Effect of chitin nanofiber on postharvest quality and shelf life of papaya (*Carica papaya* L.)

A Thesis

By

STUDENT ID: MS-230812

**MASTER OF SCIENCE
IN
HORTICULTURE**

**AGROTECHNOLOGY DISCIPLINE
KHULNA UNIVERSITY
KHULNA-9208
BANGLADESH**

DECEMBER, 2024

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A Thesis (Course No: 081208HRT-6118) is submitted to the Agrotechnology Discipline in Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture

MASTER OF SCIENCE IN HORTICULTURE

The undersigned certify that they have read and recommended to the Agrotechnology Discipline for acceptance, an MS Thesis Entitled:

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Prof. Dr. Md. Yamin Kabir
Supervisor

Prof. Dr. Shamim Ahmed Kamal Uddin Khan
Co-Supervisor

Prof. Dr. Shamim Ahmed Kamal Uddin Khan
Chairman
Examination Committee and Head, Agrotechnology Discipline
(The signature of the chairman does not necessarily
Signify that the chairman has read the thesis)

DECEMBER, 2024

DEDICATED TO

My Beloved Parents

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The author

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ABSTRACT

Papaya is a nutrient-dense fruit, but due of its climacteric nature, its shelf life is short. The effect of chitin nanofiber (CNF) on the physico-chemical changes, microbial characteristics, and shelf life of papaya cv. Shahi was examined in an experiment conducted from 29th January to 14th February 2024 at the Germplasm Centre, Molecular Horticulture Laboratory, and Plant Pathology Laboratory of Agrotechnology Discipline, Khulna University, Khulna. The experiment was replicated three times and included five treatments: control, 0.1% chitin nanofiber (CNF), 0.2% CNF, 0.3% CNF, and 0.4% CNF. Total soluble solids (TSS) and weight loss are two physicochemical measures that dramatically rise with storage in both treated and untreated fruits. The incidence and severity of the disease showed a discernible rising trend. The amount of vitamin C, however, dramatically dropped. The lowest amount of total soluble solids (8.30%) was found in the 0.1% chitin nanofiber treatment. The least amount of weight was lost (11.56%) with the 0.2% chitin nanofiber treatment. The 0.3% chitin nanofiber treatment had the lowest disease severity (45.77%) on the ninth day of storage, while the control had the highest disease severity (53.96%). Papaya's shelf life varies greatly depending on the CNF concentrations. The 0.4% CNF had the highest shelf life (10.17 days), whereas the control had the lowest duration (6.31 days). In general, papaya's shelf life and other postharvest quality attributes are better preserved at 0.4% CNF.

Keyword: CNF, Shelf life, Postharvest quality, Papaya, Disease

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CHAPTER I

INTRODUCTION

The popular, delectable, and very valuable fruit papaya (*Carica papaya* L.) belongs to the Caricaceae family and is grown in 66 countries worldwide, with the Dominican Republic, Brazil, Mexico, and India being the top producers (Shu et al., 2023; FAOSTAT, 2021; Srikantharajah et al., 2020). Papaya is an important crop regarding nutritional, economic, industrial, and medicinal aspects (Tan et al., 2022). Papaya is high in alkaloids, flavonoids, carotenoids, phenolics, fibers, vitamins A, B, and C, and minerals. Papaya has also been shown to have anticancer properties (Ovando-Martínez et al. 2020; Alara et al., 2020). Green fruits, leaves, and flowers are used as vegetables (Watson, 1997). The active ingredients in papaya's leaves are alkaloids, glycosides, tannins, saponins, and flavonoids that give them their therapeutic properties. Additionally, in patients with dengue illness, papaya leaf juice raises platelet counts (Singh et al., 2020).

Papaya's anti-inflammatory and antioxidant qualities help prevent deadly conditions like diabetes, ischemic heart disease, high blood pressure, and strokes (Eno et al., 2000). Papaya is primarily grown in Bangladesh's northern areas, such as Tangail, Pabna, Dinajpur, Rangpur, Bogura, Gazipur, Mymensingh, Dhaka and Kishorgonj, . Throughout the year, papayas are a popular fruit and vegetable in the country. From an estimated 8907 hectares, Bangladesh produced 308,000 metric tons of green papaya and 147,000 metric tons of ripe papaya in the fiscal year 2021–2022, respectively (BBS, 2022). As a result, 34.6 t ha^{-1} of green papaya and 30.3 t ha^{-1} of mature papaya were produced. However, due to physical damage, rapid pulp softening, disease incidence, pest infestation, decay, disorders, and improper storage temperature, papaya is very perishable and susceptible to both qualitative and quantitative postharvest losses (Sivakumar and Wall, 2013).

Papaya is perishable due to its short shelf life as a function of its climacteric nature, on the other hand it continues to ripen after harvest, leading to rapid softening and loss of quality (Sivakumar & Wall, 2013; Ali et al., 2016). Its high metabolic rate encourages rapid respiration, which causes texture, flavor, and nutrient content changes, thus making it highly perishable (Sabina et al., 2019). For the tropical and subtropical countries, postharvest loss is 30–50% internationally and an average of around 40% for Bangladesh due primarily to microbial rot, dehydration, and physiological changes (FAO, 2019; Mondal & Bose, 2007).

These postharvest papaya diseases such as stem-end rot, anthracnose, and Rhizopus rot have significant rates of papaya spoilage, exceeding the contributions of infection alone by fungus of over 50% of losses (Esguerra et al., 2020; Demartelaere et al., 2017). In addition, transpiration and respiration-induced weight loss, softening of the flesh, and changes in the concentration of sugars and acids further reduce fruit quality (Firmin, 1997). To reduce postharvest loss and extend shelf life, fungicides and chlorine treatments are formerly used. However, these chemicals are toxic to both the environment and human health due to their toxicity, carcinogenicity, and persistence (Zahid et al., 2015; Maqbool et al., 2010). The application of sustainable alternatives, for example natural antifungal compounds and biodegradable paints, is being increasingly sought to counteract these problems.

Thus, safe, eco-friendly, and sustainable technologies are required to ensure the desired physical and biochemical changes of papaya during storage (Hutchinson et al., 2022). Many physical, chemical, and biological methods have been tried to preserve postharvest quality and increase the shelf life of papaya (Kabir & Hossain,2024). Physical methods encompass a variety of techniques such as cold plasma, ultrasonication, ozone, hot water, low temperature, (Vázquez-Ovando et al., 2018; Terao et al., 2019, Vinod et al., 2023), packaging and modified packaging, and so on. The use of calcium, calcium chloride, 1-MCP, and other chemicals are examples of chemical methods (Madani et al., 2016; Gao et al., 2020; Shu et al., 2023) and essential oils are among the biological methods (Ali et al., 2016; Casemiro et al., 2019), surface coatings

(Rashid et al., 2019; Vilaplana et al., 2020), phytohormones (Hanif et al., 2020), packaging that is biobased (Nilsen-Nygaard et al., 2021), and so on. The methods do have certain drawbacks, though. For example, hot water treatment can result in uneven ripening and surface burning; cold storage is expensive and can result in chilling harm (Arah et al., 2016; Fallik and Ilic, 2019). And papaya, a crop that is sensitive to cold; the lowest storage temperatures that are advised are between 7 and 13 °C (McGregor, 1989). Thus, to maintain the aesthetic and nutritional quality of papaya, eco-friendly, effective, safe, bio-degradable with no residual effect, generally regarded as safe (GRAS), user-friendly, rapid, and scalable technologies are still needed (Bordoh et al., 2020).

In this context, chitin nanofiber may be one of the appropriate materials. The structural element of insects, crustaceans, and fungal mycelia is chitin, a naturally occurring and abundant mucopolysaccharide (Iñiguez-Moreno et al., 2021). Despite the fact that chitin is insoluble in water, but its nanofibers cause it to become soluble. Biodegradability, biocompatibility, renewability, and sustainability are some of the advantageous properties of CNF (Ifuku., 2012). Because of they are too tiny, chitin nanofibers readily preserve the clear appearance of clean acrylic resin. chitin nanofibers, which include hydroxyl and amine/N-acetyl functions, were prepared into a 90 mm-diameter nanofiber sheet by vacuum-filtering their aqueous solution nine times quicker than cellulose nanofibers. Taking into account this notable benefit of chitin nanofibers over cellulose nanofibers for industrial use (Shams et al., 2010). Chitin nanofiber (CNF) will be made from abundant natural resources, including environmentally hazardous shrimp shells. CNF can be employed for post-harvest management if shrimp shells can be used in its place, allowing the harmful elements to be removed from the environment (Ifuku et al., 2013). We investigated the effectiveness of different concentration of chitin nanofiber for postharvest papaya storage, thus, the purpose of this study was to determine which concentration of chitin nanofiber would be best for preserving the desired physico-chemical changes in papaya and extending its shelf life.

CHAPTER II

LITERATURE REVIEW

Despite being a significant tropical fruit, there is a lot of research on minimising postharvest losses and physio-chemical alterations that occur during storage. Papaya's shelf life and the incidence and severity of disease are extremely constrained. This chapter has made an effort to review the relevant research that is relevant to the current subject. The details are provided below under the corresponding headings

2.1. Effect of maturity stages

Papaya is a climacteric fruit and highly perishable because of fat ripening which trigger ethylene production and that's why its consumption period is very short after harvesting at green mature stage (Burg and Burg, 1962). On the other hand, papaya rot caused by fungi is a big problem during storage and marketing (Lacroix et al., 1990). Because of its naturally fragile and thin skin, papaya is damaged very easily by handling and infected by the main postharvest disease anthracnose (*Colletotrichum gloeosporoides*) (Palhano et al., 2004). Harvesting at proper maturity stage is a very important determinant for storage life and final quality. If fruits are harvested at improper maturity, it can lead to uneven ripening and over rope fruits (Ceponis and Butterfield., 1973).

Maturity stage 2 (1/3 yellow colour development on papaya fruit skin) was found to be better for shelf life and postharvest quality of papaya (Rashid et al., 2015)

2.2. Physio-chemical changes during ripening

2.2.1. Colour of the pulp

A study by Coneglian et al. (2000) examined how postharvest treatments affected papaya fruit colour, firmness, and weight loss. The fruits were treated with growth regulators and fungicides. According to their findings, no treatment was effective in keeping the papaya's decreased firmness.

Over the course of the storage time, the hue shifts from green to yellow persisted. Control and coatings with 0.5% chitosan fruits were ripening and turning yellow by the end of the 4th week of cold storage. They were also unmarketable because of shrivelling, excessive softness, and an overabundance of fungal mycelium. The experiment's use of these fruits was discontinued. Peel colour changes were delayed for fruits with increased chitosan coating concentrations. Up to the fourth week of storage, there was hardly any change in the colour of the peel on 2.0% coated fruit. By the time they were stored, the fruits had turned olive-brown (Ali et al., 2010).

According to Bautista-Banos et al. (2013), the harvest maturity stage must fall precisely within the ripe stage of colour break at ¼ (one-stripe yellow at the blossomed or apex and the quarter-ripe yellow). Fruit for the national market may be harvested at different ripening stages, and the majority of handling operations are carried out in the field where they are exposed to environmental conditions (sunlight, high relative humidity, dust).

2.2.2. Total weight loss

The primary factor influencing papaya fruit quality and storage life seemed to be weight loss. When compared to the control, the chitosan coatings considerably decreased the papaya fruit's weight loss during storage. As the concentration of chitosan increased, the weight loss reduced. According to Ali et al. (2010), the chitosan treatments that resulted in the least amount of weight reduction were 1.5% and 2.0%.

Applying a plastic film or coating can help minimise water loss. The chitosan used in this study reduced the water and weight loss by forming a film in the apple skin. When 1.5% and 2.0% chitosan coatings were applied, the weight loss was less than 6% of the control, which is enough to keep the Eksotika II papaya looking nice and maintaining its quality (Perez-Gago et al., 2006).

In an experiment on papaya postharvest behaviour, Mia (2003) found that fruits with wax coating and an unperforated polythene bag lost the least amount of weight while being stored, while untreated fruits lost the most.

According to Kodikara et al. (1997), hot water double dips therapy at 420 °C and papaya for 20 minutes did not result in any discernible weight loss. Mosca et al. (1995) discovered that papaya cv. "Improve Sunrise Solo Line 72/12" loses less weight when wrapped in PVC (polyvinyl chloride) film. Mootoo (1991) found in an experiment that untreated fruits had the highest rate of fresh weight loss.

2.2.3. Total soluble solids (TSS) content (% Brix)

Chitosan coatings have an impact on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit when it is stored in cold conditions. In contrast to fruit with a higher chitosan concentration, they observed that fruit that was untreated and covered with 0.5% chitosan had a noticeably larger concentration of soluble solids. The concentration of soluble solids decreased in direct proportion to the concentration of chitosan. At the end of the storage period, the fruit coated with 1.5% and 2.0% chitosan had the lowest amount of soluble solids concentration (Ali et al., 2010).

Chitosan's ability to lower the concentration of soluble solids in papaya fruit was most likely caused by a slowdown in respiration and metabolic activity, which in turn delayed the ripening process. According to Dong et al. (2004), chitosan's coating properties are well recognised for creating an excellent semi-permeable film around the fruit, changing the internal atmosphere by lowering O2 and/or raising CO2, and preventing the production of ethylene.

2.2.5. Titratable acidity

Capping and biological applications have the ability to influence fruit ripening process and quality properties. Maqbool et al. (2011) identified that a coating of 0.4% cinnamon oil postponed the ripening by reducing soluble solids concentration and titratable acidity. 10% gum arabic along with 0.4% cinnamon oil blended mixture was still more effective in maintaining these parameters of quality.

Biological control also affects acidity by fruits. Wangchu and Hazarika (2008) reported that orange fruits treated for five minutes with *Trichoderma* had higher titratable acidity than untreated fruits. In contrast, experiments conducted by Eisa et al. (2001) and Abd-EI-Aziz and Mansour (2006) showed that biologically controlled citrus fruits had lower titratable acidity but higher ascorbic acid content, thus higher nutritional value.

Physico-chemical changes in fruit are both environment and maturity dependent. Chadha et al. (1972) have noticed that immature pineapples contained a high TSS/acidity ratio, which changed during fruit development. Similarly, Leverington (1970) found that sweetness of fruits varies with seasons, and summer fruits have a higher TSS/acidity ratio (28) than winter fruits (9), making them much sweeter.

These results reveal that environmental conditions, biological agents, and coatings influence the ripening, acidity, and sweetness of fruit. These factors can be regulated by appropriate postharvest treatments to maintain quality and shelf life of fruit.

2.2.6. Diseases Incidence

In Pernambuco, Brazil, fungal infections are the principal cause of post-harvest losses in papaya, for a period of six months. The most frequent of these is stem end rot, with prevalence of 39.71% to 80.07%. *Colletotrichum gloeosporioides* (*Glomerella cingulata*) is the most frequently occurring pathogen and is responsible for 44.95% of infections.

Similarly, six major post-harvest diseases have been found in mature papaya in Mymensingh, Bangladesh. Of these, the highest incidence rate (14.17%) as well as the abundance (46.11%) in the market is found for anthracnose, followed by *Fusarium* rot (7.26% incidence, 24.61% abundance). The lowest incidence (0.70%) of *Penicillium* rot is reported. The study also reveals that the prevalence and severity of the diseases are the highest in May month, implying the greatest need for effective post-harvest management practices (Hamim et al., 2014).

2.2.7. Disease Severity

Papaya (*Carica papaya* L.) and banana are highly susceptible to postharvest fungal diseases, which significantly influence fruit quality and marketability. This is due to the fact that the high water and sugar content of tropical fruits creates a conducive environment for the growth of fungi (Capdeville et al., 2007).

Echerenwa et al. (2004) isolated *Fusarium solani, Aspergillus flavus, Aspergillus niger, Botryodiplodia theobromae, Colletotrichum dematium, Penicillium sp.*, and *Rhizopus stolonifera* from infected papaya tissues. Using molecular identification, Mendy et al. (2019) confirmed that *Fusarium sp., Lasiodiplodia theobromae, Aspergillus niger,* and *Colletotrichum gloeosporioides* are major causes of postharvest rot. Similarly, Rahman et al. (2008) indicated that anthracnose, caused by *Colletotrichum gloeosporioides* and *Colletotrichum capsici* was the greatest in disease incidence (90–98%) in Malaysian-grown papaya, followed by stem-end rot. Dantas et al. (2003) also indicated *Glomerella cingulata* and *Colletotrichum gloeosporioides* as the most prevalent pathogens isolated, with stem-end rot being the most prevalent disease.

Among these, *Colletotrichum gloeosporioides* is the most significant postharvest pathogen of papaya, inducing anthracnose, a disease of sunken lesions that reduce fruit quality and shelf life (Korsten, 2006). The infection can be initiated as early as the flowering phase, where it becomes latent until fruit ripening.

Fungal development and sporulation are assisted by environmental conditions of high humidity (>96%) and a pH of 4.2 to 6.1 (Lai et al., 1993).

Fungal diseases after harvesting are also a cause of concern for bananas. Cherin et al. (2007) demonstrated that banana storage at or below 10°C and 25% relative humidity largely reduced the severity of the disease and the germination of spores. Hassan et al. (2004) found that hot water treatment (50°C ± 2°C for 5 minutes) and fungicide treatment of prochloraz (250 ppm) effectively reduced disease incidence. In another study, Brown (1993) noticed that *Colletotrichum musae* caused extensive crown rot following inoculation of a small quantity of conidia onto freshly cut banana crowns, whereas *Fusarium pallidoroseum* required 20 times more conidia to produce a similar response.

For the control of postharvest fungal diseases, some natural alternatives have been explored. Chitosan, a natural biopolymer, has been discovered to inhibit the growth of various fungal pathogens, including *Rhizopus stolonifera, Botrytis cinerea,* and *Colletotrichum gloeosporioides* (Badawy & Rabea, 2011). It was also reported to have antibacterial activity against *Erwinia carotovora* and *Pseudomonas syringae* (Mansilla et al., 2013; Xing et al., 2015). All these findings suggest that chitosan can be applied as an environmentally friendly substitute for chemical fungicides.

Fungal diseases during postharvest continue to be a significant limitation to fruit production in the tropics. While classical methods such as fungicide spray and hot water treatment are efficacious, escalating demand for environment-friendly technologies calls for more work on natural alternatives for disease control such as the use of chitosan. By integrating the optimum storage techniques, effective control of diseases, and eco-friendly alternatives, losses during postharvest can be minimized to enable better fruit quality and extended shelf life.

2.2.8. Shelf Life

Papaya fruit is plagued with postharvest issues, mainly softening, which reduces its shelf life. Zerpa-Catanho et al. (2007) highlighted that the softening is connected to cell wall oligosaccharide degradation. Treatments like chitosan have been studied to reverse the problem. In a study by Ali et al. (2010), papayas treated with 1.5% chitosan were of superior quality, such as wrinkle-free and shining surface, and typical reddish-orange skin of the Eksotika II papaya, even after cold storage for five weeks. Fruits treated with 2.0% chitosan did not ripen well after five weeks. Concentrations at lower levels (1.0% chitosan) continued to have good quality.

According to Kittur et al. (2001) ,1.0% chitosan-coated mangoes had enhanced sensory characteristics after 21 DAS in comparison to control and wax-coated mangoes. In another study by Before et al. (2004), certain ripening retardants like GA (gibberellic acid) at 200 ppm were applied to papaya fruits cv. Madhubindu. GA-treated fruits also had a longer shelf life, reduced decay, reduced weight loss, and reduced ripening, as evidenced by a reduced rise in soluble solids, acidity, and sugar.

These studies report that chitosan and other treatments have the potential to significantly extend the shelf life of papaya by retarding softening and rotting. Chitosan nanofiber coatings, have shown potential in reducing disease incidence and preserving fruit quality during storage.

CHAPTER III

MATERIALS AND METHODS

3.1. Experimental site

The current experiment was carried out using a Shahi papaya at the Fruit Germplasm Centre of the Agrotechnology Discipline, Khulna University, Khulna, from January 29 to February 14, 2024.

3.2. Experimental material

The experimental material used in this experiment was papaya variety Shahi. This dioecious variety bears fruit – ovate, medium to large with the dimensions of 13-15 cm x 9-11 cm (length and diameter, respectively), flattened base, and deep green at maturity and greenish yellow at ripe – having deep orange pulp with 2 cm thickness with an average fruit weight of 850-950 g. The fruit was collected from the Horticulture Centre of Jashore – a nearby the regional substation of BARI. Papaya fruits were harvested following maturity indices - watery latex and pale green fruit – on 29th January 2024 and carried to the laboratory of Khulna University. On arrival, fruits were subjected to air dry, cleaned, and stored at room temperature before starting treatments.

3.3. Preparation and application of treatments

Various concentrations of chitin nanofiber (CNF) were produced. The initial step in making 0.1%, 0.2%, 0.3%, and 0.4% chitin nanofiber is to collect the raw chitin nanofiber. To determine the treatment concentration, a real amount of water was combined with the chitin nanofiber that had been collected.

The mature green papaya fruits were spread out on the floor in a completely randomised design (CRD) with three replications and five treatments: control (no treatment), 0.1%, 0.2%, 0.3%, and 0.4% CNF. In this experiment, a total of $8 \times 3 \times 5 = 120$ papaya were used, with 8 fruits each replication. With the exception of the control, the fruits were sprayed with a sprayer to guarantee the formation of a CNF layer at various concentrations (0.1%, 0.2%, 0.3%, and 0.4%).

3.4. Experimental Design

The fruits were allowed to air dry before being set out on the brown paper in a completely randomized pattern on the lab floor under ambient environmental conditions. A total of 24 papaya fruits—eight from each replication—were chosen at random to serve as the control. Four fruits were retained from each of the eight (eight) fruits in each replication in order to record changes in weight, colour, and other exterior fruit attributes as well as shelf life. Data on various parameters at various times was recorded using the remaining four fruits.

3.5. Organoleptic evaluation of papaya with CNF treatment

A panel of fifteen university students used a standardized questionnaire to evaluate papaya pulp organoleptically, and the results were presented appropriately.

3.6. Observation of peel colour changes

The fruits were closely inspected each day to look for any variations in the peel's colour. Additionally, information on physicochemical properties and total soluble solids (TSS) was documented throughout the ripe stage as well as three, six, and nine days after storage (DAS). The duration from storage to mature stages was divided into four phases: 3, 6, 9, and 12 DAS. The ripe stage, or 12 DAS, was identified by the colour of the skin. However, a total of 17 days of observation were needed to determine the shelf life. After 17 days of storage under chitin nanofiber treatment, the colour result changed.

3.7. Measurement of fruit attributes

Colour changes, overall weight loss, TSS, firmness, disease incidence and severity, and shelf life were among the fruit attributes that were recorded. Peel colour variations, including pale green, greenish yellow, light greenish-yellow, and yellow, were assessed using a numerical grading method at three-days intervals starting on the third day of storage (3, 6, 9, and 12 DAS). Papaya fruits were analysed chemically and physically. An electrical balance was used to weigh each papaya fruit separately, and the percentage weight loss (%WL) was computed as follows: Ranganna's (1979) methods were used to study the physicochemical characteristics.

i. Weight loss (%)

$$\%WL = \frac{IW - FW}{IW} \times 100$$

Where,

IW = Initial fruit weight (g)

FW = Final fruit weight (g)

ii. Firmness

Firmness of papaya was estimated hedonically according to Hasan (2006) following a rating scale 1-6 where, 1 represents mature hard, 2 is sprung, 3 is between sprung and eating ripe, 5 represents over ripened and 6 means totally unfit for consumption.

iii. Moisture content (%)

To determine moisture content (%), ten grams of fruit pulp from all treatments and replications were weighed in a Petri dish by a Triple Beam Balance and oven-dried at 65°C for 72 hours and moisture content was calculated as

$$\text{Moisture content (\%)} = \frac{PW - DW}{PW} \times 100$$

Where,

PW = Primary weight of pulp (g)

DW = Dried weight of pulp (g)

iv. Measurement of TSS

To obtain a direct measurement of TSS, a single drop of pulp-juice was placed on the Abbe's Refractometer's prism, and temperature adjustments were made in accordance with Ranganna (1979).

v. Disease incidence (%)

Every day, the papaya fruits from each treatment were carefully inspected for the presence of rot, and on alternate days, the incidence of rot was noted. On the sixth day of storage, the initial count was conducted. When compared to the released documents, the apparent rot was verified.

The incidence of disease was calculated as follows (Kabir and Hossain, 2024) -

$$\% \text{ Disease incidence} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits under study}} \times 100$$

vi. Disease severity

Disease severity means how much area of a fruit gets infected with diseases. It was determined through an eye estimation and expressed in percentage (Roy et al., 2011).

vii. Shelf life

The number of days that required to ripe the papaya fruits from maturity and retain its edibility without blemishes, over-ripening, wrinkling, and mould growth was considered as the shelf life of papaya.

3.8. Isolation and identification of causal pathogens

The infected specimens were transported to the Plant Pathology Laboratory of Agrotechnology Discipline, Khulna University, where they were chilled until the causative organisms could be isolated and identified. The specimen was sliced, confirmed to have healthy tissue, and surface-sterilized for three seconds using a 0.1% $HgCl_2$ solution. The specimens were cleaned three times with sterile water before being put in a Potato Dextrose Agar medium. To allow the pathogen to proliferate, five specimens were combined in a plate and incubated for seven days at room temperature. Following this time, temporary slides were made for compound microscope examination. In accordance with Roy et al.

(2011), the pathogens were identified by looking at both vegetative growth and reproductive structures.

3.9. Statistical analysis

The data were subjected to one-way analysis of variance (ANOVA) and F-test with the MSTAT program. The mean differences were tested by Tukey's HSD Test at 5% probability level.

CHAPTER IV

RESULTS AND DISCUSSION

For high-quality product, papayas must be harvested at the right time of development. Numerous criteria were employed to determine whether the fruit's quality was suitable for both consumption and preservation. This chapter presents the findings of the current study on how maturation stages and postharvest interventions affect papaya quality and shelf life in terms of fruit attributes, physic-chemical changes, disease, and shelf life during ripening.

4.1. Colour change

Fruits' colour changes during storage were significantly impacted by postharvest treatments. Papayas began to change colour in storage at 0, 3, 6, 9, and 12 days, respectively (Table 4.1).

The peel was green at first, but it changed colour throughout the course of the following few days of storage. At 3rd,6th 9th and 12th days following storage, respectively, the colour of the stored papaya changed from green to pale green, greenish yellow, light greenish yellow, and yellow for all post-harvest treatments (Table 4.1).

After 12th days of storage, it was fully ripened and decreased the shelf life. In the meantime, there increase another chemical characteristic and the characteristics of edible portion such as sweetness, juiciness, texture of pulp, aroma and fibreness.

Table 4.1. Effect of chitin nanofiber (CNF) concentration on change of skin colour of papaya at different days after storage (DAS)

Treatments	Colour change			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	Pale Green	Greenish yellow	Light greenish yellow	Yellow
0.1% CNF	Pale Green	Greenish yellow	Light greenish yellow	Yellow
0.2% CNF	Pale Green	Greenish yellow	Light greenish yellow	Yellow
0.3% CNF	Pale Green	Greenish yellow	Light greenish yellow	Yellow
0.4% CNF	Pale Green	Greenish yellow	Light greenish yellow	Yellow

4.2. Organoleptic evaluation

At the third, sixth, ninth, and twelfth days of storage, the edible portion's qualities—such as sweetness, juiciness, pulp texture, aroma, and fiberness—were also noted. Shahi papaya pulp was sweet, medium-juicy, crispy, odor-pleasing, and fibreless on the third, sixth, ninth, and twelfth days of storage, respectively (Table 4.2). However, the pulp's color was whitish at 3 DAS and 6 DAS, light orange at 9 DAS, and deep orange red at 12 DAS.

Table 4.2. Organoleptic evaluation of papaya with CNF

Sweetness	Juiciness	Texture of pulp	Aroma	Fibreness	Pulp Color			
					3 DAS	6 DAS	9 DAS	12 DAS
Sweet	Medium Juicy	Crispy	Pleasant	Fibreless	Whitish	Whitish Orange	Light orange	Deep orange red

4.3. Total weight loss of papaya

Effect of different percentages of chitin nanofiber (CNF) on papaya weight loss was quantified at 6, 9, and 12 DAS. Control had the highest weight loss (12.70%) at 12 DAS, and the least weight loss was encountered in the 0.2% CNF treatment (11.56%).

At 6 DAS weight loss ranged from 3.60% (control) to 5.23% (0.4% CNF concentration). It was highest at 9 DAS for 0.4% CNF concentration (10.36%) and lowest at the control (7.39%). Weight loss was higher by storage duration and more weight was lost in the untreated fruits compared to treated fruits. More weight loss was found at higher concentrations of CNF (0.4%), suggesting a certain level of CNF to minimize postharvest loss (Table 4.3). The rate of weight loss was higher in untreated fruits than in treated fruits, and the overall weight loss increased as the storage period rose.

Loss in weight is one of the most important indicators for maintaining fruit quality.

The physiological reason of weight loss resulting from respiration, water transpiration via peel tissue, and other organic changes occurring in the fruit is predictable. Highly significant effects, one per cent weight loss of papaya were observed due to the application of different postharvest treatments (Appendix 2).

The primary factor influencing papaya fruit quality and storage life was the overall weight decrease. Ali et al. (2010) and Mia (2003) also noted a considerable increase in total soluble solids in a similar study.

Table 4.3. Effect of chitin nanofiber (CNF) concentration on weight loss of papaya at different days after storage (DAS)

Treatments	Initial wt. (kg)	Weight loss (%)		
		6 DAS	9 DAS	12 DAS
Control	0.88	3.60 c	7.39 c	12.70 bc
0.1% CNF	0.96	4.07 b	8.38 bc	12.56 bc
0.2% CNF	0.97	3.97 b	8.36 bc	11.56 c
0.3% CNF	1.01	5.40 a	9.51 ab	14.18 ab
0.4% CNF	0.97	5.23 a	10.36 a	14.51 a
CV (%)	-	2.26	8.87	7.01
LS	-	**	**	**

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically significant at the 5% level of probability ($p<0.05$).

4.4. Firmness

The highest firmness (4.43%) is in 0.3% chitin nanofiber concentration and the lowest firmness (3.11%) in control treatment at 12 days storage condition. Significant variation was recorded between storage stage at 3, 6, 9, 12 days after storage condition of papaya.

Table 4.4. Effect of chitin nanofiber (CNF) concentration on firmness of papaya at different days after storage (DAS)

Treatments	Firmness			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	2.26 b	2.94 a	3.45 bc	3.11 d
0.1% CNF	2.38 ab	2.91 ab	3.39 c	4.23 b
0.2% CNF	2.08 b	3.00 a	3.89 a	4.25 b
0.3% CNF	2.32 ab	2.77 bc	3.62 b	4.43 a
0.4% CNF	2.60 a	2.75 c	3.57 bc	3.62 c
CV (%)	7.37	2.73	3.05	2.04
LS	*	**	**	**

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically different at the 5% level of probability ($p<0.05$).

4.5. Colour attributes

Significant variation was recorded from colorimeteric results at 3, 6, 9, 12 days of storage condition of papaya. The L value decreased significantly at storage. The highest value L was 48.98 in control at 3 DAS and the lowest L was reported 39.51 in 0.2% CNF at 12 DAS. The highest value of a* was -6.09 at 0.2% CNF at 12 DAS and that decreased to -13.20 with 0.1% CNF at 3 DAS. The highest color of b* was 28.35 in 0.1% CNF treatment at 9 DAS that decreased to 16.16 in 0.4% CNF at 9 DAS. The maximum color C* 30.51 in 0.1% at 9 DAS and minimum was 16.70 in 0.2% CNF at 12 DAS. The highest color was h* 112.63 in 0.2% CNF at 3 DAS and the lowest color of h* was 107.83 in 0.3% CNF at 3 DAS, (Table 4.5.1 and Table 4.5.2).

Table 4.5.1. Effect of chitin nanofiber (CNF) concentration on color attributes of papaya at different days after storage (DAS)

Treatments	Color attributes									
	3 DAS					6 DAS				
	L	a*	b*	C*	h°	L	a*	b*	C*	h°
Control	48.98b	-12.48ab	20.20 b	24.03 b	121.73ab	42.08 b	-11.50bc	21.04 c	23.96 b	119.49a
0.1% CNF	43.21a	-13.20b	21.64a	26.65a	121.61 b	43.21ab	-11.79c	21.78 bc	24.87ab	119.27a
0.2% CNF	41.52b	-12.81b	20.05 b	24.29 b	122.63a	43.53a	-11.03ab	23.08a	25.81a	117.38 b
0.3% CNF	42.31ab	-11.66a	21.44a	24.59 b	119.51 c	42.12 b	-10.85a	20.88 c	23.79 b	118.62ab
0.4% CNF	41.83b	-12.47ab	20.04 b	23.88 b	122.20ab	43.38a	-11.35abc	22.24ab	25.20a	118.71ab
CV (%)	1.24	-3.90	3.01	2.11	0.46	1.46	-2.91	2.45	2.52	0.71
LS	*	*	**	**	**	*	*	**	**	NS

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically different at the 5% level of probability ($p<0.05$).

Table 4.5.2. Effect of chitin nanofiber (CNF) concentration on color attributes of papaya at different days after storage (DAS)

Treatments	Color attributes									
	9 DAS					12 DAS				
	L	a*	b*	C*	h°	L	a*	b*	C*	h°
Control	47.41a	-9.97	28.35a	30.51a	111.87 b	41.02 b	-11.30d	19.57a	22.61a	120.70a
0.1% CNF	44.87 b	-10.26	23.65c	26.23 b	115.60a	41.18 b	-10.97d	18.72a	21.83a	120.78a
0.2% CNF	43.80 b	-9.65	22.15d	24.39 b	114.30a	39.51 c	-6.09a	15.25 b	16.70 d	113.28 b
0.3% CNF	44.16 b	-9.87	25.85b	27.82ab	111.80 b	42.65a	-6.95b	19.10a	20.40 b	107.83 c
0.4% CNF	44.71 b	-57.63	22.94cd	25.22 b	114.32a	40.11 bc	-9.22c	16.16 b	18.77 c	119.01a
CV (%)	1.89	-6.80	2.70	8.26	0.72	1.46	-3.00	3.68	3.15	1.09
LS	**	NS	**	*	**	**	**	**	**	**

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically differentat the 5% level of probability ($p<0.05$).

4.6. Color

The color of Shahi papaya fruits was assessed visually following a color rating scale (1 to 5) according to Dang et al. (2008).

The colours are as follows: (1) 100% green, (2) 1-25% yellow, (3) 26-50% yellow, (4) 51-75% yellow, and (5) 76-100% yellow.

Significant effect of color ratio Papaya quality and shelf life were noted due to the maturity stages (Appendix 8). The highest color showed (3.75) in 0.2% chitin nanofiber treatment and lowest color showed (3.11) in 0.1% chitin nanofiber treatment at 12 days storage of papaya.

Protoplasts transformed into chromoplasts normally in the control group, but the treatment effect inhibited this process in the treated samples (Rashid et al. 2019). When these components changed, the fruit's skin colour changed from green to yellow. According to the results, the combination therapy looked better on the outside than the other treatments for both maturity phases.

These findings are likewise comparable to those of Ali et al. (2010), who employed control and fruit covered with 5% chitosan changed colour more quickly than fruit coated with 2% chitosan. Papaya fruits ripened and turned yellow after four weeks of cold storage. They were unsellable because of shrivelling, excessive softness, and an overabundance of fungal mycelium.

Table 4.6. Effect of chitin nanofiber (CNF) concentration on color of papaya at different days after storage (DAS)

Treatments	Color			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	1.71 d	2.62 a	3.08 a	3.11 d
0.1% CNF	2.30 a	2.59 ab	2.80 c	3.33 c
0.2% CNF	2.04 bc	2.50 bc	3.0 ab	3.75 a
0.3% CNF	2.19 ab	2.42 c	2.95 b	3.50 b
0.4% CNF	1.96 c	2.69 a	3.04 ab	3.41 bc
CV (%)	3.95	2.20	2.01	2.50
LS	**	**	**	**

CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically different at the 5% level of probability ($p<0.05$).

4.7. Total soluble solid

The papaya fruits' total soluble solids content rose as they ripened. The TSS of papaya pulp was significantly impacted by the postharvest storage methods employed in this investigation. At the various storage periods, there were notable differences in the treatment means for TSS content (Appendix 3). Three days after storage, the fruits in the control treatment had the lowest TSS content (5.16%), whereas the fruits in the 0.4% chitin nanofiber (CNF) had the highest TSS content (6.73%). Similarly, at 6 DAS, the fruits maintained in 0.4% CNF treatment had a reduced TSS level (7.13%) and the control fruits had the greatest TSS content (9.53%). At 9 DAS, the fruits maintained in 0.4% CNF treatment had a reduced TSS content (7.80%) and the control fruits had the greatest TSS content (9.40%). However, the control fruits similarly had the greatest TSS level (9.13%) at 12 days following storage, while the 0.1% CNF treatment had the lowest TSS content (8.30%) (Table 4.7).

Evaluate the impact of chitosan coatings on the physicochemical properties of Eksotika II papaya (carica papaya L.) in comparison to the experiment carried out by Ali et al. (2010). In contrast to fruit with higher chitosan concentrations, Ali observed that fruit that was left untreated and covered with 0.5% chitosan had a noticeably higher concentration of soluble solids. That and the current study were comparable.

It was found that the total soluble solids (TSS) content was increased with the increasing of storage period in relation to different CNF concentration treatments (Table 4.7).

Table 4.7. Effect of chitin nanofiber (CNF) concentration on total soluble solid (TSS) of papaya at different days after storage (DAS)

Treatments	TSS (% Brix)			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	5.16	9.53 a	9.40 a	9.13 a
0.1% CNF	6.53	7.66 bc	7.83 c	8.30 d
0.2% CNF	5.43	8.00 bc	8.80 b	8.73 b
0.3% CNF	6.10	8.63ab	7.93 c	8.63 bc
0.4% CNF	6.73	7.13 c	7.80 c	8.43 cd
CV (%)	18.52	6.82	2.60	1.74
LS	NS	**	**	**

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically different at the 5% level of probability ($p<0.05$).

4.8. Titratable acidity (TA)

The TA content of papaya fruits was not significantly affected by the storage conditions of chitin nanofiber treatments (Table 4.8).

The highest titratable acidity content (5.20%) in 0.4% chitin nanofiber treatment and the lowest amounts (4.18%) in control treatment at 12 DAS condition.

The results are comparable to what Wojcik et al. (2008) observed when they observed chitosan film coatings in carrot storage. Additionally, they observed that during storage, the total soluble solids in both treated and untreated carrot fruits rose noticeably.

Table 4.8. Effect of chitin nanofiber (CNF) concentration on titratable acidity (TA) of papaya at different days after storage (DAS)

Treatments	TA (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	4.33 ab	4.81 ab	7.27 a	4.18 c
0.1% CNF	4.24 ab	3.41 c	6.12 c	4.88 b
0.2% CNF	4.21 b	5.39a	6.53 b	4.94 ab
0.3% CNF	4.61a	4.08 bc	6.37 bc	4.44 c
0.4% CNF	4.47ab	4.38 abc	6.16 c	5.20 a
CV (%)	4.64	13.95	2.39	3.14
LS	*	*	**	**

LS = Level of significant; * = Significant at 5% level of probability; ** = Significant at 1% level of probability; CV = Coefficient of variation. Treatment means in a column with dissimilar letter(s) are statistically different according to the Tukey's Honestly Significant Difference Test at 5% level of probability (p<0.05).

4.9. Vitamin C

Vitamin C level in papaya fruits augmented after the process of ripening and also among varied days of storage (Appendix 5), the variation proved to be significant. 7.42% was maximum Vitamin C level of fruits treated with 0.4% chitin nanofiber (CNF).

Various postharvest treatments showed enormous variation in Vitamin C content (Appendix). The maximum Vitamin C content (10.84%) was observed in 0.3% CNF-treated fruit at 9 DAS, and the minimum (7.946%) in 0.2% CNF-treated fruit at 9 DAS (Table 4.9).

These findings suggest that Vitamin C content decreases minimally as fruits mature, as reported by Wall et al. (2006). Ripening stage, harvest date, and postharvest organic treatments may influence Vitamin C content in the same variety.

Table 4.9. Effect of chitin nanofiber (CNF) concentration on vitamin C content of papaya at different days after storage (DAS)

Treatments	Vitamin C (mg/100 g)			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	8.05	7.84 a	10.02 b	6.64 c
0.1% CNF	7.91	6.45 c	10.57 a	6.47 c
0.2% CNF	8.07	7.07 b	7.94 c	7.30 a
0.3% CNF	7.90	6.93 b	10.84 a	6.95 b
0.4% CNF	7.65	6.30 c	9.81 b	7.42 a
CV (%)	4.86	3.66	2.91	1.90
LS	NS	**	**	**

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically different at the 5% level of probability ($p<0.05$).

4.10. Disease incidence and disease severity

Additionally, the trend towards greater illness severity was growing daily. In order to determine the percentage of disease severity, Shahi papaya was stored using postharvest chitin nanofiber treatments, which had a highly significant impact on the gap between storage periods (Appendix). At 3 DAS, no disease severity was seen in 0.1% chitin nanofiber (CNF) treatment (T1), 0.2% CNF treatment (T2), 0.3% CNF treatment (T3), and 0.4% CNF treatment (T4). The highest disease severity (80.00%) was examined in control fruits. On the ninth day of storage, the control group showed the highest illness severity (53.96%), whereas the 0.3% chitin nanofiber treatment showed the lowest disease severity (45.77%).

It is mostly made up of polysaccharides and serves as a natural defence against oxygen and moisture, which are the primary causes of fruit and vegetable deterioration (Mishra et al. 2014). They noticed that diseases diversity of tomato. Thesis was Biocontrol of tomato leaf curl virus (ToLCV) in tomato with chitosan supplemented formulation.

Table 4.10. Effect of chitin nanofiber (CNF) concentration on disease incidence and disease severity of papaya at 9 DAS

Treatments	Disease incidence (%)	Disease severity (%)
Control	62.5	15.32
0.1% CNF	54.17	20.69
0.2% CNF	66.67	21.21
0.3% CNF	50	22.52
0.4% CNF	44.17	13.75
CV (%)	16.47	20.85
LS	NS	NS

NS stands for non-significant; CV for coefficient of variation; LS for level of significance; ** for significant at the 1% level of probability. The Tukey's Honestly Significant Difference Test indicates that treatment means in a column with a dissimilar letter or letters are statistically different at the 5% level of probability ($p<0.05$).

4.11. Identification and isolation of pathogens from infected fruits

Figure 4.1. Photograph of *Colletotrichum gloeosporioides* isolated from papaya fruit.

In order to identify the causative organisms, infected fruits from various postharvest CNF treatments were examined in the Laboratory of Plant Pathology, Agrotechnology Discipline, Khulna University. The contaminated fruits were used to create semi-permanent slides. Colletotrichum gloeosporioides was the primary cause of infection in the majority of the fruits.

Additionally, according to Miller and McDonald (1999), 1/3 of yellow-colored fruits showed more signs of decay than mature green apples. This is likely due to the higher frequency of peel damage sustained during handling; decay organisms are known to infiltrate fruit at injury sites.

4.12. Shelf life

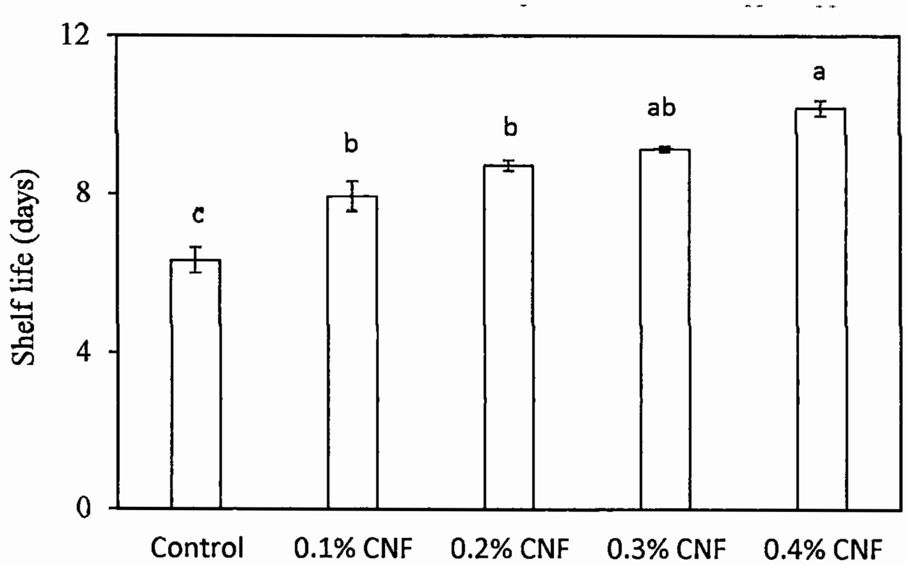

Fig. 4. 2. Shelf life of papaya as affected by chitin nanofiber (CNF) treatments. The error bar represents mean ± standard error (SE) of three measurements. Different letter(s) on a bar represent statistically significant difference at 5% level of probability according to Tukey's HSD Test.

The papaya fruit's shelf life varies depending on the treatment. 0.4% CNF had the longest shelf life (10.17 days), which was statistically comparable to 0.3% CNF (9.14 days), 0.2% CNF (8.72 days), and 0.1% CNF (7.92 days) (Fig. 4.2).

Papaya from the untreated control had the shortest shelf life (6.31 days) (Fig. 4.2).

Various postharvest chitin nanofiber treatments have a substantial impact on the shelf life of the Shahi papaya variety (Appendix). One of the experts' top focusses has been extending the shelf life of fruits. According to the results, papaya fruits treated with 0.4% chitin nanofiber had the longest shelf life (10.17 days), followed by the control treatment (9 days).

The shortest shelf life of 6.31 days was observed from the control treatment fruits. (8.72 days) and (9.14 days) also produced from both postharvest treatments of 0.2% chitin nanofiber (CNF) treatment and 0.3% CNF treatment. Other postharvest 0.1%CNF treatment showed (7.92 days) in shelf life.

All the postharvest treatments of CNF treated fruits of papaya var. Shahi showed the following ranking order for shelf life 0.4% CNF treatment (10.17 days) > 0.3% CNF treatment (9.14 days) > 0.2% % CNF treatment (8.72 days) > 0.1% % CNF treatment (7.92 days) > control (6.31 days). Reduced weight loss, little disease severity, and a slower rate of physico-chemical alterations may have contributed to the 0.4% CNF treatment's longest shelf life.

CHAPTER V

SUMMARY

At the Fruit Germplasm Centre of the Agrotechnology Discipline, Khulna University, Khulna, an experiment was carried out from January 29 to February 14, 2024, to examine the effects of concentration of CNF treatment to control postharvest fungal infection, shelf-life extension, and quality retention of papaya. One factor experiment consisted of maturity stages at T_0 = Control T_1 = 0.1%CNF treatment, T_2 = 0.2% CNF treatment, T_3 = 0.3% CNF treatment, T_4 = 0.4% CNF treatment. The experiment was laid out in a completely randomize design.

The objectives of the experiment were to develop appropriate storage method and maintain quality of fruits during storage. Fruit characteristics such as colour, shelf life, physio-chemical characteristics like total weight loss, TA, vitamin C content, and diseases incidence and severity were observed. The physio-chemical data were recorded at alternate days during storage.

The postharvest quality of papaya was significantly impacted by both maturity stages and CNF treatments. Keeping up on the 3rd, 6th, 9th, and 12th days of storage, papayas were turning from green to pale green, greenish yellow, light greenish yellow, and yellow, among all other postharvest treatments. Its shelf life was limited since it was fully matured after 12 days of storage. Vitamin C, titratable acidity, TSS, disease incidence, and disease severity were all strongly impacted by maturity stage.

Significantly, the maximum (14.51%) weight loss occurred with the control and 1the minimum (11.56%) weight loss occurred in the 0.2% CNF treatment at 12 DAS. At the 12 days after storage, the highest (9.13%) TSS content was also observed in control fruits and the lowest (8.30%) in 0.1% CNF treatment. The highest Titratable acidity content (5.20%) in 0.4% CNF treatment and the lowest amounts (4.18%) in control treatment at 12 days after storage condition.

Higher Vitamin C (7.42%) were found in 0.4% CNF treatment than 0.1% CNF treatment (6.47%) at the 12 days of storage. Vitamin C content was decreasing gradually in the storage of papaya.

In order to determine the percentage of disease severity, CNF treatments were applied to Shahi papaya. These treatments had a highly significant impact on the gap between storage periods. At three days of storage, no disease severity was seen in the extracts treated with 0.1% CNF (T1), 0.2% CNF (T2), 0.3% CNF (T3), and 0.4% CNF (T4). The highest disease severity (80.00%) was examined in control fruits. On 9th DAS, the control group showed the highest disease severity (53.96%), whereas the 0.3% CNF treatment showed the lowest disease severity (45.77%).

In order to identify the causative organisms, infected fruits were extracted from various postharvest chitin nanofiber (CNF) treatments and examined in the Laboratory of Plant Pathology, Agrotechnology Discipline, Khulna University. The contaminated fruits were used to create semi-permanent slides. *Colletotrichum gloeosporioides* was the primary cause of infection in the majority of the fruits.

The development phases have a significant impact on the papaya's color ratio, shelf life, and quality. After 12 days of papaya storage, the maximum color (3.75%) was seen with a 0.2% chitin nanofiber (CNF) treatment, and the lowest color (3.11%) was seen with a 0.1% CNF treatment.

The development phases had a significant impact on the papaya's colour ratio, shelf life, and quality (Appendix). The highest color showed (3.75%) in 0.2% CNF treatment and lowest color showed (3.11%) in 0.1% CNF at 12 days storage of papaya.

The highest firmness (4.43%) in 0.3% CNF treatment and the lowest firmness (3.11%) in control treatment at 12 days storage condition. Significant variation was recorded between storage stage at 3, 6, 9, 12 days after storage condition of papaya.

At the very end of the storage period, it was discovered that the application of CNF and maturity stage treatments had a substantial impact on nearly every parameter examined, with the exception of titratable acidity. Following treatments, the peel's colour changed from light greenish to yellow.

Various postharvest treatments of CNF had a substantial impact on the shelf life of the Shahi variety (Appendix). One of the experts' top focuses has been extending the shelf life of fruits. In terms of shelf life, the 0.4% CNF treatment lasted the longest (10.17 days), followed by the control treatment (6.31 days). With an average shelf life of 6.13 days, the fruits in the control treatment had the shortest shelf life. The postharvest treatments of 0.2% and 0.3% chitin nano-fiber also produced results of 8.72 days and 9.14 days, respectively. Another 0.1% chitin nanofiber postharvest treatment had a 7.92-day shelf life.

Every papaya variety fruit was treated with chitin nano-fiber postharvest. For shelf life, Shahi papaya displayed the following rating order: 0.4% chitin nanofiber (CNF) treatment (10.17 days) > 0.3% CNF treatment (9.14 days) > 0.2% CNF treatment (8.72days) > 0.1% CNF treatment (7.92 days) > control (6.31 days). The 0.4% CNF treatment had the longest shelf life, which was likely due to the decreased rate of physico-chemical changes, less weight loss, and less severe disease.

CHAPTER VI

CONCLUSION

0.4% concentration of the CNF treatments improved shelf life, reduced disease incidence and severity, and preserved fruit firmness, colour, TSS, and vitamin C. CNF (0.4%) increased the shelf life of papaya fruit by 3.86 days compared to control. Therefore, 0.4% CNF can be chosen for postharvest quality management of papaya. However, further experiments are suggested for the final recommendation.

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APPENDICES

Appendix 1. Analysis of variance (mean square) of the data for fresh weight at different days after storage of papaya chitin nano- fiber.

Source of variation	df	Fresh weight (g)			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	341.16**	9.166**	156.43**	175.73**
Error	10	23.942	1.733	9.467	36.20
Total	14				

** = Significant at 1% level of probability

Appendix 2. Analysis of variance (mean square) of the data for percent weight loss at different days after storage of papaya chitin nano-fiber.

Source of variation	df	Weight loss (%)			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	0.000049NS	1.957**	3.96**	4.498**
Error	10	0.000070	0.010	0.61	0.844
Total	14				

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Appendix 3. Analysis of variance (mean square) of the data for TSS at different days after storage of papaya chitin nano-fiber.

Source of variation	df	TSS (%brix)			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	1.385NS	2.570**	1.536**	0.307**
Error	10	1.232	0.312	0.047	0.022
Total	14				

** = Significant at 1% level of probability, NS = Non-significant

Appendix 4. Analysis of variance (mean square) of the data for TA at different days after storage of papaya chitin nano-fiber.

Source of variation	df	TA			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	0.0831*	1.662*	0.6523**	0.503**
Error	10	0.0412	0.379	0.0241	0.022
Total	14				

** = Significant at 1% level of probability, * = Significant at 5% level of probability

Appendix 5. Analysis of variance (mean square) of the data for vitamin C (mg/100) at different days after storage of papaya chitin nano-fiber.

Source of variation	df	Vitamin C (mg/100 gm)			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	0.0831NS	1.111**	3.873**	0.510**
Error	10	0.1483	0.064	0.082	0.017
Total	14				

** = Significant at 1% level of probability, NS = Non-significant

Appendix 6. Analysis of variance (mean square) of the data for dry weight at different days after storage of papaya chitin nano-fiber.

Source of variation	df	Dry weight (g)			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	1.655NS	0.000006NS	0.00095**	0.000014**
Error	10	3.648	0.000004	0.0000802	0.0000021
Total	14				

** = Significant at 1% level of probability, NS = Non-significant

Appendix 7 Analysis of variance (mean square) of the data for percent severity at different days after storage of papaya chitin nano-fiber.

Source of variation	df	% Disease severity			
		3 DAS	**6 DAS**	**9 DAS**	**12 DAS**
Treatment	4	3.750**	40.453**	34.422**	186.87NS
Error	10	0.450	3.101	0.553	60.828
Total	14				

** = Significant at 1% level of probability, NS = Non significant

Appendix 8 Analysis of variance (mean square) of the data for color at different days after storage of papaya chitin nano-fiber.

Source of variation	df	Color			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	4	0.155**	0.0359**	0.0384**	0.1642**
Error	10	0.006	0.0031	0.0036	0.0072
Total	14				

** = Significant at 1% level of probability, * = Significant at 5% level of probability

Appendix 9. Analysis of variance (mean square) of the data for colorimeter at different days after storage of papaya chitin nanofiber.

Source of variation	df	Colorimeter at different days after storage									
		3 DAS					6 DAS				
		l	a	b	c	h	l	a	b	c	h
Treatment	4	1.273*	0.966*	1.906**	3.814**	4.330**	1.499*	0.414*	2.438**	2.162**	2.023NS
Error	10	0.272	0.238	0.388	0.272	0.312	0.392	0.107	0.285	0.388	0.713
Total	14										

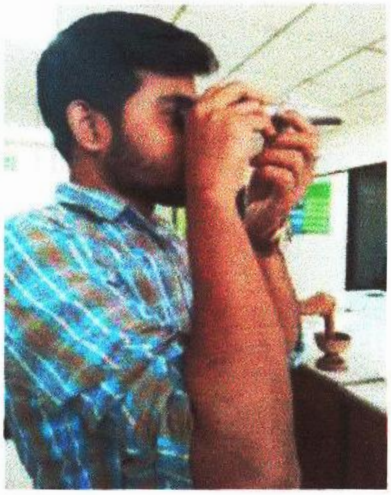
** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Non-significant

Appendix 10 Analysis of variance (mean square) of the data for colorimeter at different days after storage of papaya chitin*****

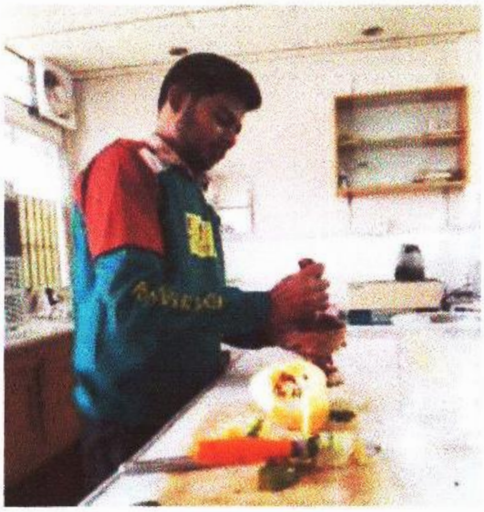
Source of variation	df	Colorimeter at different days after storage									
		9 DAS					12 DAS				
		l	a	b	c	h	l	a	b	c	h
Treatment	4	6.057**	0.143NS	18.97**	17.569*	8.443**	4.278**	16.36**	11.11**	17.032**	95.72**
Error	10	0.724	0.457	0.440	4.9128	0.665	0.355	0.071	0.426	0.399	1.601
Total	14										

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Non-significant

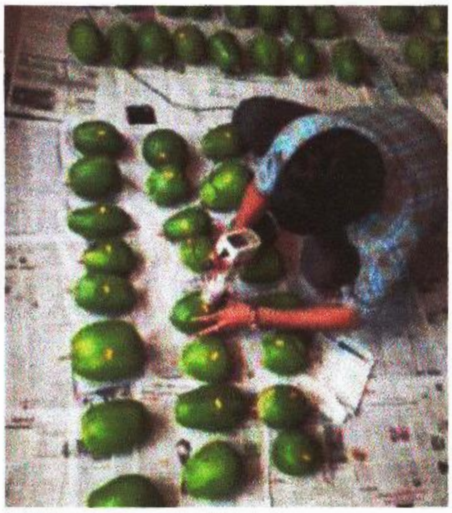
Photograph 1: Weight measurement of papaya



Photograph 2: TSS measurement of papaya



Photograph 3: Grinding of papaya



Photograph 4: Color measurement by colorimeter