (*L, a*, b*, c*, and h*) increased in comparison to the initial values from all varieties except c* values. The findings from the current study showed that Ball Sundori Kul covered with a 0.5% chitosan solution outperformed the other variety regarding every desirable metric examined. Therefore, it may be recommended to store jujube fruits at room temperature using Ball Sundori Kul and a 0.5% chitosan solution.

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CHAPTER I

1 INTRODUCTION

Jujube (*Ziziphus jujuba*) is a tropical fruit tree that is economically significant and a member of the Rhamnaceae family. It is also called Ber fruits. It has a poor shelf life and is extremely perishable (Meena et al. 2009). Customers are attracted to this fruit due to its mouthwatering flavor, appealing scent, and substantial nutrient content (Rashwan et al., 2020). It has a high calorific value, a high ascorbic acid content, an adequate amount of calcium, phosphorus, iron, and vitamins A and B, and is very nutritious (Jawanda et al. 1978).

In Asia, jujube fruits are typically used for traditional medicine as well as food (fresh, dried, candied, pickled, juice, flour, meal, and butter) (Wang et al., 2023; Aldhanhani et al., 2022). Jujube helps to reduce oxidative stress, boost the immune system (Yu et al., 2012; Pu et al., 2018), and treat several illnesses, including anemia, cancer, and heart disease (Gao et al., 2013). In addition to these characteristics, consumers favour this fruit species because of its high vitamin C content, flavour, and taste, and its production is growing day by day (San and Yildirim, 2010).

One of the biggest obstacles to the growth of this fruit industry is its short storage duration (Rao et al., 2016). In simpler terms, postharvest treatment and transportation shorten their postharvest life, and it is difficult to maintain fruit in storage (Aboutalebi and Ramazani, 2014). Fresh *Z. jujuba* fruits decay quickly and cannot be stored at room temperature for longer than 10 days without experiencing severe degradation (Kadzere et al., 2004; Pareek, 2001). Therefore, to preserve improved fruit quality when handling and transporting fresh produce, suitable postharvest procedures and treatments must be developed. Numerous techniques, such as lowering the temperature, storing in a controlled atmosphere, applying preservatives, or coating edible film, were considered to preserve the physiological quality and extend the shelf life of fresh *Ziziphus* fruits (Nallathambi et al., 2009; Rao et al., 2016; Wu et al., 2010; Zhang et al., 2014). Due to its better biocompatibility and lack of toxicity, chitosan, a natural alkaline polysaccharide, has emerged as one of the most widely used edible film materials in recent years, replacing the use of chemical fungicides.

For the treatment of postharvest fruits and vegetables, chitosan is a popular food additive and a good substitute for synthetic fungicides (Romanazzi et al., 2017).

Deacetylation of chitin yields chitosan, a naturally occurring and eco-friendly substance (Khoshgozaran et al., 2012). By inhibiting deterioration, chitosan and its derivatives extend the shelf life of a variety of fruits and vegetables. Because it may be used as a coating material, product preservation is one of the biopolymer's interesting uses (Chien et al., 2007; Devlieghere et al., 2004; Qiuping and Wenshui, 2007; Sabir et al., 2019). According to Hughes et al. (1994), chitosan's antibacterial properties are ascribed to its amino groups or hydrogen bonds with extracellular polymers. According to El-Badawy and ElSally (2011), Hong et al. (2012), and Xing et al. (2011), chitosan is a biopolymer with exceptional film-forming qualities. It can create a semipermeable film on fruit that may alter the internal atmosphere, reduce weight loss and shrivelling brought on by transpiration, and improve the overall quality of the fruit. By stopping the loss of fruit weight, soluble solid contents, vitamin C, titratable acidity, and firmness, chitosan coating preserves fruit quality while it is being stored (Chiabrando and Giacalone, 2013; Lin et al., 2020), Romanazzi et al., 2002).

According to Krishna and Rao (2016), a 1% chitosan treatment prolonged the guava's shelf life by up to 7 days by postponing ripening and halting physiological weight loss. By lowering the respiration rate without impairing the ripening of the fruit, chitosan made with cassava starch enhanced shelf life and considerably retained the mango's weight, color, texture, and aroma (Camatari et al., 2018). Apart from chitosan coating, temperature control is an important technique for prolonging fruit shelf life and is the primary environmental factor influencing fruit quality (Lee and Kader, 2000). Between mid-January and mid-March, when there is still a shortage of fruits in Bangladesh's rural areas, millions of impoverished people depend upon jujube as a food source. At this time, a lot of jujube is introduced to the market. However, a significant amount of this is damaged due to insufficient storage facilities.

However, from October to March, there is a severe fruit shortage. Superior jujube fruits can be chosen from the field, and gathering them helps to reduce the fruit and nutritional deficiency during the season of scarcity (Kadir et al., 1997).

The environment and human health are at risk when artificial chemicals are used to prolong the shelf life of perishables and reduce postharvest losses. A number of chemicals have recently been taken off the market due to health concerns. For postharvest shelf-life extension with maintained quality, efforts must be made to

optimize or create appropriate substitutes, such as chitosan coatings. To decrease postharvest losses and support the growth of the local and national economies, it is imperative to develop an appropriate way to extend the shelf life of jujube. A thorough investigation into the postharvest behavior of the jujube cultivars found in Bangladesh's Khulna region is crucial in light of these factors. From the discussion made above it is clear that similar research on utilizing chitosan coating to preserve jujube fruits has not been carried out in Bangladesh. So, the present study was undertaken to investigate the impact of chitosan coatings on the quality and shelf life of jujube fruit, with the following objectives:

1. To determine the physico-chemical variations and shelf life of jujube varieties treated with chitosan coating kept at room temperature:

CHAPTER II



2 LITERATURE REVIEW

2.1 Introduction

For a prosperous country to survive, agriculture is a vital business. The growth of exceptional people is developed by an adequate quantity of high-quality food. One approach used by farmers and manufacturers to improve quality and yield is the introduction of additional agricultural inputs, such as plant regulators or growth promoters. Due to consumer demand, farmers and producers of agricultural products are now choosing safe and clean technologies and agricultural inputs. To meet the needs, growth boosters with chemical or natural bases are commercially available. Materials derived from naturally occurring bacteria, plants, animals, and algae are known as natural-based promoters (Hernández-Carmona et al., 2013).

In Bangladesh, jujube is a popular fruit. Its distinct flavor and taste appeal to everyone. The midland of Malaysia, the southwestern region of China, and the northern region of India are the origins of jujube. In jujube, 85.9% water, 0.8% protein, 0.1% fat, 12.8% carbohydrates, 0.033% calcium, 0.03% phosphorus, and 0.8% iron are present. Jujube has 55K Cal, 70IU carotene, and 50-150 mg vitamin C per 100g of edible portion (Banglapedia, 2021).

Since jujube yields higher earnings faster than other crops, thousands of farmers in Bangladesh's southwest region are taking the advantage of the benefits of growing the fruit. Jujube farming is therefore becoming increasingly popular in the area, particularly in Satkhira, Khulna, and Bagerhat, where the majority of farmers formerly concentrated on prawns or vegetables that are more adapted to the saline-prone soil. According to sources at the local Department of Agricultural Extension (DAE), Satkhira alone now produces about 15,000 tonnes of fruit a year. Nowadays, increased cultivation of jujube has been witnessed in other regions in the world, including Russia, southern Asia, southern Europe, southwestern United States, and Australia (AlSaeedi, Al- Ghafri, & Hossain, 2016; Li, Fan, Ding, & Ding, 2007; Liu, Ye, & Jiang, 2016).

Bakhshi and Singh. (1974) discussed that fruit pulp is commonly known to be rich in nutritional components. However, pulp composition has no quantifiable values. But oranges are higher in phosphorus, iron, vitamin C, and carbohydrates than apples, while

ber is higher in protein, phosphorus, calcium, carotene, and vitamin C According to Singh et al. (1973), ripe fruits have 20.9 K calories per 100g of pulp.

Baldwin et al. (1996) and Park et al. (1999) reported that the fresh fruit industry has long used edible coatings 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. According to Pranoto, Salokhe, and Rakshit (2005), credible coatings can include active ingredients such as anti-browning agents, colorants, flavorings, minerals, spices, and antimicrobial chemicals that can extend product shelf life and decrease the risk of excess pathogen growth on food surfaces.

Low molecular weight chitosan (LMCt), which is made by breaking down chitosan, can promote plant development. According to Garcia et al. (2015) and Rokhati et al. (2018), chitosan can be broken down by chemical reactions like oxidative and acidolysis, biological reactions like enzymatic hydrolysis, and physical reactions like gamma, microwave, electron beam, and sonication.

The application of chitosan treatment, either before or following harvest, has been suggested as a viable alternative to synthetic fungicides. Maintaining the general quality of the many fresh commodities can help to prevent postharvest fruit infections and extend storage life (Bautista-Banos et al., 2006). One natural substance that may be used to prevent and treat horticultural product illnesses before and after harvest is chitosan. A modified, naturally occurring biopolymer made from chitin, chitosan is formed from the waste products of shellfish exoskeletons or the cell walls of certain bacteria and fungi. It has demonstrated remarkable potential for use in food preservation. It is a linear polymer of β -1, 4-linked glucosamine (GlcN) with varying amounts of N-acetylated GlcN residues, and it is a cationic polysaccharide with a high molecular weight. Chitosan is used to safeguard food since it contains antibacterial and antifungal qualities (No et al., 2007). Chitosan's antimicrobial activity and film-forming properties make it a potential natural food preservative or coating material source. Use chitosan as a health-promoting ingredient to regulate and preserve the overall quality of the product.

2.2 Factors Contributing to Postharvest Loss (PHLs)

Seasons, production regions, and commodities all have quite different postharvest losses. PHLs can arise from a variety of sources when a product progresses through the postharvest chain, including incorrect handling or bio deterioration by insects, rodents, birds, or microorganisms.

One significant issue in developed nations is that a significant portion of the food produced is thrown out rather than consumed, either because it has passed its expiration date or was left on the plate after a meal. Conversely, in Less Developed Countries (LDCs), the very poor rely on the subpar food that is left in markets as subsistence, and failure to consume the food that is provided is not a recognized worry. The issue in LDCs is ineffective postharvest agricultural systems that lead to food loss that people would otherwise eat, sell, or barter to improve their livelihoods (Hodges et al., 2010). The scale of PHLs can range from 5 to 35% in developed countries and from 20 to 50% in developing countries (Hailu & Derbew 2015). The postharvest period has a major effect on food supply, human health, and the environment (Lipinski et al. 2013)

According to Parfitt et al. (2010), the main drivers of high PHLs in developing countries are inadequate harvesting stage, poor harvesting technique, transport, lack of a cold chain system, inadequate storage facilities, limited processing knowledge, and a lack of appropriate packaging and trading facilities.

Customers seek out fruits with a high nutritional content, a firm texture, a pleasing flavor, and a good appearance. Long post-harvest life, texture quality, and appearance are the top priorities for the farmers and handlers. The primary determinant of storage life and eventual fruit quality is maturity upon harvest. When ripe, immature fruits frequently shrivel, sustain mechanical damage, and lose quality. The unwanted flavor is frequently added after harvest, causing overripe fruits to become mushy and mealy. According to Kader (1999), fruit that is picked too early or too late in the season is more prone to physiological problems and has a shorter shelf life than fruit that is selected at the right ripeness.

2.3 Main Reasons for Fruit Loss After Harvest

Measurable qualitative and quantitative food loss along the supply chain, from harvest to consumption or other end uses, is known as post-harvest food loss (PHL) (De Lucia and Assennato, 1994; Hodges, Buzby, and Bennett, 2011). Food waste or unintentional

losses during transit can both result in PHLs. Food losses can be qualitative, such as decreased nutrient content and unintended changes to the food's flavor, color, texture, or aesthetic qualities, or quantitative, such as decreased weight or volume (Buzby and Hyman, 2012). A decrease in the weight of edible grain or food that is available for human consumption is known as quantitative food loss. Physical changes in temperature, moisture content, and chemical changes, as well as spills and pest ingestion, all contribute to the quantitative loss of weight (FAO, 1980). This definition is inadequate since drying, a postharvest procedure that is required for all grains, causes food grains to lose weight (FAO, 1980).

The occurrence of insect pests, mites, rodents, and birds, as well as handling, physical or chemical alterations in fat, carbs, and protein, and contamination from mycotoxins, pesticide residues, insect fragments, or rodent and bird excrement, and dead bodies, can all result in a loss of quality. Food loss occurs when this quality decline renders food unfit for human consumption and is discarded. Utilizing emerging technologies to optimize and eradicate risks across processing techniques is the primary objective of post-harvest operations. Following harvest, fresh food undergoes a series of biochemical changes that result in color, smell, unique scents, a reduction in acidity, and softer tissue (El-Ramady et al., 2015; Salveit, 2005).

Mechanical, physiological, pathological, or environmental factors are the primary causes of postharvest loss in fruits and vegetables (Yahaya, 2005). Mechanical damage occurs when fruits and vegetables are handled carelessly during harvest, packing, shipping, storage, etc. Certain insects and birds can also mechanically harm fruits and vegetables (Alao, 2000; Hayatu, 2000; Yahaya, 2005). Bruising and cracking are examples of mechanical damage to fruits and vegetables that often increases their susceptibility to organism assault and speeds up gas exchange and water loss. Such products deteriorate more rapidly as they age normally (Alao, 2000; Yahaya, 2005). Processing techniques including spilling, abrasion, excessive polishing, peeling, and cutting enhance the amount of commodity lost. Perforations in the containers and defective seals can also result in mechanical damage (Yahaya, 2005). Environmental factors like 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 microorganisms that flourish at high temperatures and relative

humidity cause significant harm to the crop. Additionally, fruits and vegetables breathe more quickly in hot weather, which accelerates the breakdown of internal tissues.

2.4 Strategies to Lower Fruit Waste and Postharvest Losses

Yadav et al., (2023) studied fruits and vegetables to develop normally and have a longer shelf life, a good cultural operation is necessary. Although a consistent supply of potassium fertilizers improves the quality of fruit and vegetable storage, fruits and vegetables usually undergo faster tissue degeneration when nitrogenous fertilizers are administered heavily.

According to Shimshoni et al., (2019), natural produce is preserved by chemical treatments using synthetic or natural pesticides, which are very effective methods of stopping microbial activity and minimize 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 because of many health and environmental issues regarding the possibility of dangerous food contamination from preharvest pesticide application, as demonstrated for cherry tomatoes (Fallik and Ziy, 2021).

2.5 Chitosan coating's impact on fruits

Chitosan's commercial uses in the food, chemical, and medicinal sectors have drawn more attention recently. Because of its many unique biological activities and functional qualities, chitosan is widely used in the food business. Chitosan's antibacterial action and film-forming qualities make it a promising natural food preservative or coating material (Meyers et al., 2007).

According to Alvarez et al. (2013), it has the ability to form a semipermeable barrier that regulates gas exchange and minimizes water loss, preserving tissue stiffness and lowering microbial deterioration of harvested fruit and vegetables. In their 2001 study, Jiang and Li examined how chitosan coating could prolong the postharvest life of Logan fruits while also preserving their quality. According to their research, applying chitosan coating decreased weight loss and respiration rate, postponed the rise in PPO activity, and partially prevented fruit deterioration while being stored.

Additionally, the positive effects of chitosan on fruit quality and postharvest life were amplified by increasing the concentration of chitosan covering. The use of chitosan

coating slowed down the loss of eating quality linked to higher levels of fresh-cut CWC's total soluble solids, titratable acidity, and ascorbic acid. It also delayed discoloration sited to reduced activities of PAL, PPO, and POD as well as lower total phenolic content. Comparing the fresh-cut CWC-treated chitosan covering to the control, disease growth was likewise prevented. The positive benefits were significantly increased by raising the chitosan coating concentration (Pen and Jiang, 2003).

According to Dong et al. (2004), the application of chitosan coating effectively saved quality characteristics and extend the shelf life of the peeled litchi fruits. It also delayed weight loss and the decline in sensory quality, with higher contents of total soluble solids, titratable acid, and ascorbic acid. It also suppressed the increase in PPO and POD activities. The application of chitosan coating reduced eating quality, decreased concentrations of total soluble solids and titratable acidity, and partially slowed decay. It also postponed changes in the colour index, anthocyanin content, and PPO activity.

Furthermore, when litchi fruits were taken out of cold storage, chitosan coating treatment may have extended their shelf life at room temperature (Jiang et al., 2005). According to Munoz et al. (2008), the chitosan coating in strawberry fruits decreased respiration activity, which postponed ripening and the advancement of senescence-induced fruit deterioration. According to Chien et al. (2013), the sliced papayas' lightness may be preserved by a chitosan covering. The papaya slices' chitosan coating successfully stopped water loss and stopped microbes from growing. The findings show that covering the sliced papayas with chitosan successfully preserved their qualitative characteristics and increased their shelf life.

2.5.1 Loss of weight

Fruit weight loss is mostly caused by respiration and epidermal moisture loss. Strawberries' thin skin makes them vulnerable to quick water loss, which leads to shrivelment and degradation. Among other things, the water pressure differential between the fruit tissue and the atmosphere, as well as the storage temperature, affect the rate of water loss (Nguyen et al., 2020). Low temperatures and little variation in vapor pressure between the fruit and its environment are ideal for storing strawberries (Qamar et al., 2018).

Dehydration will cause an increase in fruit with damaged surfaces. In order to prevent 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 CaCl₂, lost weight while being stored at 10°C and 70% relative humidity (Petriccione et al., 2015). Weight loss occurred in every sample during storage.

Fruits that lose more than 50% of their weight are no longer marketable, according to Abbott (1999). At the end of the storage period, the weight loss % of passion fruit coated with chitosan alone was moderately controlled. The fresh weight of the passion fruit was better preserved by the chitosan coating, which served as a barrier against desiccation. Chitosan coatings act as a semi-permeable barrier against oxygen, carbon dioxide, and moisture, lowering respiration, water loss, and reactive oxygen species (ROS) (Riva et al., 2020; Duan et al., 2011).

As a result, every coating provided a robust water vapor barrier, except the pure chitosan coating, which saw less weight loss than the untreated samples. Bergamot oil was added to both matrices and enhanced this feature, as may be expected given its hydrophobic qualities. According to previous studies, chitosan films exhibited higher water vapor permeability (WVP) than HPMC films (Vargas et al., 2008). In both instances, adding an essential oil resulted in a significant decrease in this property (Sanchez-Gonzalez et al., 2011). These results are consistent with the WVP values of the isolated films reported in those studies. Chitosan coatings have shown effective in lowering water loss from a variety of items, including papaya, cucumber, pepper, and Longan fruit, in addition to strawberries and grapefruits (Li and Jiang, 2001).

The removal of natural wax from the fruit's surface, particularly after washing, may be the reason for the increased weight loss of uncoated fruit. This causes more lenticels to open than coated fruit, which raises the respiration rate (Magwaza et al., 2013). This is consistent with research showing that, when compared to control fruit, the weight loss % of passion fruit was caused by the efficacy of the applied chitosan coating alone and chitosan enhanced with various medicinal plants. Medeiros et al. (2021) revealed similar findings, finding that when applied to *Spondias tuberosa*, edible coatings of *Chlorella sp.* containing pomegranate seed oil exhibited the least amount of weight loss (8.97%–10.42%) in comparison to the control group (11.56%).

Lipids and surfactants are added to improve the coating's moisture retention, but they also detract from the fruit's sensory appeal. Studies on mango and banana (Kittur et al.,

2001) and strawberries (Ribeiro et al., 2007) have shown that chitosan is more effective than starch and cellulose derivatives at preventing weight loss. Weight loss appears to be the primary factor influencing fruit quality and shelf life. Chitosan coatings significantly reduced the fruits' weight loss during storage as compared to the control. The least degree of weight reduction was observed in the chitosan treatments that decreased weight by 1.5% and 2.0%. The chitosan-coated fruits may have a lower rate of moisture loss because of the additional barrier that prevents diffusion through stomata (Paull and Chen, 1989).

2.5.2 Color of fruit

The synthesis and breakdown of carotenoids and phenolic pigments like anthocyanins, as well as the breakdown of chlorophyll, can all contribute to changes in fruit color (Lancaster and colleagues, 1997). Apples' development of red color has been linked to a decrease in chlorophyll that reveals anthocyanins (Marsh and colleagues, 1996). Nutrition that contains potassium and nitrogen can also alter color. Fruit's ability to retain its green hue has been directly linked to nitrogen (Crisosto and others, 1997). Improved Hunter "a," "b," and chroma values for fruit puree can be obtained via increased nitrogen fertilization of peaches (Olienik and colleagues, 1997). Papaya fruit treated with chitosan showed slight changes in peel color, 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 color 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 color 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 Vitamin C, pH, Titrable Acidity, and Total Soluble Solid

Kittur et al (2001) reported that fruit weight loss, titratable acidity, and carbon dioxide evolution were all decreased by applying coatings based on chitosan and other polysaccharides. Additionally, compared to the untreated fruit, the coated fruit had lower levels of reduced sugar and total soluble solids, indicating that the slower metabolism of the coated fruit led to a slower rate of reducing sugar synthesis. In a similar vein, chitosan increased total soluble solids and decreased titratable acidity

while reducing respiration in bananas by 32% when applied either alone or in conjunction with 1-methylcyclopropene (Baez-Saudo et al., 2009).

The fruits treated with the various treatments did not change substantially in terms of pH or titratable acidity contents. As the tomatoes became older, their titratable acidity dropped, and coating treatment had no discernible impact ($p>0.05$). According to a study by Raffo et al. (2002), the acidity of fruit increased with a high percentage of sugar content and reduced with maturation. The rise in pH indicates that the majority of the hydrogen ions in tomatoes are provided by organic acids, which typically decrease as tomatoes ripen, raising pH. Cultivar, cultural techniques, cultivation region, and season can all have an impact on physicochemical parameters such as pH, titratable acidity, and total soluble solids (Suarez et al., 2008).

Chitosan treatment delayed changes in eating quality, respiration rate, and weight loss while increasing the total soluble solid and titratable acidity of preserved longan (Jiang and Li, 2001) and guava (Hong et al., 2012) fruit. Chitosan delayed the increase in total soluble solids during storage of mango fruit and considerably avoided the decline in respiration rate, fruit weight, and titratable acidity (Jitareerat et al., 2007). Mango fruit coated with chitosan and hydrothermally treated lost less weight, had a higher acidity, a lower pH, and soluble solids regardless of the hydrothermal process (Salvador-Figueroa et al., 2011).

The internal CO₂ concentration of papaya treated with chitosan was significantly higher than that of untreated fruit. The fruit's ripening process was slowed by the formation of a chitosan film that blocked O₂ intake and reduced respiration rates, and metabolic activity (Hewajulige et al., 2009). Once more, chitosan provided effective papaya weight loss control and postponed changes in the concentrations of soluble solids over a 5-week storage period. Although it happened more slowly in the chitosan-coated papaya fruit than in the untreated fruit, the titratable acidity of the fruit dropped over the course of storage (Bautista-Baos et al., 2003).

Al Eryani et al (2008) demonstrated by the fruit's lack of weight loss, delay in the drop in titratable acidity, and increase in soluble solids and pH, chitosan coating dramatically inhibited papaya's capacity to ripen, whether or not calcium infiltration was present.

When litchi fruit was treated with chitosan, it developed an effective covering that

reduced transpiration and respiration, as well as titratable acidity and total soluble solids concentrations (Lin et al., 2011). Combining chitosan and ascorbic acid produced similar results, significantly increasing the titratable acidity and total soluble solids of preserved litchi fruit (Sun et al., 2010).

2.5.4 Disease incidence

According to Hasan et al. (2004), using a fungicide (Prochloraz 250 ppm) and treating banana fruit with hot water greatly decreased the severity of the disease. The latter treatment also decreased incidence. On the other hand, the fungicide-treated and edible-coated fruits displayed surprisingly minimal disease-covered areas (<3.4%). The Plano fix (NAA) was the most successful both before and after vaccination, according to Gupta and Pathak (1990). All diseases are prevented by aerated steam. Although hot water treatment was also quite efficient, ailments were not entirely controlled by it.

2.6 Conclusions

Studying the above reviews, it is clear that the postharvest treatments of chitosan has positive role in the maintenance of postharvest physico-chemical properties. It is also clear that the postharvest treatments are very effective in extending the shelf life of jujube. But very little research has been performed in Bangladesh and rare practical application of such treatment in food conservation is noticed. Inspiring from the above reviews the present study has attempted to investigate the effectiveness of chitosan coating in maintaining the physico-chemical properties of jujube during the postharvest period and also prolongation the shelf life of jujube. Chitosan's film-forming abilities, antibacterial qualities, and ability to induce plant resistance seem to be the key contributors to its success.

CHAPTER III

3 MATERIALS AND METHODS

An experiment was conducted to determine the effect of chitosan coating on the physico-chemical quality of jujube fruit varieties from December 2022 to March 2023. Five jujube fruit varieties—Ball Sundori Kul, Apple Kul, Kashmiri Kul, Thai, and Narkeli Kul—were used in this study. The jujube fruits were collected from the Satkhira district of Bangladesh. To improve the postharvest management technology of jujube fruits relevant to Bangladesh, the collected fruits were taken to the Molecular Horticulture Laboratory, Agrotechnology Discipline, Khulna University, Khulna, to evaluate the impact of chitosan coating on postharvest quality and shelf life of jujube fruits at ambient conditions.

3.1 Design of the experiment

A completely randomized design (CRD) with three replications was used to set up the two-factor experiment. After collecting the fruits, they were stored at room temperature to examine their physico-chemical properties.

3.2 Experimental treatments

Factor A: Five varieties of jujube fruits that are fully ripen Ball Sundori Kul, Apple Kul, Kashmiri Kul, Thai Kul, and Narkeli Kul. Factor B is the four concentrations of chitosan solution: T_1 was uncoated fruits, T_2 was 0.1%, T_3 was 0.3%, and T_4 was 0.5%.

3.2.1 Chitosan solution preparation for experimental treatments

The chitosan stock solution was made by weighing 5 g of synthesized chitosan with an electric balance, then thoroughly mixing it with 250 ml of vinegar and 250 ml of distilled water to reach a volume of 500 ml. The solution was then used to make chitosan solutions at concentrations of 0.1%, 0.3%, and 0.5% to apply to the fruits being studied. As a control, untreated fruits were kept. In the study, the chosen jujube fruits were allocated at random to the postharvest treatments randomly. Using a hand sprayer, the prepared chitosan solutions were administered to the fruits in accordance with the instructions. Then, the fruits were stored at room temperature on a newspaper that had been laid out on the lab table.

3.2.2 Jujube fruit preparation for the experiment

After being cleaned with tap water to get rid of any dirt or dust, fresh, fully ripe, uniformly proportioned, and disease-free jujube fruits were allowed to dry at room temperature. Ball Sundori Kul, Apple, Kashmiri Kul, Thai, and Narkeli Kul fruits were separated into four sections for the application of four different chitosan coating treatments: T_1 = control, T_2 = 0.1%, T_3 = 0.3%, and T_4 = 0.5%. All of the samples were treated with chitosan coating by immersing the fruits for ten minutes and stored them at room temperature. Three-day intervals were used to record the data on the selected parameters. Data collection lasted for eight days following the jujube fruits' treatment. The gathered information was documented in writing and stored on the computer as Excel files for later analysis.

3.3 Parameters studied

The following methods were used to investigate the physicochemical characteristics and shelf life of jujube fruits.

3.3.1 Physical characteristics

3.3.1.1 Estimating jujube fruit weight loss

The jujube fruit was chosen at random from each treatment to weigh it every three days after storage. The weight difference was then compared to the fresh weight on the first day. The weight was measured using an electric balance, and the result was reported as percentage. The weight reduction was evaluated using the formula (Ahmad et al., 2013).

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

M_0 = is the fresh weight of jujube fruit on the first day, and M_1 = is the measured weight at different DAS (three-days intervals).

3.3.1.2 Fruit Size Determination

The fruit size was measured with a slide caliper and calculated by estimating the fruits' length and width. Centimeters (cm) were used to measure these parameters' values.

3.3.1.3 Surface color determination

Using a chromameter (CR-400, Konica Minolta, Japan), the surface color of two sides of jujube fruit was measured on the equatorial zone using the Commission International de l'Eclairage (CIE) LAB color parameters. 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: $h^\circ = \tan^{-1} b^*/a^*$. Chroma (C*) was defined as the intensity of colour saturation from dull to a vivid colour (low-to-high values, respectively) and was calculated as: $C^* = (a^{*2} + b^{*2})^{1/2}$. Hue angle and chroma value were calculated following the formula mentioned earlier by McGuire (1992).

3.3.2 Determination of Vitamin C

The traditional method for titrating vitamin C was to use a dye solution of 2, 6-dichlorophenol indophenols. In an acidic solution, this dye turns red, and in an alkaline solution, it turns blue. The dye becomes colorless when ascorbic acid is added. For ascorbic acid at pH 1.0–3.5, the reaction is both quantitative and selective.

Methodology:

1. After the fruits were ground to obtain their juice, 30 ml of juice was collected.
2. The juice was divided into three sections, with 10 milliliters of juice in each section.
3. A solution of 2, 6-dichlorophenol indophenol was used to titrate it.
4. A standard ascorbic acid solution (0.01%) and 5 ml of metaphosphoric acid were used.

The method for calculating vitamin C

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

In this case,

a = Weight of sample

b = Volume made with metaphosphoric acid

c = Volume of aliquot taken for estimation

d = Dye factor

e = Average burette reading for sample

3.3.2.1 Determination of TSS

A refractometer (REF 105) was used to assess the fruit pulp's total soluble solids (TSS) concentration, which was known as the degree of Brix. Then, it aids in figuring out how

much sugar is in the goods. A drop of fruit pulp juice is maintained on the refractometer's prism. The instrument's direct reading was used to determine the percentage of TSS.

3.3.2.2 Determination of Tritable Acidity (TA)

Both organic and inorganic acids can be found in fruits. Fruits contain only one inorganic acid, phosphoric acid. Together with sugars, these acids play a crucial role in determining the quality and flavor of fruits. Many fruits' level of acids, sugars, or soluble solids is another indicator of how mature they are for harvest. As recommended by Sugri (2013), TA was computed using the following formula.

Malic acid (%) is equal to $0.0067 \times 30 \times 100 \times$

the volume of NaOH. $5 \times 10/5 \times 10$

where, 0.0067 = The malic acid Milli-equivalent weight.

30 = Volume Total (ml)

5 = Sample of extract juice (ml)

10 = Aliquot volume (ml)

Titrateable acidity was determined using the following reagents. a. 0.1N standard NaOH solution b. A solution of phenolphthalein (about 0.5% in 80% ethanol, W/V).

Equipment:

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

Method:

1. A 10-gram sample of fruit was collected. Using pure water, this was extracted after being completely crushed in a blender. Following the filtering of the extract, 100 milliliters of distilled water were added to the filtrate.
2. To dilute 10 ml of fruit juice, 20 ml of distilled water was added. Thirty milliliters were the final volume.
3. A conical flask was filled with 5 ml of an aliquot from a 30 ml diluted solution. Only one or two drops of phenolphthalein solution were added to this aliquot, and it was shaken well.

4. Following washing and rinsing, the sodium hydroxide solution was put into a burette and titrated.
5. The pink color's arrival and persistence for at least 10 to 15 seconds served as the end point of the titration.

3.3.2.3 Calculating pH

A desktop pH meter was used to measure the fruit's pH at room temperature ($28 \pm 2^\circ\text{C}$). In a beaker, 5 g of the sample was combined with 10 mL of distilled water to prepare juice. The pH of the sample was then determined by dipping the pH meter into the beaker.

3.3.2.4 Determination of Anthocyanin

Ethanoic hydrochloride is used to extract anthocyanin, and calorimetric measurement is used to determine how intense the color is. The amount of pigment present is ascertained from the reading.

Reagents:

- a) 95% ethanol
- b) 1.5 N of hydrochloric acid (HCl)
- c) To make the ethanol-hydrochloric acid mixture, mix 15 parts Regent B by volume with 85 parts Reagent A.

Procedure:

1. A tissue sample of a known weight was obtained. Reagent C, a combination of ethanol and hydrochloric acid, is used to extract this. It is left to stand at roughly 4°C for the entire night.
2. The mixture is filtered via filter paper (Whatman No. 1) following extraction. To recover as much pigment as possible, the extraction process was repeated.
3. The solvent was then added to the extract to any volume.
4. From the extract above, a known volume of aliquot was taken. Fine (mille pore) filter paper was used to filter it.
5. The filtered aliquot was kept in the dark for around two hours while the container was covered.

6. The solvent was then added to this at a specified volume (for colour measurement). A colorimeter was then used to measure the solution's optical density (O.D.) value at a wavelength of 535 nm in comparison to a blank.

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

Where,

a=Weight of sample

b=Volume of made for color measurement

c=Total volume made

d=Volume of aliquot taken for estimation

e=Volume for 535 nm

3.3.2.5 Determination of Flavonoid

Reagent:

A. 80% methanol

Methodology:

1. A 5g fruit pulp was obtained and ground into a fine powder.
2. It was put in a water bath at 40 degrees Celsius for 10 hours after adding 50 milliliters of 80% methanol.
3. A 125mm filter paper was used to filter the entire solution.
4. After that, the filtrate is moved to a crucible and allowed to dry out at room temperature over a water bath.
5. Determined the ultimate flavonoid weight

3.3.3 Microbiological characteristics

3.3.3.1 Fruit Disease Incidence

Disease incidence is the proportion of jujube that has the disease. Visible signs and black spots were regarded as illnesses. Jujube was numbered to estimate the percentage of fruit disease-infected, and this estimation was made using eye estimation. The incidence is then determined using the formula: Disease incidence = Number of infected jujube/Total number of jujube X100 (Ullah, 2007).

3.4 Shelf Life

The shelf life was determined by recording the number of days for which the fruits remained in good condition. In this regard, the considerations were made as the days to record at least 20% fruits as infected and the days required for disease incidence. The number of days for attaining a loss of 20% weight was also considered to calculate shelf life (Tabassum et al., 2018).

These parameters were judged visually from a consumer perspective as marketable or unmarketable and the shelf life was estimated at the last point of consumer acceptance.

3.5 Analysis of Statistics

The statistical program Statistix-10 was used to do a two-way analysis of variance (ANOVA) to analyze the data, and Duncan's New Multiple Range Test (DMRT) was used to compare the means (Gomez and Gomez, 1989).

CHAPTER IV

4 RESULTS AND DISCUSSION

The following headings and subheadings present and examine the effects of chitosan coating on the physio-chemical characteristics of jujube fruit cultivars and their shelf life:

4.1 Physiological characteristics

4.1.1 Weight loss

The physiological loss in weight of the fruit increased significantly during the storage period (Table 1).

From the study it was found that the uncoated Narkeli Kul lost maximum physiological weight (32.91%), followed by uncoated Thai Kul (30.83%). On the other hand, the treatment of 0.5% chitosan coating displayed superior results, with minimum weight loss in Ball Sundori Kul (14.33%), followed by the Kashmiri Kul treated with 0.3% chitosan (15.75%) and the Kashmiri Kul treated with 0.5% chitosan (16.67%).

Chitosan coatings play as a semi-permeable barrier against the flow of oxygen, carbon dioxide, moisture, and solutes likely contributed to the decrease in weight loss by lowering respiration, water loss, and oxidation reaction rates (Baldwin et al. 1999).

The findings of the present study suggest that the 0.5% chitosan coating lowered down the rate of respiration irrespective of the cultivar of the jujube fruit resulting the minimum loss of water and reduced rate of oxidation reactions. According to Shao et al. (2012), chitosan coating reduces the respiration rate of fruit as apple and thereby minimize the weight loss. Dang et al. (2010) also found that delicious cherries coated with chitosan could successfully delay water loss of fruit.

Table 4.1. The interaction effect of variety and chitosan coating on weight loss of jujube fruit on different days after storage (DAS)

Treatment Combination	Weight loss (%)		
	3DAS	6DAS	9DAS
V ₁ T ₁	11.75bcd	15.41efg	19.0hij
V ₁ T ₂	11.50bcde	14.33efg	16.83ijk
V ₁ T ₃	8.0ef	12.29ghh	15.75jkl
V ₁ T ₄	7.41f	9.58h	14.33k
V ₂ T ₁	12.41bc	17.29def	23.33efg
V ₂ T ₂	14.58b	21.0cd	27.50bcd
V ₂ T ₃	10.41cdef	17.08def	20.41ghi
V ₂ T ₄	8.58def	13.20fgh	21.16fgh
V ₃ T ₁	14.25b	21.08cd	24.58def
V ₃ T ₂	12.16bcd	18.12de	22.91efgh
V ₃ T ₃	9.91cdef	15.87efg	20.41ghi
V ₃ T ₄	8.58def	12.20gh	16.67ijk
V ₄ T ₁	21.0a	28.41a	30.83ab
V ₄ T ₂	12.41bc	18.37de	23.75defg
V ₄ T ₃	22.5a	26.08ab	29.18abc
V ₄ T ₄	20.41a	22.83bc	26.75cde
V ₅ T ₁	23.0a	27.91a	32.91a
V ₅ T ₂	12.0bcd	17.54de	23.33efg
V ₅ T ₃	12.23bc	18.16de	26.33cde
V ₅ T ₄	20.83a	24.87abc	29.16abc
Level of significance	**	**	**
CV (%)	15.97	13.94	10.30

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance, respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.1.2 Size (length and breadth)

There were significant interaction effects of jujube varieties and chitosan coating in regard to the length (Table 2) and breadth (Table 3) of fruits gradually decreasing.

During this study it was recorded that Ball Sundori Kul was the largest fruit (52.57 cm) and coated with 0.5% chitosan solution and uncoated Thai Kul was smaller (30.29 cm) than other cultivars, followed by uncoated Apple Kul (31.70 cm) and Apple Kul (31.74 cm) with 0.3% chitosan solution (Table 2).

Ball Sundori Kul was the widest cultivar (40.99 cm) and coated with 0.5% chitosan solution, followed by the Kashmiri Kul coated with 0.5% chitosan (40.29 cm), and the Ball Sundori Kul coated with 0.3% chitosan (40.11 cm). The uncoated Thai Kul was less wide than others (25.14 cm), which was statistically similar to the uncoated Apple Kul (26.73 cm) and the uncoated Kashmiri Kul (26.21 cm) (Table 3).

According to the study mentioned above, the Ball Sundori Kul variety of jujube was the largest and broadest fruit, and the effect of a 0.5% chitosan concentration was carried out at the best level of treatments. It may be due to the coating's anti-senescent properties inhibiting ethylene biosynthesis and delaying the activity of ripening enzymes and senescence, preventing cell degradation and decreased the shrinkage percentage (Sudha et al. 2007). According to similar findings of Ibrahim et al. (2019) and Alwea (2018), grape vines and mango fruits treated with chitosan showed noticeably longer fruits.

According to Shokrollahfam et al. (2012), increased enzyme activity that broke down the cell wall structure caused tissue metabolism to rise and tissue and cellular strength to fall, which was the main contributor to shrinking the diameter of fruit during storage. Normal metabolic activity, transpiration, and respiration tend to soften or reduce the firmness of fruit tissue, which decreases during storage (Fischer, Benet, 1991; Prasana et al., 2007)

Table 4.2. The interaction effect of variety and chitosan coating on the length of jujube fruit on different days after storage (DAS)

Treatment Combination	Length (cm)		
	3DAS	6DAS	9DAS
V ₁ T ₁	39.15ef	38.82ef	37.26f
V ₁ T ₂	41.60bcdef	40.74cdef	38.89def
V ₁ T ₃	55.32a	53.60a	51.78ab
V ₁ T ₄	55.74a	53.73a	52.57a
V ₂ T ₁	34.41gh	33.66hi	31.70gh
V ₂ T ₂	35.67g	35.44gh	37.95g
V ₂ T ₃	34.39gh	33.60hi	31.74g
V ₂ T ₄	53.00a	51.13a	49.10b
V ₃ T ₁	43.38bcd	42.25bcd	40.61cde
V ₃ T ₂	43.42bc	42.72bc	41.60cd
V ₃ T ₃	42.04bcde	41.02cde	39.48cdef
V ₃ T ₄	54.29a	52.40a	50.79ab
V ₄ T ₁	32.40h	31.74i	30.29gh
V ₄ T ₂	41.39cdef	40.17cdef	38.73ef
V ₄ T ₃	41.73bcdef	40.57cdef	39.43cdef
V ₄ T ₄	44.61b	44.09b	41.95c
V ₅ T ₁	38.81f	38.00fg	36.72f
V ₅ T ₂	40.79cdef	39.47def	37.49f
V ₅ T ₃	40.39def	40.48cdef	38.44ef
V ₅ T ₄	32.02bcde	40.48cdef	38.82def
Level of significance	**	**	**
CV (%)	4.28	4.16	4.33

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%. In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

Table 4.3. The interaction effect of variety and chitosan coating on the breadth of jujube fruit on different days after storage (DAS).

Treatment Combination	Breadth (cm)		
	3DAS	6DAS	9DAS
V ₁ T ₁	33.33e	31.78g	30.40hi
V ₁ T ₂	36.93bcd	34.26efg	32.53fgh
V ₁ T ₃	41.93bc	41.51a	40.11a
V ₁ T ₄	42.11a	41.53a	40.99a
V ₂ T ₁	28.89f	27.84i	26.73j
V ₂ T ₂	29.37f	29.02hi	27.60ij
V ₂ T ₃	39.03ab	38.41bc	37.26bc
V ₂ T ₄	39.88ab	39.70ab	38.63ab
V ₃ T ₁	28.55f	27.60i	26.21j
V ₃ T ₂	39.06ab	38.34bcd	36.92bcd
V ₃ T ₃	38.22b	36.93cde	35.66cde
V ₃ T ₄	41.96a	41.30a	40.29a
V ₄ T ₁	27.02f	26.28i	25.14j
V ₄ T ₂	34.64cde	33.35fg	31.75fgh
V ₄ T ₃	33.22e	31.54gh	30.52h
V ₄ T ₄	33.55e	31.92g	30.91gh
V ₅ T ₁	37.97bc	35.65def	34.19def
V ₅ T ₂	34.45de	34.71ef	33.53efg
V ₅ T ₃	37.07bcd	34.19efg	33.00efgh
V ₅ T ₄	37.32bcd	35.83cdef	34.50cdef
Level of significance	**	**	**
CV (%)	5.66	4.80	5.14

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column

4.1.3 Fruit color change

Treatments with chitosan affected the chromaticity color coordinates, such as L* in jujube. At every DAS, this color feature was significantly distinct (Table 4). From the beginning of the experiment to the end of the storage life, the L-value shows a progressive increase in brightness. At 9 DAS, it rose. The Ball Sundori Kul treated with

0.5% chitosan recorded the highest L^* value (53.22), whereas the uncoated Thai Kul had the lowest value (36.18) (Table 4.4).

Greenness is indicated by a negative a^* -value, while redness is indicated by a positive a^* value. Fruit loses its greenness when the negative value gradually drops while being stored. Regardless of treatment, the negative a^* value dropped from the harvest date to the end of their storage life. The color attributes a^* was noteworthy; at 9 DAS, the Thai Kul coated with 0.3% chitosan recorded the highest value of a^* (-1.47), while the uncoated Apple Kul found the lowest value (-6.0). For the storage period, the value of a^* rose. In the majority of instances, the additional color coordinates (b^* , C^* , and h) varied (Table 5).

Yellowness is indicated by a positive b^* value, which rose from the day of harvest until the end of their storage life. Significantly, the color attribute b^* grew throughout their storage. The Ball Sundori Kul treated with 0.3% chitosan recorded the highest b^* value (18.41) at 9DAS, whereas the uncoated Narkeli Kul was the lowest b^* value (10.49). (Table 4.6)

Throughout storage, chitosan treatments typically increased to L^* , a^* , and b^* and a decrease in c^* and h^* , suggesting that chitosan may postpone the jujube fruit's color development process. Ball Sundori Kul coated with 0.3% chitosan had the highest estimated c^* value at 9 DAS (17.17), while uncoated Narkeli Kul had the lowest (6.43).

On the final day storage, the uncoated Thai Kul obtained the lowest hue angle (96.39), while the Ball Sundori Kul with 0.1% chitosan recorded the highest hue angle (127.98) (Table 4.7).

Purwoko et al., (2002) and Petriccione et al., (2015) reported that chitosan coating delayed the decrease in L^* of bananas and strawberries which supports the present study's findings. Similar to that of jujube evaluation Ngo et al. (2021) reported a greater negative value of a^* in fruits coated with Nano chitosan. According to the present study, fruits covered with Nano chitosan also maintained their maximal color, b^* . It also revealed comparable findings, which may be the consequence of variations in the fruits or storage conditions, even though the C^* value of the fruit dropped and the color angle rose in strawberries kept in cold storage (Koyuncu, 2004).

Table 4.4. The interaction effect of variety and chitosan coating on the Color L value of jujube fruit on different days after storage (DAS).

Treatment Combination	Color L		
	3DAS	6DAS	9DAS
V ₁ T ₁	27.93cd	38.34cd	40.27ghi
V ₁ T ₂	30.38c	38.44cd	45.09cdef
V ₁ T ₃	36.34b	49.73a	49.37ab
V ₁ T ₄	42.62a	51.69a	53.22a
V ₂ T ₁	36.98b	38.28cd	44.71cdef
V ₂ T ₂	27.99cd	43.85bc	44.33defg
V ₂ T ₃	21.52g	31.19ef	40.38gh
V ₂ T ₄	21.64g	31.95e	48.36bcd
V ₃ T ₁	22.28fg	40.50c	44.43cdefg
V ₃ T ₂	25.33def	47.31ab	46.63bcde
V ₃ T ₃	23.48efg	47.71ab	42.68efg
V ₃ T ₄	20.54g	47.81ab	48.58bc
V ₄ T ₁	20.08g	22.52g	36.18i
V ₄ T ₂	27.24cd	40.82c	41.25fg
V ₄ T ₃	26.45de	42.35bc	42.02fg
V ₄ T ₄	25.98de	47.37ab	36.59hi
V ₅ T ₁	21.05g	25.52fg	43.75efg
V ₅ T ₂	28.17cd	34.05de	44.32defg
V ₅ T ₃	27.83cd	30.03ef	44.37defg
V ₅ T ₄	30.58c	34.34de	44.81cdef
Level of significance	**	**	*
CV (%)	8.93	5.71	6.42

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column

Table 4.5. The interaction effect of variety and chitosan coating on the color a* of jujube fruit on different days after storage (DAS).

Treatment Combination	Color a		
	3DAS	6DAS	9DAS
V ₁ T ₁	-5.8i	-4.3bcd	-4.2defg
V ₁ T ₂	-5.5hi	-5.1defg	-5.3efg
V ₁ T ₃	-4.5c-i	-4.8cdef	-5.6fg
V ₁ T ₄	-5.3ghi	-3.3b	-3.5bcde
V ₂ T ₁	-1.8a	-4.2bcd	-6.0g
V ₂ T ₂	3.7b-f	-5.0defg	-3.5bcde
V ₂ T ₃	-3.32bcd	-1.7a	-3.7bcde
V ₂ T ₄	-3.3bc	-5.9gh	-3.3bcd
V ₃ T ₁	-5.8i	-5.6fgh	-2.5abcd
V ₃ T ₂	-4.7d-i	-3.6b	-2.0ab
V ₃ T ₃	-3.2bc	-3.6b	-2.4abcd
V ₃ T ₄	-2.6ab	-6.3h	-3.5bcde
V ₄ T ₁	-4.8fghi	-4.9defg	-3.9cdef
V ₄ T ₂	-3.2bc	-4.2bcde	-5.2efg
V ₄ T ₃	-3.5bcde	-3.8bc	-1.4a
V ₄ T ₄	-2.6ab	-5.2efgh	-2.6abcd
V ₅ T ₁	-4.9fghi	-5.0defg	-3.0abcd
V ₅ T ₂	-4.3c-h	-4.2bcd	-2.6abcd
V ₅ T ₃	-4.0c-g	-5.2defg	-3.1abcd
V ₅ T ₄	-4.1c-g	-4.3bcde	-2.2abc
Level of significance	*	**	*
CV (%)	-19.95	-14.70	-32.04

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

Table 4.6. The interaction effect of variety and chitosan coating on the color b* of jujube fruit on different days after storage (DAS)

Treatment Combination	Color b		
	3DAS	6DAS	9DAS
V ₁ T ₁	5.99gh	14.16de	12.72ghi
V ₁ T ₂	6.83fgh	12.83efg	12.97fghi
V ₁ T ₃	16.22a	19.92a	18.41a
V ₁ T ₄	16.11a	19.74a	17.67ab
V ₂ T ₁	5.51h	11.24fgh	15.03cde
V ₂ T ₂	9.49cd	12.92efg	15.74bcde
V ₂ T ₃	10.76c	6.56jk	15.21cd
V ₂ T ₄	12.55b	17.15bc	14.80cdef
V ₃ T ₁	6.86fgh	14.51de	14.3efgh
V ₃ T ₂	8.38def	14.55de	16.96abc
V ₃ T ₃	7.56efg	15.56cd	12.89fghi
V ₃ T ₄	15.29a	18.19ab	16.87abcd
V ₄ T ₁	6.28gh	13.36def	11.49ij
V ₄ T ₂	9.57cd	12.78efg	14.23efgh
V ₄ T ₃	9.3cd	12.59efg	12.22hij
V ₄ T ₄	9.24cd	12.18efgh	16.62abcd
V ₅ T ₁	5.67h	5.26k	10.49j
V ₅ T ₂	8.87de	10.12hi	14.70defg
V ₅ T ₃	6.56gh	8.49ij	16.11bcde
V ₅ T ₄	9.45cd	10.85ghi	16.59abcd
Level of significance	**	**	**
CV (%)	10.45	10.98	8.93

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

Table 4.7. The interaction effect of variety and chitosan coating on the color c* of jujube fruit on different days after storage (DAS)

Treatment Combination	Color c		
	3DAS	6DAS	9DAS
V ₁ T ₁	13.99fgh	14.78def	7.33ij
V ₁ T ₂	14.10fgh	13.82defg	8.67ghi
V ₁ T ₃	18.99a	20.50a	17.17a
V ₁ T ₄	18.47ab	20.03ab	16.49a
V ₂ T ₁	15.49cdef	12.36ghi	6.53j
V ₂ T ₂	15.85cdef	12.94fghi	11.27cd
V ₂ T ₃	15.59cdef	6.79k	11.36c
V ₂ T ₄	15.17defg	18.19bc	13.00b
V ₃ T ₁	15.43defg	15.56de	7.31ij
V ₃ T ₂	17.59abc	15.00def	8.64ghi
V ₃ T ₃	13.29ghi	15.98cd	7.95hij
V ₃ T ₄	17.08abcd	19.29ab	15.70a
V ₄ T ₁	12.54hi	14.32defg	7.41ij
V ₄ T ₂	14.59efgh	13.47efgh	10.93cde
V ₄ T ₃	12.73hi	13.20fghi	10.29cdef
V ₄ T ₄	16.83bcd	13.29efgh	9.62efg
V ₅ T ₁	11.61i	7.28k	6.43j
V ₅ T ₂	15.37defg	10.995ij	9.24fgh
V ₅ T ₃	16.62bcde	9.99j	7.33ij
V ₅ T ₄	17.12abcd	11.72hij	9.73defg
Level of significance	**	**	**
CV (%)	8.44	9.85	9.29

V₁ = Ball Sundori Kul, V₂ = Apple kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

Table 4.8. The interaction effect of variety and chitosan coating on the color h* of jujube fruit on different days after storage (DAS)

Treatment Combination	Color h		
	3DAS	6DAS	9DAS
V ₁ T ₁	114.65a	106.64cde	125.26ab
V ₁ T ₂	113.09ab	111.85cd	127.98a
V ₁ T ₃	103.96bcd	103.53ef	109.14abc
V ₁ T ₄	106.63abc	99.79fg	102.39cd
V ₂ T ₁	103.92bcd	114.46bc	122.10ab
V ₂ T ₂	96.74d	93.50g	122.83abc
V ₂ T ₃	102.34cd	104.59cde	108.80abc
V ₂ T ₄	102.62cd	109.52cde	105.17bcd
V ₃ T ₁	111.90abc	111.21cd	110.22abc
V ₃ T ₂	105.39abc	104.01def	103.96bcd
V ₃ T ₃	104.13bcd	103.16efg	107.88abc
V ₃ T ₄	99.05d	109.41cde	103.06cd
V ₄ T ₁	113.29ab	110.47cd	96.39d
V ₄ T ₂	102.76cd	108.54cde	118.94ab
V ₄ T ₃	105.89abc	107.26cde	122.10ab
V ₄ T ₄	99.05d	113.68bcd	106.05bcd
V ₅ T ₁	115.01a	133.53a	118.07abc
V ₅ T ₂	106.40abc	112.78bc	106.22abc
V ₅ T ₃	104.29bcd	121.77b	116.39abc
V ₅ T ₄	104.07bcd	111.90bcd	103.96bcd
Level of significance	**	**	**
CV (%)	3.03	2.91	6.28

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column

4.2 Chemical Characteristics Jujube fruit

4.2.1 Vitamin C

It was observed that the differences in Vitamin C value of jujube fruits decreased significantly during the storage period (Table 4.9).

On the last day after storage, it was found that Ball Sundori Kul treated with 0.5% chitosan obtained the maximum concentration of vitamin C (19.62 mg/100g), followed by Ball Sundori Kul treated with 0.3% chitosan (15.8 mg/100g) and Ball Sundori Kul treated with 0.1% chitosan (12.5 mg/100g). Uncoated Narkeli Kul recorded the lowest vitamin C content (5.85 mg/100g), which was statistically similar to Ball Sundori Kul treated with 0.1% chitosan (6.9 mg/100g), Kashmiri Kul treated with 0.1% chitosan (9.4 mg/100g), and Narkeli Kul treated with 0.3% chitosan (9.6 mg/100g).

Vitamin C content was higher in chitosan-treated fruits than in untreated ones. By blocking oxygen from reaching the fruits, the coating has the benefit of reducing ascorbic acid oxidation (Oluwaseun, 2013). Similar findings about ascorbic acid were reported by Gupta et al. (1987), who found that jujube fruits coated with chitosan and treated with CaCl_2 had greater ascorbic acid levels. They can retain their ascorbic acid content for a longer period since it postpones their ripening (Park, 1999).

Table 4.9. The interaction effect of variety and chitosan coating on Vitamin C of jujube fruit at different days after storage (DAS).

Treatment Combination	Vitamin C (mg/100g)		
	3DAS	6DAS	9DAS
V ₁ T ₁	8.15ef	12.8bc	12.5c
V ₁ T ₂	5.95ghi	5.85h	6.9fg
V ₁ T ₃	16.25b	13.92b	15.8b
V ₁ T ₄	23.7a	20.95a	19.62a
V ₂ T ₁	9.7de	9.68fg	11.1cd
V ₂ T ₂	12.1c	9.62fg	11.55c
V ₂ T ₃	13c	12.28bcd	11.3cd
V ₂ T ₄	9.8de	9.52fg	11.33cd
V ₃ T ₁	5.25hi	5.9h	7.8ef
V ₃ T ₂	7.8efg	10.05efg	9.4de
V ₃ T ₃	11.5cd	12.42bcd	12.4c
V ₃ T ₄	12.15c	10.88def	12c
V ₄ T ₁	4.95i	5.62h	6.75fg

V ₄ T ₂	11.6cd	13.55b	11.95c
V ₄ T ₃	5.75ghi	10.62defg	14.5b
V ₄ T ₄	7.3fgh	8.95g	11.05cd
V ₅ T ₁	5.7ghi	5.98h	5.85g
V ₅ T ₂	11.45cd	11.6cde	10.65cd
V ₅ T ₃	9.9de	10.58defg	9.6de
V ₅ T ₄	6.9fghi	11.1cdef	10.93cd
Level of significance	**	**	**
CV (%)	12.98	10.93	10.56

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.2.2 Total soluble solids (TSS)

The TSS of the fruit increased significantly during the storage period (Table 4.10).

On the 9 DAS, Ball Sundori Kul coated with 0.3% chitosan recorded the highest total soluble solids content (15.13%), which was statistically similar to Apple Kul coated with 0.5% chitosan (14.87%).

The uncoated Narkeli Kul found the lowest percentage of total soluble solids (10.40%), followed by the uncoated Apple Kul (10.97%) and the Apple Kul with 0.3% chitosan (11.00%) (Table 10).

It was revealed from the results of the study that the uncoated jujube fruits have lower TSS values than the chitosan-coated fruits. The increase in TSS contents is known to be due to the hydrolytic change in starch and the conversion of starch to sugar is an important index of the ripening process in fruits (Arthy and Philip, 2005) and also a decrease in respiration rate and conversion of sugar to carbon dioxide and H₂O at later stage of storage.

Table 4.10. The interaction effect of variety and chitosan coating on TSS content of jujube fruit on different days after storage (DAS)

Treatment Combination	TSS (% Brix)		
	3DAS	6DAS	9DAS
V ₁ T ₁	10.50defg	11.35cdef	11.97h
V ₁ T ₂	10.87cdef	11.88bcd	13.60cd
V ₁ T ₃	12.50a	13.23a	15.13a
V ₁ T ₄	12.97a	12.88ab	14.40b
V ₂ T ₁	9.93fg	10.17def	10.97j
V ₂ T ₂	10.20defg	10.15f	11.16f
V ₂ T ₃	10.90cdef	11.88bcd	11.00i
V ₂ T ₄	12.00abc	12.78ab	14.30bc
V ₃ T ₁	10.03efg	11.73bcd	13.23de
V ₃ T ₂	9.90fg	11.25cdef	12.33gh
V ₃ T ₃	11.17bcde	11.98abcd	14.33b
V ₃ T ₄	12.30ab	12.80ab	14.87ab
V ₄ T ₁	10.10defg	11.87bcd	13.37d
V ₄ T ₂	10.07efg	11.67bcde	12.50fgh
V ₄ T ₃	10.13defg	10.90def	11.00i
V ₄ T ₄	11.23bcd	12.27abc	13.00defg
V ₅ T ₁	9.53g	10.27ef	10.40j
V ₅ T ₂	10.03efg	11.68bcde	12.57efgh
V ₅ T ₃	11.03cdef	12.15abcd	13.10def
V ₅ T ₄	10.57defg	11.42cdef	12.30gh
Level of significance	*	**	**
CV (%)	6.42	6.66	3.42

V₁ = Ball Sundori Kul, V₂=Apple Kul, V₃=Kashmiri Kul, V₄=Thai Kul, V₅=Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.2.3 Titratable acidity (TA)

It is noted from (Table 4.11) that the interaction between treatment with chitosan and varieties on jujube significantly affected the percentage of total titratable acidity on different days after storage.

The untreated Thai Kul had the highest percentage of total acidity (4.00%) on the last days after storage (9DAS), followed by Kashmiri Kul treated with 0.5% chitosan (3.57%) and Apple Kul treated with 0.1% chitosan (3.53%). Ball Sundori Kul treated with 0.5% chitosan had the lowest percentage of total acidity (1.40%), followed by Thai Kul treated with 0.1% chitosan (1.60%) and Ball Sundori Kul treated with 0.5% chitosan (1.40%).

From the above results, it was observed that TA decreases in the increasing concentration of chitosan coating compared to uncoated fruits. Reducing titratable acidity is caused by the Krebs cycle, which oxidizes organic acids throughout the ripening process to create energy reserves for fruits (Kays, 1991). Similar results were reported by Bahmani *et al.* (2015), who found that the TA levels of sapodilla fruit decreased with the application of chitosan coatings.

Table 4.11. The interaction effect of variety and chitosan coating on TA of jujube fruit on different days after storage (DAS)

Treatment Combination	TA (%)		
	3DAS	6DAS	9DAS
V ₁ T ₁	5.93b	3.28de	2.26ef
V ₁ T ₂	4.27d	3.93bc	2.87cd
V ₁ T ₃	6.93a	4.75a	3.41b
V ₁ T ₄	0.90f	4.78a	1.40h
V ₂ T ₁	1.00g	2.02h	2.07efg
V ₂ T ₂	5.00cd	3.90bc	3.53ab
V ₂ T ₃	5.63bc	2.88efg	2.37de
V ₂ T ₄	3.20e	2.93ef	2.27ef
V ₃ T ₁	2.90e	3.42cde	3.09bc
V ₃ T ₂	1.17f	2.17h	2.50de
V ₃ T ₃	5.67bc	3.70cd	3.20bc
V ₃ T ₄	5.73bc	4.30ab	3.57ab
V ₄ T ₁	0.90f	1.10j	4.00a
V ₄ T ₂	0.97f	1.11j	1.60gh

V ₄ T ₃	4.70d	1.93hi	2.83cd
V ₄ T ₄	4.43d	1.30j	1.80fgh
V ₅ T ₁	1.20g	2.47fgh	3.17bc
V ₅ T ₂	1.00f	2.38gh	2.43de
V ₅ T ₃	2.80e	2.72fg	2.17ef
V ₅ T ₄	4.40d	1.42ij	2.40de
Level of significance	**	**	**
CV (%)	13.40	11.58	11.82

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.2.4 Fruit pH

The values of pH significantly increased during the storage period (Table 4.12).

The uncoated Ball Sundori Kul recorded the highest pH value (4.11), which was statistically comparable to the uncoated Thai Kul (4.10) and the lowest pH (3.31) was found in Apple Kul coated with 0.3% chitosan, followed by Ball Sundori Kul coated with 0.1% chitosan (3.33) and Ball Sundori Kul coated with 0.5% chitosan (3.41). These findings suggest that uncoated jujube fruits had a relatively higher pH rate.

The change in pH is due to the treatment's effect on the fruit's biochemical condition and a slower rate of respiration and metabolic activity. The breakdown of acids during storage through respiration could be the cause of the pH rise (Abbasi et al., 2009). The increase in pH may be due to the continuous reduction of acidity during ripening. In the current study, a rise in pH was noted throughout the storage period. This outcome is consistent with study by Pathak and Sanwal (1999), who found that soaking banana fruits in a 0.2% chitosan solution caused the pH of the fruit pulp to rise more quickly. The results of this study were similarly consistent with those of Kumar and Singh (1993), who noted that the pH of mango pulp rose while it was being stored.

Table 4.12. The interaction effect of variety and chitosan coating on the pH of jujube fruit on different days after storage (DAS)

Treatment Combination	pH		
	3DAS	6DAS	9DAS
V ₁ T ₁	3.22bc	3.35abc	4.11a
V ₁ T ₂	3.10jk	3.27i	3.33fg
V ₁ T ₃	3.73d	3.65efgh	3.68cde
V ₁ T ₄	3.92ijk	4.13hi	3.41efg
V ₂ T ₁	3.09k	3.84cdef	3.99ab
V ₂ T ₂	3.24i	3.38hi	3.54defg
V ₂ T ₃	3.23ij	3.42ghi	3.31g
V ₂ T ₄	3.34hi	3.61efgh	3.96abc
V ₃ T ₁	3.41c	3.70ab	3.90abc
V ₃ T ₂	3.48fg	3.79def	3.69cde
V ₃ T ₃	3.58ef	3.84cdef	3.79bcd
V ₃ T ₄	3.91gh	4.18defg	3.60defg
V ₄ T ₁	4.07a	4.32a	4.10a
V ₄ T ₂	3.74d	3.97bcd	3.84abcd
V ₄ T ₃	3.63de	3.91bcde	3.77bcd
V ₄ T ₄	4.05ab	4.01abcd	3.97abc
V ₅ T ₁	3.45gh	3.83cdef	3.56defg
V ₅ T ₂	3.68de	3.91bcde	3.83abcd
V ₅ T ₃	3.33hi	3.60efgh	3.65de
V ₅ T ₄	3.21ijk	3.54fghi	3.62def
Level of significance	***	*	***
CV (%)	2.31	5.09	4.90

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.2.5 Total Flavonoids

It was observed that the total flavonoid value of jujube fruits was significantly decreased during the storage period (Table 4.13).

The highest total flavonoid value (0.90 mg/100g) was recorded Ball Sundori Kul coated with 0.5% chitosan. This was followed by Ball Sundori Kul coated with 0.3% chitosan (0.86 mg/100g) and Apple Kul coated with 0.5% chitosan (0.82 mg/100g). The lowest decreasing total flavonoid value (0.41 mg/100g) was found uncoated Thai Kul fruit, preceded by Ball Sundori Kul with 0.1% chitosan (0.42 mg/100g) and untreated Narkeli Kul (0.49 mg/100g) (Table 13). The loss of total flavonoids in fruits may be caused by a greater respiration rate (Gil et al., 1998). Chitosan edible-coated fruits have a film layer that can control the temperature surrounding the fruit's surface, preventing respiration and slowing down the rapid breakdown of all the flavonoids (Riva et al., 2020; Fawole et al., 2020).

Table 4.13. The interaction effect of variety and chitosan coating on total flavonoid of jujube fruit at different days after storage (DAS)

Treatment Combination	Flavonoid (mg/100g FW)	
	3DAS	9DAS
V ₁ T ₁	0.75bcd	0.54defg
V ₁ T ₂	0.63defg	0.42fg
V ₁ T ₃	0.86ab	0.68bc
V ₁ T ₄	0.90a	0.83a
V ₂ T ₁	0.78ab	0.75ab
V ₂ T ₂	0.69cdef	0.64cd
V ₂ T ₃	0.74bcde	0.70bc
V ₂ T ₄	0.82ab	0.78ab
V ₃ T ₁	0.61efg	0.55def
V ₃ T ₂	0.57fgh	0.52defg
V ₃ T ₃	0.54gh	0.60cde
V ₃ T ₄	0.80abc	0.72abc
V ₄ T ₁	0.46h	0.41g
V ₄ T ₂	0.73bcde	0.69bc
V ₄ T ₃	0.68cdef	0.63cd
V ₄ T ₄	0.79abc	0.73abc
V ₅ T ₁	0.55gh	0.49efg

V ₅ T ₂	0.57fgh	0.52defg
V ₅ T ₃	0.57fgh	0.51defg
V ₅ T ₄	0.54gh	0.46fg
Level of significance	**	**
CV(%)	11.58	13.29

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.2.6 Anthocyanin of fruits

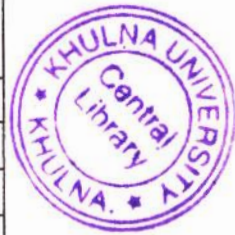
The interaction effect in anthocyanin content significantly decreased during the storage period (Table 4.14).

The highest concentration of anthocyanin (37.37mg/100g) was recorded in the Ball Sundori Kul treated with 0.5% chitosan which was statistically similar to (35.74mg/100g) Kashmiri Kul coated with 0.5% chitosan and the lowest concentration of anthocyanin (3.72mg/100g) was found in Thai Kul coated with 0.1% chitosan preceded by uncoated Narkeli Kul (4.86mg/100g) and uncoated Apple Kul (9.25mg/100g).

According to Bastos et al. (2016), jujube fruits' anthocyanin content rises during the start of the fruit's color development and falls as it ripens and reaches maturity. Shi et al. (2018) also observed that when the ripening stage increases, the anthocyanin content falls. Jujube fruits are therefore a good source of anthocyanin.

Table 4.14. The interaction effect of variety and chitosan coating on anthocyanin of jujube fruit on different days after storage (DAS)

Treatment Combination	Anthocyanin (mg/100g)	
	3DAS	9DAS
V ₁ T ₁	18.06de	17.83def
V ₁ T ₂	24.13bc	22.65cd
V ₁ T ₃	35.67c	32.52ab
V ₁ T ₄	37.37a	35.25a
V ₂ T ₁	6.83fg	9.25ghij
V ₂ T ₂	14.86e	13.86fghi
V ₂ T ₃	24.33bc	22.62cd
V ₂ T ₄	27.85b	26.44ab
V ₃ T ₁	17.41e	15.91ef
V ₃ T ₂	22.50cd	21.79def
V ₃ T ₃	27.95b	26.19abc
V ₃ T ₄	35.74a	33.86ab
V ₄ T ₁	4.79fg	19.01de
V ₄ T ₂	3.93g	3.72j
V ₄ T ₃	9.05f	8.92hi
V ₄ T ₄	16.39e	16.21ef
V ₅ T ₁	5.08fg	4.86ij
V ₅ T ₂	18.27de	17.56de
V ₅ T ₃	26.83bc	24.68bcd
V ₅ T ₄	27.18bc	25.32abc
Level of significance	**	*
CV(%)	13.57	30.27



V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column.

4.3 Microbiological characteristics of jujube fruit

4.3.1 Disease Incidence

The illness peaked on the 9DAS after beginning on the 6DAS. The uncoated Narkeli Kul and Thai Kul observed the highest disease incidence (83.33%), followed by Thai Kul coated with 0.1% chitosan (71.67%) and Thai Kul coated with 0.5% (70.60%). Ball Sundori Kul fruits coated with 0.5% chitosan solution recorded the lowest percentage (55.00%), followed by Kashmiri Kul (58.33%) with 0.5% chitosan and Ball Sundori Kul (58.33%) with 0.3% chitosan (Table 10). The study's findings showed that the Ball Sundori Kul and treatments with 0.5% chitosan-coated fruits performed the lowest disease incidence (Table 4.15).

This results is consistent with the findings by Ibrahim et al. (2014) and Jitareerat et al. (2007). The chitosan coating may have preserved the bananas' quality. According to Li, & Yu (2001), applying 0.5% and 1% chitosan coating significantly reduced the incidence of *Monilinia fructicola*-caused brown rot in peaches and postponed the onset of the illness. Additionally, according to Feliziani et al. (2013), applying 1% chitosan coating reduced the incidence of postharvest illness in sweet cherries.

Table 4.15. The interaction effect of variety and chitosan coating on disease incidence of jujube fruit on different days after storage (DAS)

Treatment Combination	Disease incidence (%)		
	3DAS	6DAS	9DAS
V ₁ T ₁	0.00b	36.67bcde	68.33abcd
V ₁ T ₂	0.00b	38.33abcd	66.67abcd
V ₁ T ₃	0.00b	25.00ef	58.33ef
V ₁ T ₄	0.00b	23.33f	55.00f
V ₂ T ₁	0.00b	30.00def	68.33abcd
V ₂ T ₂	6.67ab	36.67bcde	65.00bcde
V ₂ T ₃	0.00b	43.33abc	70.00abc
V ₂ T ₄	0.00b	28.33def	61.67def
V ₃ T ₁	6.67ab	25.00ef	63.33cde
V ₃ T ₂	0.00b	30.00def	63.33cde
V ₃ T ₃	6.67ab	23.33f	63.33cde
V ₃ T ₄	0.00b	25.00ef	58.33ef
V ₄ T ₁	6.67ab	46.67ab	83.33a
V ₄ T ₂	6.67ab	43.33abc	71.67ab

V ₄ T ₃	6.67ab	28.33def	63.33cde
V ₄ T ₄	6.60ab	40.00abcd	70.60ab
V ₅ T ₁	13.33a	50.00a	83.33a
V ₅ T ₂	6.67ab	38.33abcd	65.00bcde
V ₅ T ₃	0.00b	31.67cdef	63.33cde
V ₅ T ₄	0.00b	40.00abcd	66.67abcd
Level of significance	NS	**	*
CV (%)	212.50	22.06	6.31

V₁ = Ball Sundori Kul, V₂ = Apple Kul, V₃ = Kashmiri Kul, V₄ = Thai Kul, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

In a column * and ** = significant at 5% and 1% level of significance respectively. CV = Coefficient of variation. Non-significant differences are indicated by similar alphabets in a column

4.4 Shelf life

The application of chitosan could be beneficial in prolonging with the shelf life and maintaining the quality of jujube fruits by inhibiting the respiration rate in jujube fruits and decreasing postharvest diseases. Chitosan not only maintains weight loss but also improves the postharvest quality during storage.

Shelf life of jujube was significantly affected by the different postharvest treatments of chitosan concentration (Fig 4.1). The maximum shelf life (9 days) was recorded in Ball Sundori Kul coated with 0.5% chitosan, whereas the shortest shelf life found uncoated Narkeli Kul (4 days). Based on the aforementioned findings, it was determined that chitosan coating significantly affected the jujube's shelf life and that 0.5% chitosan coating was better suited for increasing the shelf life than other treatments. According to similar findings, dipping in garlic extract and coating with chitosan increased the shelf life of papaya and mango by seven and ten days, respectively (Kabir and Hossain, 2024; Salunkhe and Desai, 1984). Our study on chitosan-treated jujube also increased its shelf life.

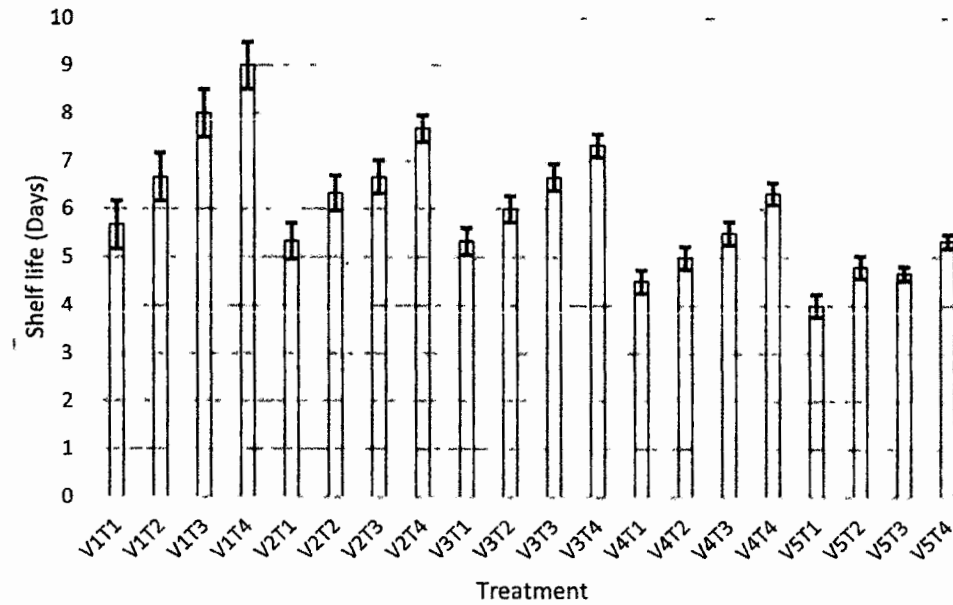


Fig 4.1. The interaction effect of chitosan coating on the shelf life of Jujube fruit.

V₁ = Ball Sundori Kul, V₂ = Apple, V₃ = Kashmiri Kul, V₄ = Thai, V₅ = Narkeli Kul, T₁ = Control, T₂ = 0.1%, T₃ = 0.3%, T₄ = 0.5%.

CHAPTER V

5 SUMMARY AND CONCLUSIONS

5.1 Summary

The experiment on physico-chemical quality of jujube fruits as affected by chitosan coating was carried out during December 2022 to March 2023. The collected fruits were brought to the Molecular Horticulture Laboratory, Agrotechnology Discipline, Khulna University, Khulna. To assess the effect of chitosan coating on postharvest quality and shelf life of jujube fruits varieties at ambient condition of postharvest management of jujube fruits in Bangladesh.

The experiments had two factors, variety (Factor A) and chitosan level (Factor B), were set up using a completely randomized design (CRD) with three replications for each treatment. Five well-matured jujube fruit varieties were used viz. Ball Sundori Kul, Apple, Kashmiri Kul, Thai, and Narkeli Kul. Chitosan solutions with concentrations of T_1 = control, T_2 = 0.1%, T_3 = 0.3%, and T_4 = 0.5% were employed as treatment. Additionally, as a control, uncoated jujube fruits were stored in an open area at room temperature ($24 \pm 1^\circ \text{C}$).

Weight loss, length, breadth, and color were among the quantitative variables used to determine the physical attributes of jujube fruits. A number of metrics, including vitamin C, total soluble solids, titratable acidity, pH, total flavonoid, anthocyanin content, and the microbiological characteristics of disease incidence were measured. The fruit kinds' shelf life as a result of the chitosan coating allocation was also assessed until the fruits from each treatment were no longer fit for human consumption.

Based on the aforementioned findings, the current study was found that the uncoated Narkeli Kul fruits recorded the maximum weight loss value (32.91%), while the Ball Sundori Kul fruits coated with 0.5% chitosan expressed the lowest weight loss (14.33%).

The largest fruit size (52.57cm) and largest breadth (40.29cm) were found in Ball Sundori Kul coated with 0.5% chitosan solution, while uncoated Thai Kul maintained the lowest value(30.29cm) long and (25.14cm) wide.

Ball Sundori Kul coated with 0.3% chitosan recorded the highest estimated color coordinate c^* value (17.17), uncoated Narkeli Kul had the lowest c^* value (6.43), Ball



CHAPTER VI

6 REFERENCES

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CHAPTER VII

7 APPENDICES

Appendix i. Analysis of variance of weight loss of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	3226.61*	3767.70*	4387.48*
Treatment	3	845.29*	1287.79*	922.38*
Interaction	12	645.16*	585.21*	393.57*
Error	38	76.62	107.34	91.76

Appendix ii. Analysis of variance of length of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	180.399*	165.153*	178.396*
Treatment	3	412.687*	357.789*	352.151*
Interaction	12	63.959*	55.643*	56.398*
Error	38	3.346	3.014	3.001

Appendix iii. Analysis of variance of breadth of fruits.

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	77.271*	74.534*	72.406*
Treatment	3	184.146*	194.028*	208.281*
Interaction	12	30.372*	32.824*	33.046*
Error	38	4.092	2.752	2.940

Appendix iv. Analysis of variance of color L* of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	109.810*	447.687*	222.872*
Treatment	3	50.147*	268.499*	19.511*
Interaction	12	30.826*	108.524*	90.996*
Error	38	6.326	12.244	4.929

Appendix v. Analysis of variance of color a* of fruits.

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	8.62786*	4.06711*	9.25689*
Treatment	3	6.23373*	8.74627*	4.04036*
Interaction	12	1.46646*	5.04045*	3.33949*
Error	38	0.65950	0.41400	1.26743

Appendix v. Analysis of variance of color b* of fruits.

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	6.6872*	121.193*	21.875*
Treatment	3	34.7149*	43.647*	110.045*
Interaction	12	10.9918*	20.785*	18.767*
Error	38	1.7478	2.084	0.950

Appendix vi. Analysis of variance of color c* of fruits.

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	8.2471*	105.179*	28.7209*
Treatment	3	24.4127*	43.167*	90.6096*
Interaction	12	9.9395*	20.382*	17.9560*
Error	38	1.6940	1.896	0.8846

Appendix vii. Analysis of variance of color h* of fruits.

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	111.246*	447.465*	180.574*
Treatment	3	257.316*	234.918*	775.159*
Interaction	12	31.150*	114.690*	137.824*
Error	38	10.239	10.180	49.381

Appendix ix. Analysis of variance of vitamin c of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	70.1199*	29.7413*	32.1045*
Treatment	3	80.5905*	58.4386*	62.4217*
Interaction	12	50.9689*	34.4675*	21.6937*
Error	38	1.6669	1.3406	1.3862

Appendix x. Analysis of variance of Total Soluble Solids of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	3.7839*	1.77948*	7.4932*
Treatment	3	10.4979*	4.78115*	13.3769*
Interaction	12	0.6100*	1.32001*	4.5066*
Error	38	0.4810	0.61413	0.1948

Appendix xi. Analysis of variance of Titratable Acidity of fruits.

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	19.8468*	14.0031*	3.00909*
Treatment	3	30.5397*	1.5270*	0.59289*
Interaction	12	5.4547*	1.4177*	1.19939*
Error	38	0.2416	0.1069	0.09772

Appendix xii. Analysis of variance of pH of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	0.6858*	0.4990*	0.1291*
Treatment	3	0.1974*	0.5928*	0.3147*
Interaction	12	0.1812*	0.0810*	0.1516*
Error	38	0.0066	0.0367	0.0334

Appendix xiii. Analysis of variance of Flavonoid of fruits.

Source of variation	Degree of freedom	Mean square	
		3DAS	9DAS
Variety	4	0.10794*	0.08306*
Treatment	3	0.05872*	0.07060*
Interaction	12	0.02514*	0.03212*
Error	38	0.00640	0.00668

Appendix xiv. Analysis of variance of Anthocyanins of fruits

Source of variation	Degree of freedom	Mean square	
		3DAS	9DAS
Variety	4	1832868*	1061476*
Treatment	3	2426053*	1556796*
Interaction	12	668587*	220519*
Error	38	16249	90947

Appendix xv. Analysis of variance of Disease incidence of fruits

Source of variation	Degree of freedom	Mean square		
		3DAS	6DAS	9DAS
Variety	4	83.333 NS	432.292*	140.000*
Treatment	3	44.444 NS	225.000*	131.667*
Interaction	12	38.889 NS	121.181*	42.778*
Error	38	50.175	56.820	17.083

Appendix xvi. Analysis of variance of shelf life of fruits.

Source of variation	Degree of freedom	Mean square
		Days
Variety	4	60.5900
Treatment	3	13.8190*
Interaction	12	0.4066
Error	38	0.4268