EFFECT OF BOTANICAL EXTRACTS ON SHELF LIFE AND QUALITY OF PAPAYA (*Carica papaya* L.)

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of

MASTER OF SCIENCE IN HORTICULTURE

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

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DEDICATED TO

My Beloved Parents

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ABSTRACT

The study was conducted to develop an appropriate storage method and investigate the pattern of physico-chemical changes and shelf life of Shahi papaya under different storage conditions. The experiment was carried out at the Germplasm Centre, Plant Pathology and Molecular Horticulture Laboratory of the Discipline of Agrotechnology, Khulna University, Khulna during the period from April to May, 2013, to investigate the effect of different postharvest treatments of plant extract on fruit characteristics, physico-chemical changes, disease incidence and severity and shelf life of papaya cv. Shahi. The experiment comprised of six plant extract treatments including control viz., control (T_1), onion (T_2), neem (T_3), garlic (T_4), bishkantali (T_5), datura (T_6) extracts. The single-factor experiment was laid out in completely randomized design (CRD) with three replications. Among the physico-chemical parameters such as TSS, weight loss and dry matter content increases significantly whereas pulp to peel ratio, moisture content decreases during storage in all treated and untreated fruits. There was significant increasing tendency was also obtained in relation to disease incidence and severity. Among the physico-chemical parameters, garlic extract treated fruits of Shahi papaya produced significantly the maximum pulp to peel ratio 3.82. It was also observed that the lowest total soluble solid (11.27%), was in garlic treated fruits. Per cent of total weight loss was lowest in garlic extract treated fruits (36.18%), highest moisture content was in datura extract treated fruits (76.67%). Per cent dry matter content of fruits was higher in bishkantali extract treated fruits (29.67%). Postharvest disease was severe at 10 DAS it was the maximum (100%) in untreated and datura treated fruits where the minimum (59.33%) was in bishkantali treated fruits and it was increase 80% up to 14 DAS. Botanical extracts showed highly significant variation in the shelf life of papaya. On the basis of storage performance, garlic extract resulted in the longest shelf life (15.95 days) and shortest (8.67 days) was recorded in untreated fruits preceded by those kept in neem extract (10.98 days), onion extract (12.82 days), datura extract (13.00 days), and bishkantali extract (14.90 days), respectively.

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has made its way from kitchen gardens to that of commercial orchards in many tropical and subtropical countries because of its highest production of fruits and contributed an income next to banana. Papaya has been called as 'common man's fruit' which is a nutritious table fruit of high digestive value and rich in vitamins and minerals. It is a good source of vitamin A, vitamin C and calcium (Nakasone and Paull, 1998; Hayes, 1993 and Arriola *et al.*, 1980). The amount of vitamin A in papaya is the second highest among fruits and comes next to mango (Aykroyed, 1951). It contains fair quantities of vitamin C, some riboflavin and niacin and it is a good source of calcium, phosphorus and iron. Bose (1985) reported that papaya contains 89.6% moisture, 0.5% protein, 0.1% fat, 9.5% carbohydrate, 0.01% calcium, 0.01% phosphorus, 2020 IU/g vitamin A, 40 mg/100 g vitamin C and 0.2 mg/100 g nicotinic acid. 'Papain' is one of the most powerful plant proteolytic enzymes obtained from papaya fruits (Hami, 1960). The raw fruits contain an alkaloid or proteolytic enzyme 'Papain', which is a commercial product of several tropical American nations and is useing in several medicine and food preparations. Economically, Carica papaya is the most important species within the Caricaceae, being cultivated widely for consumption as a fresh fruit and for use in drinks, jams, candies and as dried and crystallized fruit (Villegas, 1997). Green fruit and the leaves and flowers may also be used as cooked vegetable (Watson, 1997). Apart from the fruit, papaya leaves also have some medicinal values and the roots are used to cure typhoid fever and piles, the stem and bark can be used for making ropes. The other uses include extraction of oils as a source of protein and in medicine to thirst and as a vermifuse. Papaya is known for its fine and natural laxative virtue which aids digestion. Papaya are rich in enzymes called 'papain' and 'chymopapain' that break down the proteins from the food a person eats into amino acids and therefore helps digestion. The anti-inflammatory properties and high antioxidant content of papaya is known to prevent cholesterol oxidation and can be used in preventative treatments against strokes, heart

An experiment was carried out by Chadha *et al.* (1972), at Banglaore in India, with pineapple fruits of different stage of maturity in respect of physico-chemical changes in them, concluded that very young pineapple had a high TSS.

2.1.4. Pulp to peel ratio

Uddin and Hossain (1993) carried out an experiment on the pineapple fruits (cv. Giant Kew) in the field laboratory of BARI at Joydebpur. They found that pulp to peel ration increased up to 15 days of storage after which it decreased slightly.

Tripathi *et al.* (1981) mentioned an increase in pulp to peel ration during ripening. The reason for this was explained by him that the pulp increase in weight due to an increase in water content. This water is obtained from the peel and probably also from the stalk. This causes weight loss in peel with concomitant rise in pulp to peel ratio.

2.2. Effect of plant extract on disease incidence and severity

Echerenwa and Umechuruba (2004) carried out an experiment on postharvest fungal diseases of papaya (*Carica papaya* L.) fruits and the following fungi were isolated from the tissues of diseased fruits: *Fusariurn solani, Phoma caricae* papayae, *Aspergillus flavus, Aspergillus niger, Botrrydiplodia theobrimae, Cladosporium herbarurn, Colletotrichum dematiurn, Fusarium moniliforme (Gibberella moniliformis,), Phornopsis caricae-papavae, Penicilliurn sp.*, and *Rhizopus stlionifer* and *F. solani* caused the greatest rot on the fruits.

Muniz *et al.* (2003) conducted an experiment to identify the fungal diseases on eight different fruit cultivars during storage. The fungi were isolated on PDA medium and

Singh *et al.* (2000) studied the effect of plant extract, castor oil and neem oil on storage behaviour of mango (*Mangifera indica*) cv. Langra and reported that the treatment of neem oil (10%) showed the minimum physiological weight loss when compared to other treatments and controls, wherein, the maximum physiological weight loss (17.28%) was recorded on the 12^{th} day of storage.

Maqbool *et al.* (2011) were studied on the management of anthracnose caused by *Colletotrichum spp.* Antifungal effects of gum arabic (GA) (10%), lemongrass oil (LG) (0.05%), cinnamon oil (CM) (0.4%), and their combinations were investigated *in vitro* and *in vivo* for controlling postharvest anthracnose of banana and papaya. LG at 0.05% and 0.4% CM showed fungicidal effects against *Colletotrichum musae* and *Colletotrichum gloeosporioides*, causal organisms of banana and papaya anthracnose, respectively. The results suggest the possibility of using 10% gum arabic combined with 0.4% cinnamon oil as a biofungicide for controlling postharvest anthracnose in major tropical fruit such as banana and papaya.

Anthracnose, caused by *Colletotrichum gloeosporioides*, a fungal pathogen. It infects new flushes of leaves or may occur at the various stages of development from fruit set to maturity. The disease is common during wet season as it spreads and reproduces rapidly specially in warm areas. At present, pesticide is the most widely recommended and adopted method of controlling the pest. Ines *et al.* (2008) evaluated the efficacy of promising plant materials against anthracnose of Hawaiian and native mango seedlings. The Plant materials evaluated were neem (*Azadirachta indica A.* Juss), 'Malunggay' (*Moringa oleifera* L.), and garlic (*Allium sativum*). The effect of the Plant extracts was compared with those of untreated plants and fungicide-treated plants.

Meah (2007) stated that garlic clove completely arrested that mycelia growth and spore germination of *Phomopsis vexans* and produced larger inhibition zeones (5.7 cm and 5.5 cm diameter, respectively) in *in vitro* tests. In the nursery, garlic bulb extracts completely controlled damping off and seedling blight and promoted seed germination.

Hossain (2007) conducted an experiment and showed that tablets of garlic clove extract were evaluated for controlling *Phomopsis* blight and fruit rot of brinjal cv. Laffa(s) caused by *Phomopsis vexans.* Five different doses of garlic tablet viz. 1:1, 1:2, 1:3, 1:4 and 1:5 were applied at pre-flowering, fruiting and ripening stage. All the doses showed good results. The lowest percent leaf infection (11.49%), percent leaf area diseased (1.07%), percent fruit infection (26.33%) and lesion size (1 cm^2) was recorded in 1:4 spray dose.

Inoculating orange fruits with the *Trichoderma hamatum, Trichoderma harzianum* and *Bacillus subtilis* as biological control agents reduced the severity of fruit rot, with considerable decrease in fruit acidity. These changes differed according to the concentration of the tested biological control agents (Eisa *et al.*, 2001; Abd-El-Aziz and Mansour, 2006).

Dhali (2006) showed that garlic tablets treatment controlling *Phomopsis* blight and fruit rot of *Solanum melongena* cv. Dohazari caused by *Phomopsis vexans* was evaluated different doses (1:1, 1:2, 1:3 and 1:4 w/v) at three crop growth stage. Among four doses, 1:4 w/v concentration garlic was found most effective to reduce incidence and severity of leaf and fruit infection. The effect of allamanda extract was also promising against fungi (Khan, 1999; Meah *et al.*, 2002).

Hernandez-Castro *et al.* (2005) conducted an experiment on the effect of neem extracts on feeding behavior of Aphis nerii, as well as Papaya Ringspot Virus (PRSV-p) transmission, was determined. We evaluated papaya seedlings sprayed under laboratory conditions with a 10% aqueous extract of unpeeled neem seed and with a water control. Two time periods, exploratory (0 to 3 min) and feeding (>3 to 20 min), were used to evaluate aphid feeding behavior. Aphid mortality was determined 24 h after spraying. Viral transmission was measured by ELISA tests. No significant differences ($p > 0.05$) were obtained in the exploratory feeding behavior. However, significantly more aphids ($p < 0.05$) stopped feeding on neem-sprayed plants from the >3 to 20 min period. Also, higher ($p < 0.05$) aphid mortality (37% vs. 10%) was found in neem-sprayed plants. However, no significant differences ($p > 0.05$) were found in PRSV-p transmission, thus indicating that neem seed aqueous extracts did not prevent viral transmission.

Bagwan (2001) stated that treatment of banana fruits with neem extract (*Azadirachta indica*) for 5 minutes were most effective for controlling various post harvest disease of banana. The use of crude plant extracts as an alternative to commercial fungicides in the control of capsicum anthracnose as estimated by (Singh *et al.*, 1999) 5000ppm on *capsicum annum* was compatible with the fungicide carbendazim (Bavistin) at 1000 ppm.

Ashrafuzzaman and Khan (1992) studied the sclerotial formation and mycelia growth of *Rhizoctonia solani in vitro*. They found no sclerotial formation using garlic extract against abundant sclerotial formation in case of control. However, the effects of garlic extract on postharvest disease reduction is scantly.

Fakir and Khan (1992) reported that seed treatment with garlic bulb extracts at different concentrations significantly reduced seed borne infection of *Macrophomina phaseolina, Colletotrichum corchori* and *Fusarium* spp. in jute. Both concentration of garlic extract and vitavax 200 were more or less equally effective in controlling *Macrophomina phaseolina* reducing 90.9% and 87.9% seed borne infection respectively. More than 80% control of seed borne infection of *Fusarium* spp. was achieved with 1:4 garlic extract. Emeruwa (1982) reported that the ripe and unripe *Carica papaya* fruits (epicarp, endocarp, seeds and leaves) were extracted separately and purified. All the plant extracts except that of leaves produced very significant antibacterial activity on *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Pseudomonas aeruginosa* and *Shigella flexneri.* The MIC of the substance was small (0.2-0.3 mg/ml) for gram-positive bacteria and large (1.5-4 mg/ml) for gram-negative bacteria. The substance was bactericidal and showed properties of a protein. Other proteins previously found in C. *papaya* did not show antibacterial activity.

Sing and Dwivedi (1987) observed that hyphal dry weight and sclerotic production of *Sclerotium rolfsii* sace were significantly reduced by leaf extracts of neem. They conducted an experiment to compare antifungal property of garlic clove juice with recommended dose of fungicidal treatments against Fusarium wilt of watermelon. They reported that garlic extract inhibited spore germination and mycelial growth of *Fusarium oxysporum f.sp. niveum* in extent similarly to five different fungicides.

2.3. Effect of plant extract on shelf life

Shelf life is the period of time which start from the time of harvesting and extend up to the start of rotting of fruit (Mondal, 2000), and it is the basic quality of fruit as well as it is the most important parameter in lose of reduction biochemical reaction of fruit.

Bose and Mitra (1996) stated that in tropical climate pineapple fruits could be stored for up to 10 days under ambient condition.

Wijewardane and Guleria (2009) were investigated on the use of natural flora as one of the sources for crop protection. The fruits were analyzed for physicochemical and physiological characters such as loss in weight, fruit firmness, total soluble solids (TSS) content, titratable acidity (TA), pH, content of reducing sugars etc. The results revealed that, the surface-coating of apple with 2% neem oil together with shrink-wrapped tray packing provided better retention of storage life of fruit and the treatment effect on physico-chemical characteristics of fruits were significant.

An experiment was conducted by Shakila and Anburani (2009) to know the effect storage temperature (5, 10, 15, 25°C and at ambient temperature or control) on quality and shelf life of papaya. It was observed that fruits subjected to storage temperatures of 5 and 10°C failed to ripen, while fruits stored at 15°C ripened normally. The fruits stored at 25°C and at ambient temperatures ripened on 7^{th} and 5^{th} day after storage respectively. Assessment of quality parameters like TSS, reducing and non-reducing sugars, total sugars and ascorbic acid revealed that fruits stored at 15°C and ripened thereafter registered the highest values for all the quality parameters.

Osuna-Garcia *et al.* (2005) observed the effects of 1-methylcyclopropene (1-MCP; 1,100 and 200 ml/litre) on the shelf life and quality of papaya cv. Maradol, stored for 4 days at room temperature, 4 days under refrigerated conditions and 6 more days at room temperature. Alongside this, the effects of 200 ml 1- MCP/ litre on the shelf life and quality of papaya compared to a control were determined. Under room and refrigerated conditions, 1-MCP increased the shelf and quality life of papaya by inhibiting weight losses, delaying the development of external and internal color and evolution of soluble solids. The treatment also reduced the incidence of diseases and maintained fruit firmness for a longer time.

Singh *et al.* (2003) also reported the effect of various plant extracts such as neem leaves, castor oil and neem oil on citrus fruits and identified neem leaf extract as the best in retaining most of the biochemical characteristics and shelf life.

The shelf life of fruits was maximum (19.33 days) at 13°C followed by zero energy cool chamber (8.33 days) and the least was under ambient condition (8.67 days) compared to control. Non significant variation was observed for total soluble solids (TSS) of fruits under all the 3 storage conditions. The acidity increased gradually up to the end of green life and the decreased or remained the same until the end of yellow life. Reducing sugars and total sugars increased gradually throughout the storage period and was maximum in the control (Narayana *et al.*, 2002).

Biochemical reaction known to continue in harvested fruit until ripened, this process cannot be stopped. These biochemical reactions decreased free energy and increase the randomness of the system (Salunkhe and Desai, 1984). Geetha and Thirumaran (2010) concluded that the shelf life of the fruits increased under vacuum packing with room and

refrigeration temperatures for one and four weeks, respectively. During storage moisture, acidity, vitamin C and total sugar decreased whereas reducing sugar and total soluble solids (TSS) increased

An experiment was conducted by Rahman *et al.* (1979) with pineapple fruits (cv. Giant Kew) at BCSIR laboratory to study the changes in physiological and biochemical characteristics in full-ripe fruits during storage and observed that the fruits retained their shelf life for 12 days when stored under ambient temperature of between 30-32^{O}C.

From the above reviews, it is clear that quite large volumes of works have been done in different parts of the world. Different issues related to the physico-chemical changes, shelf life extension, and diseases have been cited in the above. The similar reports are scanty in Bangladesh. Very little information available in Bangladesh with the regards to the use of plant extracts as a postharvest treatment on physico-chemical changes, shelf life and diseases during storage and ripening. Hence, the present study attempts to investigate the physico-chemical changes, shelf life and quality maintenance of papaya using different promising postharvest treatments of plant extract.

CHAPTER III
MATERIALS AND METHODS

The present experiment was conducted at the Germplasm Centre of the Agrotechnology Discipline, Khulna University, Khulna during the period from April to May, 2013 to study the shelf life and quality changes of papaya cv. BARI papaya-1 (Shahi) as influenced by promising postharvest treatments of botanical extract. The detailed methodology followed to conduct the experiment is described in the following.

3.1. Atmospheric conditions of storage room

The temperature and relative humidity of the storage room were recorded daily during the study period with a digital thermo hygrometer (THERMO, TFA, Germany). The minimum and maximum temperatures during the study period of the storage room were 24.0 to 33.5°C, respectively. The minimum and maximum relative humidities were 67 and 98%, respectively (Appendix I).

3.2. Experimental Materials

One variety of papaya, namely BARI Papaya 1 (Shahi) was selected as experimental materials for this present study which was collected from Horticulture Centre of Jessore district. Commercially mature hard fruits of papaya were harvested on 20 April, 2013. Maturity of papaya was identified by external features i.e. when the latex of the fruits became watery and the color of the fruit was pale green that indicated maturity of papaya. A short description of one variety of papaya under the study is given below.

3.2.1. Shahi papaya

In 1992, BARI developed an improved variety of papaya from the line p-011 named 'Shahi' and recommended for commercial cultivation in Bangladesh. This is a dioecious variety and the plant bears fruit low on the trunk. Three female flowers appear in one cluster with a dense and alternate cyme type inflorescence in the leaf axil. The stem color is greenish and the color of the leaves is bottle green with a light green petiole. The fruit shape is round to ovate, large size, flattened base, not so prominent apex, smooth and glabrous, deep green in mature stage but greenish yellow in ripe stage, peel thick sweet, medium juicy, crispy, pleasant aroma, fibreless light orange pulp at pre-ripe stage but deep orange red in ripe, more number of seeds, seed size medium and average fruit weight 2 kg (Roy, 2003).

3.3. Postharvest treatments (6)

a) Control (T_1)

b) Onion extract (T_2)

c) Neem extract (T_3)

d) Garlic extract (T_4)

e) Bishkantali extract (T_5)

f) Datura extract (T_6)

3.4. Experimental design

Single factor (6 levels) experiment was laid out in a completely randomized design (CRD) with three replications. The postharvest treatments were assigned randomly in each replication. The fruits were carefully selected during the harvesting time. 10 (Ten) fruits were in each replication. Thus, there was $6 \times 3 \times 10 = 180$ papaya in this experiment. Five of them were kept to record shelf-life, changes in weight, colour and other external

fruit characteristics. The remaining five fruits were kept for recording the data on different characteristics at different dates.

3.5. Preparation and application of postharvest treatments

The postharvest treatments of plant extract used in the storage were sequentially assigned to the collected fruits. After applying the treatments, fruits were kept on a brown paper which was previously laid out in completely randomized design and placed on the laboratory floor at ambient conditions. To ensure the application of different storage treatments to the fruits of the variety, the following procedures were adopted.

3.5.1. Control (T_1)

Thirty fruits (ten fruits of each replication) were selected randomly from a lot of papaya and the fruits were kept on brown paper of the laboratory floor at ambient condition arranging at random by replication.

3.5.2. Onion extract (T_2)

Randomly 30 fruits were separated from the experimental fruit lot. The seperated fruits were then individually dipped in prepared onion extract and placed on the laboratory table at ambient condition for observation.

Extract preparation: Initially stock of onion bulb extract (500 g onion bulb and 500 ml water) was prepared by crushing the fresh bulbs in water using a blender through straining and then cheesed. The stock extract was then used to prepare treatment concentrations of 1:1 (500 ml stock : 500 ml water). The fruits were then dipped into the treatment solutions for 5 minutes to ensure that enough quantity of extract being

absorbed. The treated fruits were allowed to air dry for a period of 10 min and then kept on brown paper for observation.

3.5.3. Neem extract (T_3)

Thirty fruits were randomly seperated from the experimental fruit lot. The selected fruits were then individually dipped in neem extract and placed on the table of the laboratory at ambient condition for observation.

Extract preparation: Initially stock of neem extract (400 g leaves crushed with 400 ml water) was prepared by crushing the fresh leaves in water using a blender through straining and then cheesed. The stock extract was then used to prepare treatment concentrations of 1:1 (400 ml stock : 400 ml water). The fruits were then dipped into the treatment solutions for 5 minutes to ensure that enough quantity of extract being absorbed. The treated fruits were allowed to air dry for a period of 10 min and then kept on brown paper for observation (Mia, 2003).

3.5.4. Garlic extract (T_4)

Randomly 30 fruits were separated from the experimental fruit lot. The selected fruits were then individually dipped in prepared garlic extract and placed on the laboratory table at ambient condition for observation.

Extract preparation: Initially stock garlic extract (400 g garlic cloves and 400 ml water) was prepared by crushing the fresh cloves in water using a blender through straining and then cheesed. The stock extract was then used to prepare treatment concentrations of 1:1 (400 ml stock : 400 ml water). The fruits were then dipped into the

treatment solutions for 5 minutes to ensure that enough quantity of extract being absorbed. The treated fruits were allowed to air dry for a period of 10 min and then kept on brown paper for observation.

3.5.5. Bishkantali extract (T_5)

Randomly 30 fruits were separated from the experimental fruit lot which were then individually dipped in Bishkantali extract and placed on the table of the laboratory at ambient condition for observation.

Extract preparation: The leaf of Bishkantali were used for this extract where it was prepared by crushing the fresh leaves in water using a blender through straining and then cheesed. After that the 1000 g leaf extract of Bishkantali crushed with 1000 ml water and mixed properly using blender. The created Bishkantali stock extract was then used to prepare treatment concentrations of 1:1 (1000 ml stock:1000 ml water) stock solution. The fruits were then dipped into the treatment solutions for 5 minutes to ensure that enough quantity of extract being absorbed. The treated fruits were allowed to air dry for a period of 10 min and then kept on brown paper for observation (Mia, 2003).

3.5.6. Datura extract (T_6)

Randomly 30 fruits were separated from the experimental fruit lot which were then individually dipped in datura extract and placed on the table of the laboratory at ambient condition for observation.

Extract preparation: Initially stock of datura extract (250 g leaves and 250 ml water) was prepared by crushing the fresh leaves in water using a blender through straining and

then cheesed. The stock extract was then used to prepare treatment concentrations of 1:1 (250 ml stock : 250 ml water). The fruits were then dipped into the treatment solutions for 5 minutes to ensure that enough quantity of extract being absorbed. The treated fruits were allowed to air dry for a period of 10 min and then kept on brown paper for observation (Mia, 2003).

3.6. Organoleptic evaluation

Organoleptic evaluation of fresh papaya pulp at full ripe stage during storage was made by taste panel with a group of 15 male and female students of the university using a questionnaire. The results have presented both in per centage and in acceptable scores.

3.7. Observation

During the entire storage period, the fruits, used for the experiment, were keenly observed everyday but data was recorded on TSS as well as physico-chemical changes during 3, 6, 9 days after storage (DAS) and ripe stage as influenced by different treatments. But 16 days observation was needed for shelf life.

3.8. Stages of physico-chemical analysis during storage

The period from storage and ripe or edible stage were divided into four stages viz 3, 6, 9 DAS and ripe stage or 12 DAS. Each stage being defined by different fruit characteristics as follows:

3.8.1. Three days after storage (TDAS)

Peel color of 'Shahi' was pale green and greenish yellow, consequently. The texture of pulp was semi-hard.

3.8.2. Six days after storage (SDAS)

Peel color of 'Shahi' was greenish yellow and light greenish yellow, consequently and light greenish yellow respectively. The texture of pulp was slight soft.

3.8.3. Nine days after storage (NDAS)

Peel color of 'Shahi' was light greenish yellow and yellow, consequently. The texture of pulp was somehow softer than 6 DAS.

3.8.4. Ripe stage

It is the stage when the fruits are reaching at the most advantageous edible stage. Peel color of 'Shahi' was yellow. The texture of pulp was soft.

3.9. Parameter studied

In this experiment the following parameters of papaya were studied.

I. Colour changes
II. Total weight loss
III. Per cent moisture content
IV. Per cent dry matter
V. Total soluble solids (TSS) content of pulp (% Brix)
VI. Pulp to peel ratio
VII. Disease incidence (percentage of fruits infected)
VIII. Disease severity (percentage of fruits skin infected)
IX. Organoleptic Test
X. Shelf life

3.10. Methods of studying the parameters

External features of papaya like colour changes was recorded visually just after harvesting to 12 DAS of the fruits.

3.10.1. Colour

The changes in colour of papaya were determined using a numerical rating viz. pale green, greenish yellow, light greenish yellow and yellow at 3, 6, 9 and 12 DAS, respectively.

3 .11. Method of studying physico-chemical parameters

Fruits of papaya from each treatment were selected with three replications and four stages of ripening during storage for physical and chemical analysis. Care was taken while collecting the fruits from the storage treatments. Chemical analysis was performed mostly in the Horticulture and Plant Pathology Laboratory of the Agrotechnology Discipline of Khulna University, Khulna. The physico-chemical Parameters were studied through the methods adopted by Ranganna (1979).

3.11.1. Total Weight Loss

The fruits of each treatment were individually weighed by using electrical balance and then kept for storage.

Calculation

Per cent total weight loss was calculated at the four stages by using the following formula-

$$\text{Per cent weight loss (\%WL)} = \frac{IW - FW}{IW} \times 100$$

where,

%WL = Per cent total weight loss

IW = Initial weight of fruits (g)

FW = Final weight of fruits (g)

3.11.2. Moisture content (%)

Ten grams of fruit pulp was weighed by Triple Beam Balance and taken in a Petri-dish from each treatment out of each replication. The Petri-dish placed in an electric oven at 65°C for 72 hours until the constant weight attained. It was then cooled and weighed again.

Calculation

Per cent moisture content of papaya pulp was calculated using the following formula-

$$\text{Moisture content (\%)} = \frac{IW - FW}{IW} \times 100$$

where,

IW = Initial weight of pulp (g)

FW = Final weight of pulp (g)

3.11.3. Dry matter content (%)

Per cent dry matter content of papaya pulp was estimated from the data obtained during moisture estimation using the following formula-

Per cent dry matter = (100 – per cent moisture content).

3.11.4. Total Soluble Solids (% Brix)

TSS content of papaya pulp was estimated by using Abbe's Refractometer. A drop of papaya juice squeezed from the fruit pulp on the prism of the Refractometer. Per cent TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods described by Ranganna (1979).

3.12. Pulp to peel ratio

The fruits were placed at 4 days interval starting 4 days after storing. Pulp to peel ratio was determined by separately weighing pulps and peels of fruits of each treatment and each replication by using electrical balance. The pulp to peel ratio was measured with the following formula-

$$\text{Pulp to peel ratio} = \frac{\text{Weight of fruit pulp}}{\text{Weight of peel}}$$

3.13. Assessment of per cent disease incidence

The fruits were critically examined every day for the appearance of rot. The incidence of fruit rot was recorded every 2nd day. The first count was made at the 6th day of storage. The fruit rot of papaya was identified by the visual comparison with those of the symptoms already published. The incidence of fruit rot was calculated as follows-

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

3.14. Assessment of per cent disease severity

The percentage fruit skin disease was recorded five times starting at the 6 th day of storage. All the infected fruits were selected to determine per cent fruit area infected. The percentage fruit area diseased was measured based on eye estimation. The mean values regarding infected fruit area were calculated, presented and discussed in result and discussion chapter (Roy, 2003).

3.15. Isolation and identification of causal pathogens

Diseased samples from each infected fruits were collected and carried to the Plant Pathology Laboratory of the Agrotechnology Discipline of Khulna University, Khulna. for isolation and identification of the organisms. The collected samples were kept in the refrigerator over night. The visible symptoms and signs on the diseased samples were studied in detail. Diseased fruit samples with typical symptoms were selected and several pieces from the diseased area of the fruit were cut in such a way so that each cut piece possess diseased and healthy tissues. The cut pieces were then surface sterilized in 0.1 per cent $HgCl_2$ solution for three seconds. After disinfection, the materials were washed thrice in sterile water. After wards, the pieces were placed in PDA (Potato Dextrose Agar) plate. Five pieces were placed in each plate and were incubated at room temperature for seven days to grow the pathogen. Seven days after inoculation, a temporary or Semi permanent slide was prepared from the culture. Then the prepared slides were observed under compound microscope for studying the pathogenic structures. The pathogen was identified on the basis of its vegetative and reproductive structures (Roy, 2003).

3.16. Shelf life

Shelf life of papaya fruits as influenced by different storage treatments and variety was calculated by counting the days required to ripe fully as to retaining optimum marketing and eating qualities.

3.17. Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT statistical package. The means for all the treatments were calculated and analysis of variances (ANOVA) for all the parameters were performed by F-test. The significance of difference between the pairs of means was compared by least significant difference (LSD) test at the 1% and 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

The present study was carried out in the Germplasm Centre, Horticulture and Plant Pathology Laboratory of the Agrotechnology Discipline of Khulna University, Khulna. The experimental results due to the application of different postharvest treatments of plant extract were observed which was presented and discussed in this chapter. The data were recorded at 3, 6, 9 DAS and ripe stage on different characteristics of physical, chemical and microbial properties and also shelf life of papaya. These results have been presented in Tables and Figures, and interpretations were made.

4.1. Fruit characteristics of papaya

Various characters of papaya such as shape, size, base of fruits, apex, texture of pulp, colour and thickness of peel were observed for Shahi after the harvest. Those characteristics of the collected Shahi papayas were presented in Plate 1 where the shape, size, base of fruits, apex, texture, colour and thickness in attendance. Shahi papayas shape size was round to ovate; large and medium. In Shahi, the base of the fruits was found flattened. Apex was not so prominent in Shahi. Peel in Shahi was smooth and glabrous (Plate 1a to 1f).

Initially the peel colour was green after that it was changing to different colour at different days after storage. Storage papaya were changing the colour from green to pale green, greenish yellow, light greenish yellow and yellow at 3^{rd}, 6^{th}, 9^{th} and 12^{th} day of storage (Table 1) among the all postharvest treatments. After 12 days of storage, it was fully ripened and decreased the shelf life and pulp to peel ratio.

T_1

T_2

T_3

T_4

T_5

T_6

Plate 1a. Photograph showing differences in external appearance of papaya cv. Shahi under different postharvest treatments at 1st day of storage.

T_1= Control, T_2= Onion extract, T_3= Neem extract, T_4= Garlic extract, T_5= Bishkantali extract, T_6= Datura extract.

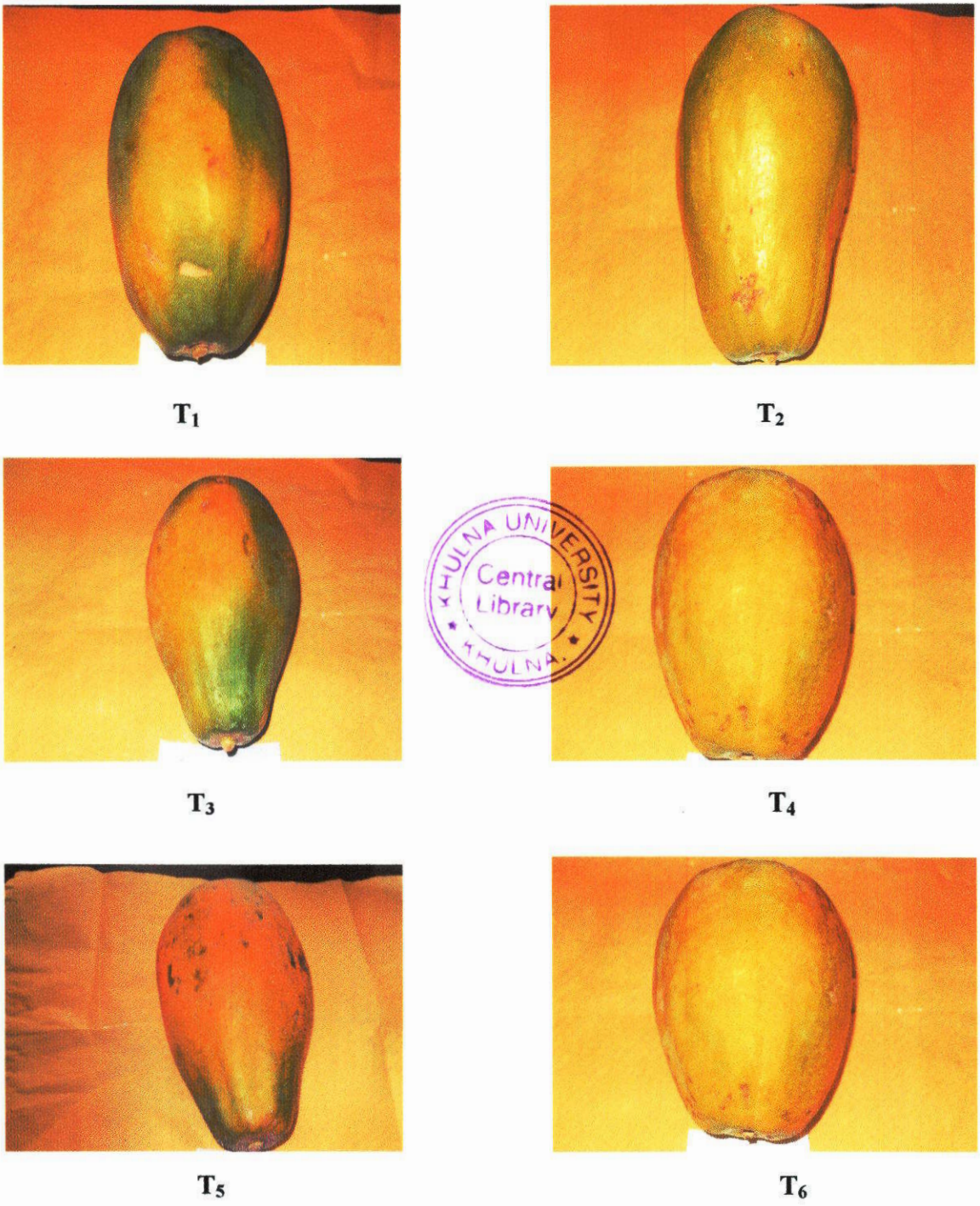

Plate 1b. Photograph showing differences in external appearance of papaya cv. Shahi under different postharvest treatments at 3rd day of storage.

T_1= Control, T_2= Onion extract, T_3= Neem extract, T_4= Garlic extract, T_5= Bishkantali extract, T_6= Datura extract.

T_1

T_2

T_3

T_4

T_5

T_6

Plate 1c. Photograph showing differences in external appearance of papaya cv. Shahi under different postharvest treatments at 6th day of storage.

T_1= Control, T_2= Onion extract, T_3= Neem extract, T_4= Garlic extract, T_5= Bishkantali extract, T_6= Datura extract.

T_1

T_2

T_3

T_4

T_5

T_6

Plate 1d. Photograph showing differences in external appearance of papaya cv. Shahi under different postharvest treatments at 9th day of storage.

T_1= Control, T_2= Onion extract, T_3= Neem extract, T_4= Garlic extract, T_5= Bishkantali extract, T_6= Datura extract.

T_4

T_5

Plate 1f. Photograph showing differences in external appearance of papaya cv. Shahi under different postharvest treatments at 15th day of storage.

T_1= Control, T_2= Onion extract, T_3= Neem extract, T_4= Garlic extract, T_5= Bishkantali extract, T_6= Datura extract.

At 15th day of storage, garlic treated fruit and bishkantali treated fruit showed dark yellow peel color where other fruits which were treated with rest treatments were not in satisfactory level.

Table 1. Effect of plant extracts on colour change of papaya

Postharvest treatments	Colour change			
	3 DAS	6 DAS	9 DAS	12 DAS
Control	Pale Green	Greenish yellow	Light greenish yellow	Yellow
Onion extract	Pale Green	Greenish yellow	Light greenish yellow	Yellow
Neem extract	Pale Green	Greenish yellow	Light greenish yellow	Yellow
Garlic extract	Pale Green	Greenish yellow	Light greenish yellow	Yellow
Bishkantali extract	Pale Green	Greenish yellow	Light greenish yellow	Yellow
Datura extract	Pale Green	Greenish yellow	Light greenish yellow	Yellow

The characteristics of edible portion such as sweetness, juiciness, texture of pulp, aroma and fibreness were also observed at 3rd, 6th, 9th and 12th day of storage. The pulp of Shahi papaya was sweet, medium juicy, crispy with pleasant aroma and fibreless also at 3rd, 6th, 9th and 12th day of storage, respectively. But the pulp color was whitish at 3rd DAS, whitish orange at 6th DAS, light orange at 9th DAS and deep orange red at 12th DAS (Table 2).

Table 2. Organoleptic evaluation of Shahi papaya

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

4.2. Physico-chemical changes of papaya during storage

Different changes of physico-chemical characteristics of papaya that observed in the present study have been discussed and interpreted under the following sub-headings.

4.2.1. Pulp to peel ratio

The plant extracts used in the present study had marked influenced on pulp to peel ratio of shahi papaya. The variations among the treatments means in terms of pulp to peel ratio were significant at the different storage period (Appendix IV). Among the plant extracts, garlic extract produced the maximum pulp to peel ratio (6.01) and the minimum (4.67) was recorded in control treatment at 3 DAS. At 6 DAS, the maximum pulp to peel ratio (5.88) was also obtained from the garlic treated fruit where the minimum (4.43) was recorded in bishkantali treatment. On the other hand, pulp to peel

ratio was the maximum (4.81 and 3.82) in garlic extract and the minimum (3.19 and 3.02) in control treatment at 9 and 12 days after storage, respectively (Table 3). Table 3 indicates that the pulp to peel ratio gradually decreased with the increasing storage period in case of postharvest treatments of plant extract.

Table 3. Effect of plant extracts on pulp to peel ratio of papaya

Postharvest treatments	Pulp to peel ratio			
	3 DAS	6 DAS	9 DAS	12 DAS
Control (T_1)	4.67	4.49	3.19	3.02
Onion extract (T_2)	5.28	4.60	3.37	3.09
Neem extract (T_3)	5.44	4.51	3.30	3.11
Garlic extract (T_4)	6.01	5.88	4.81	3.82
Bishkantali extract (T_5)	5.61	4.43	3.30	3.05
Datura extract (T_6)	5.27	4.55	3.51	3.06
$LSD_{(0.05)}$	0.33	0.36	0.32	0.30
$LSD_{(0.01)}$	0.47	0.50	0.45	0.42
Level of significant	**	**	**	**
CV (%)	3.49	4.26	5.07	5.34

**= Significant at 1% level of probability.

Uddin and Hossain (1993) carried out an experiment on the pineapple fruits (cv. Giant Kew) in the field laboratory of BARI at Joydebpur, Gazipur. They found that pulp to peel ration increased up to 15 days of storage after which it decreased slightly.

4.2.2. Total weight loss of papaya

The changes in weight loss are one of the important indicators for maintaining the quality of fruits. The lessening in weight is predictable to the physiological loss in weight due to respiration and transpiration of water through peel tissue, and other organic changes taking place in the fruit. Highly significant effects, on per cent weight loss of papaya were observed due to the application of different postharvest treatments (Appendix II). Significantly, the maximum (54.19%) weight loss occurred with the control and the minimum (36.18%) weight loss occurred in the garlic treatment at 12 days after storage. The maximum (10.49%, 21.98% and 33.53%) weight loss was recorded in datura treatment where the minimum was in garlic treatment (7.98%, 12.81% and 22.56%) at 3rd, 6th and 9th days after storage, respectively (Table 4). Total weight loss increased with the increasing of storage period and rate of weight loss was higher in untreated fruits than treated fruits. The present result was somehow similar to Mia (2003) and he reported that unperforated polythene bag and wax coated fruits showed minimum weight loss during storage, whereas the untreated fruits exhibited maximum weight loss. (Benjawan *et al.*, 1997) investigated that the weight loss was the lowest when papaya fruits were treated with Benlate. Alam (2003) reported that Benzyl Adenine treated fruits had the lowest weight loss (25.40%) at ripe stage, whereas the untreated fruits exhibited maximum weight loss. The weight loss in papaya during ripening may be attributed to substrate loss by respiration and loss of water through various mechanisms. The results were similar to the findings of Pesis *et al.*, (1992).

Haque (1985) reported that the weight loss of bananas occurred due to the loss of water from the fruits, microbial decay and storage environment like temperature and humidity. High temperature enhanced weight loss but low temperature reduced weight loss during ripening and storage. In an experiment, Mootoo (1991) observed that the rate of fresh weight loss was the highest in untreated fruits. Polythene bag could be used to reduce of the weight of stored papaya (Thompson and Lee, 1971). The fruits treated with neem oil 10 per cent proved to be most effective with respect to lower physiological loss in weight and higher firmness of fruits (Shindem *et al.*, 2009).

Table 4. Effect of plant extracts on weight loss (%) of papaya

Postharvest treatments	Weight loss (%)				
	Initial (g)	3 DAS	6 DAS	9 DAS	12 DAS
Control (T_1)	0.80	9.11	19.76	30.93	54.19
Onion extract (T_2)	0.77	9.05	17.23	28.65	42.32
Neem extract (T_3)	0.82	8.27	18.88	31.25	47.90
Garlic extract (T_4)	0.79	7.98	12.81	22.56	36.18
Bishkantali extract (T_5)	1.25	10.15	18.92	25.19	38.69
Datura extract (T_6)	0.68	10.49	21.98	33.53	48.63
$LSD_{(0.05)}$	-	1.11	3.27	3.20	2.82
$LSD_{(0.01)}$	-	1.55	4.55	4.45	3.93
Level of significant	-	**	**	**	**
CV (%)	-	6.79	10.01	6.23	3.54

**= Significant at 1% level of probability.

4.2.3. Moisture content

In general, the moisture content decreased with the increase in storage time under different postharvest treatments. It was observed that the significant variations were found in moisture content at all the days after storage due to different postharvest treatments (Appendix V). Moisture content in the pulp of papaya was the highest (85.33%) at 3 days after storage (DAS) due to the use of onion extract. On the other hand, at 3 days after storage (DAS) the lowest moisture content (80.67%) was found in bishkantali treated fruits. At 6 days after storage (DAS) the highest value of moisture content was (82.67%) in neem treated fruit where the lowest (76.33%) was in bishkantali treated fruits. In case of 9 and 12 days after storage (DAS) the highest moisture content was (80.33% and 76.67%) in datura treated fruits and the lowest was (73.33% and 70.33%) in bishkantali treated fruits (Table 5).

Table 5. Effect of plant extracts on moisture content (%) of papaya

Postharvest treatments	Moisture content (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
Control (T_1)	84.00	78.33	75.67	72.33
Onion extract (T_2)	85.33	81.89	76.33	73.67
Neem extract (T_3)	85.00	82.67	79.67	75.67
Garlic extract (T_4)	81.67	80.33	75.67	72.66
Bishkantali extract (T_5)	80.67	76.33	73.33	70.33
Datura extract (T_6)	84.33	81.66	80.33	76.67
$LSD_{(0.05)}$	2.33	2.74	3.08	2.71
$LSD_{(0.01)}$	3.25	3.82	4.29	3.77
Level of significant	**	**	**	**
CV (%)	1.57	1.91	2.25	2.06

**= Significant at 1% level of probability.

In case of moisture content datura played a vital role which was better than control, somehow similar result as the present study was noted in (Yusof and Salleh, 1992). They found that moisture loss and colour change were delayed when papaya fruits cv. Eksotica were coated with polythene wax emulsion (1:2,1:4, or 1:6, wax: total volume of water) and stored at 10°C.

The decrease in moisture content during storage was also reported by Pathmanaban *et al.*, (1995) observed that moisture loss was higher in untreated mature fruits during the period of storage, whereas only minimum water loss was observed in fruits treated with fused Ca salts.

4.2.4. Dry matter content

Dry matter content varied significantly due to the effect of different postharvest treatments (Appendix VI). From the Table 6, it was observed that the per cent dry matter content increased with the increase in storage duration. Bishkantali extract treated fruits showed the highest (19.33, 23.67, 26.67 and 29.67%) dry matter content throughout the whole storage period (3, 6, 9, 12 DAS, respectively). On the other hand at 3 DAS onion treated fruits showed 14.67% , at 6 DAS neem treated fruits showed 17.33%, at 9 and 12 DAS datura treated fruits showed 19.67% and 23.33% dry matter content which were the lowest (Table 6).

Selvaraj and Pal (1982) studied with papaya cv. Thailand, and observed that dry matter was increased considerably from the earliest stage of development until 140 days after anthesis. The increase in dry matter per cent with increasing storage period may be due to osmotic withdrawal of water from the pulp to peel.

Table 6. Effect of plant extracts on dry matter content (%) of papaya

Postharvest treatments	Dry matter content (%)			
	3 DAS	6 DAS	9 DAS	12 DAS
Control (T_1)	16.00	21.67	24.33	27.67
Onion extract (T_2)	14.67	18.11	23.67	26.33
Neem extract (T_3)	15.00	17.33	20.33	24.33
Garlic extract (T_4)	18.33	19.67	24.33	27.34
Bishkantali extract (T_5)	19.33	23.67	26.67	29.67
Datura extract (T_6)	15.67	18.34	19.67	23.33
$LSD_{(0.05)}$	2.18	1.07	1.87	2.06
$LSD_{(0.01)}$	3.03	1.49	2.60	2.87
Level of significant	**	**	**	**
CV (%)	7.38	3.02	4.51	4.37

**= Significant at 1% level of probability.

4.2.5 Total soluble solid

The postharvest storage treatments used in the present study had marked influenced on TSS of papaya pulp. The variations among the treatments means in terms of TSS content were significant at the different storage period (Appendix III).The highest TSS content (9.67% Brix) was observed in control where the lowest (8.57%) was noticed in garlic extract treated fruits of Shahi papaya at 3 days after storage. Similarly, at 6 DAS, the higher and the lower TSS content was also observed in control fruits (10.43%) and the fruits kept in garlic and onion extract (9.33%), respectively. The higher (12.83%) and the lower (10.17%) TSS content was obtained in control fruits and the fruits kept in garlic treatment, respectively at 9 DAS. On the other hand, at the 12 days

Table 7. Effect of plant extracts on total soluble solid of papaya

Postharvest treatments	TSS (%Brix)			
	3 DAS	6 DAS	9 DAS	12 DAS
Control (T_1)	9.67	10.43	12.83	14.27
Onion extract (T_2)	8.63	9.73	10.53	12.83
Neem extract (T_3)	8.63	9.33	11.33	11.93
Garlic extract (T_4)	8.57	9.33	10.17	11.27
Bishkantali extract (T_5)	8.67	9.53	12.43	14.13
Datura extract (T_6)	8.63	9.47	10.53	11.53
$LSD_{(0.05)}$	0.46	0.42	0.62	2.03
$LSD_{(0.01)}$	0.63	0.58	0.86	2.83
Level of significant	**	**	**	*
CV (%)	2.90	2.43	3.06	8.99

**= Significant at 1% level of probability; * = Significant at 5% level of probability.

4.3. Postharvest diseases

Various postharvest diseases were identified during the storage. It increased with the advancement of storage duration. During storage period some fungal diseases like anthracnose, stem end rot and *Rhizopus* rot were recognized by observing the typical symptoms of those diseases which were caused by *Colletotrichum gloeosporioides, Botryodiplodia theobromae* and *Rhizopus stolonifer,* respectively.

4.3.1. Symptoms of anthracnose of papaya during storage

Lesions first appear as small, circular hydrotic areas which increase in size as the fruit ripens. They are depressed and frequently turn brown or black as they age. Sometimes, pink spore masses appear in concentric rings on the dark lesions.

4.3.2. Symptoms of stem end rot of papaya during storage

The disease is recognized by the presence of water soaked lesions on contaminated areas of the stem and fruits. In severe cases the whole parts of the fruit become rotten and black in colour.

4.3.3. Identification and isolation of pathogens from infected fruits

Infected fruits were taken from the different postharvest treatments of plant extract and were studied in the Laboratory of Plant Pathology, Agrotechnology Discipline, Khulna University, Khulna for identifying the causal organisms. Semi-permanent slides were prepared from the infected fruits. Most of the fruits were infected predominantly by *Colletotrichum gloeosporioides.*

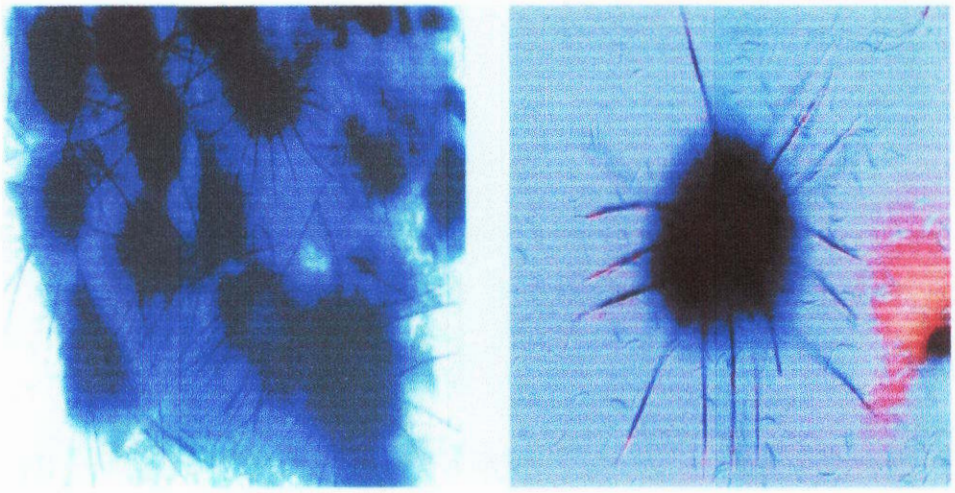

Plate 2. Different structures acervuli of *Colletrotichum gloeosporioides*.

4.3.4. Morphological characters of *colletotrichum gloeosporioides*

Acervuli disc shaped or cushion shaped, waxy, sub-epidermal, typically with dark, spines or setae at the edge or among the condiophores; conidiophores simple, elongate, conidia hyaline, one celled, ovoid or oblong. Setae were black and needle shape.

4.3.5. Assessment of per cent Disease incidence

The postharvest treatments of plant extract showed highly significant effect on per cent disease incidence at storage period of papaya (Appendix VII and Fig. 1). At 6 DAS, the highest per cent disease incidence was identified in control fruits (60.00%) whereas a few infection was found from garlic (T_4), bishkantali (T_5), datura (T_6) extract treated fruits (7.33%, 20.00%, 20.33%, respectively). The maximum 92.33% disease incidence was observed at the 9th day of storage in control treated fruits and at 10 DAS it became 100% disease infested whereas the minimum 39.33% infection was identified in bishkantali extract at 9th day of storage and at 10 DAS it was 59.33% (Fig. 1).

It was found that the disease incidence was started at the 3rd day of storage where the postharvest treatments of plant extract viz. control (T_1), datura (T_6) showed the 100% disease incidence at 10 day of storage. But the treatments with bishkantali and garlic extract (59.33% and 60.33%) incidence was below the 80% at 10 DAS (Fig. 1).

Dantas *et al.*, (2003). They reported that great diversity of diseases occurred in papaya fruits, where incidences ranged from 39.71 to 90.07%, with the higher level for stem end rot.

Shirshikar (2002) found that Onion *(Allium sativum)* has shown best fungicide activity with its bulb extract totally inhibiting fungal growth and spore germination of *Colletotrichum gloeosporioides* and *Botryodiplodia theobromae*. Leaf extract of *Ocimum*

sanctum, Glyricidia maculate, Pongamia pinnata L. were also effective in reducing per cent spore germination of *B. theobromae* whereas, leaf extract of *Pongamia pinnata* and *Catharanthus roseus* were effective in reducing spore germination of *Colletotrichum gloeosporioides.*

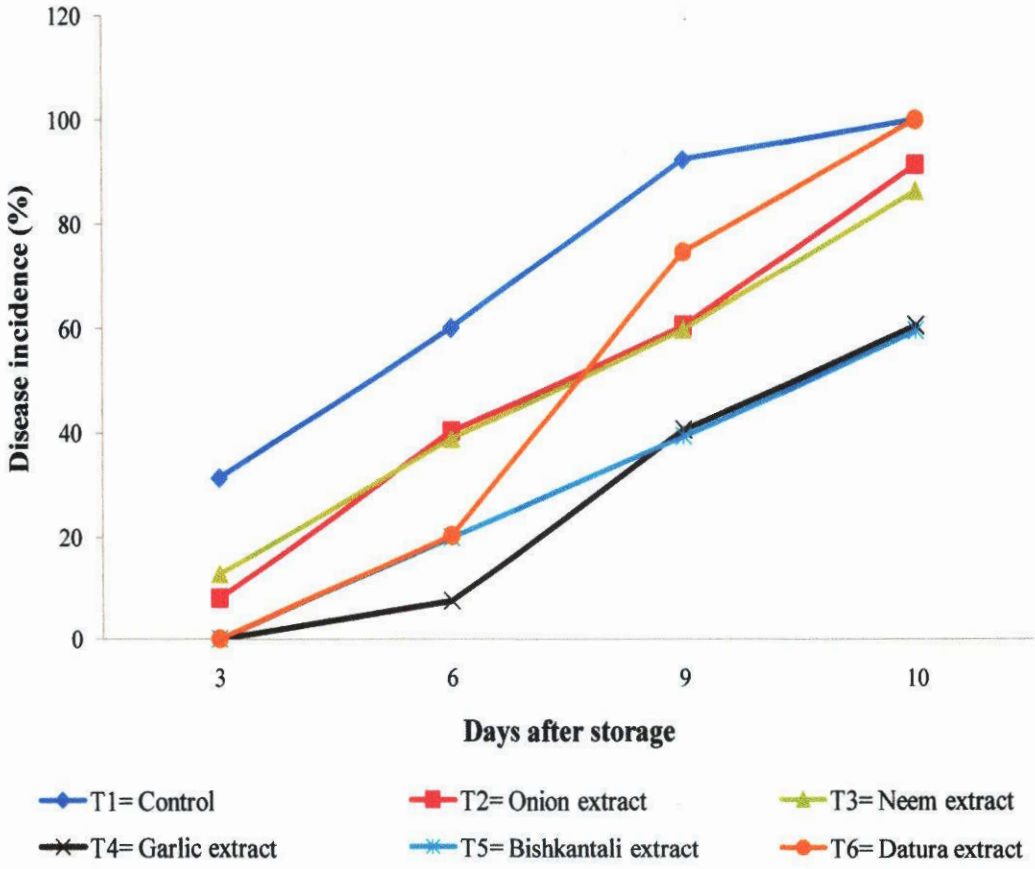

Fig. 1. Effect of plant extracts on disease incidence at different days after storage of papaya.

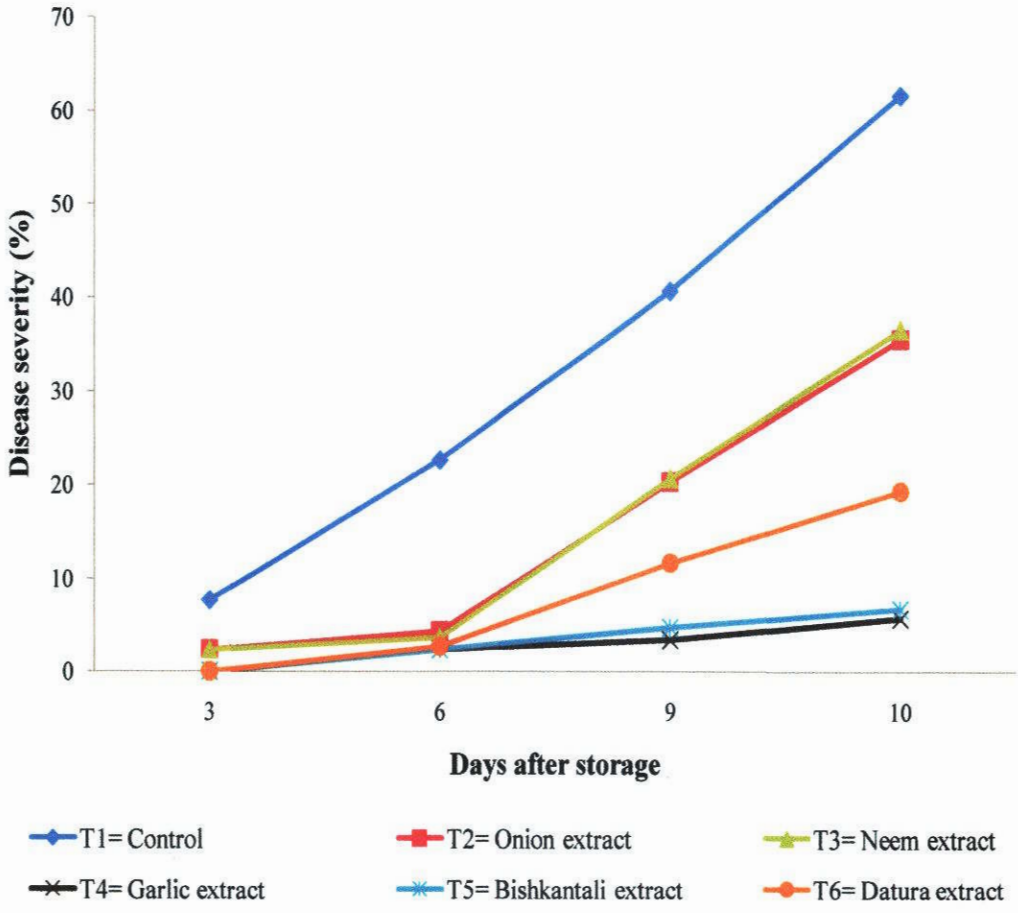

Fig. 2: Effect of plant extracts on disease severity at different days after storage of papaya.

4.4. Shelf life

Shelf life of BARI Papaya 1 cv. Shahi was significantly affected by different postharvest treatments of plant extract (Appendix IX). The extension of shelf life of fruits has been one of the most important concerns of the researchers. Results revealed that the longest shelf life (15.95 days) of papaya fruits was from garlic extract which was followed by the Bishkantali extract (14.90 days). The shortest shelf life of 8.67 days was observed from the control fruits (Fig. 3). (13.00 days) and (12.82 days) also produced from both postharvest treatments of datura and onion extract. Other postharvest treatment neem extract showed (10.98 days) in shelf life.

All the postharvest treatments of plant extract treated fruits of papaya var. Shahi showed the following ranking order for shelf life viz. garlic (15.95 days) > bishkantali (14.90 days) > datura (13.00 days) > onion (12.82 days) > neem (10.98 days) > control (8.67 days). The longest shelf life as obtained for garlic extract was possibly due to the reduced rate of physico-chemical changes, reduced weight loss and minimal disease severity.

Borase *et al.*, (2004) conducted a study to evaluate the effects of ripen ingretardants on the shelf life of papaya cv. Madhubindu fruits. He noticed that the fruits treated with GA3 had longer shelf life, less shrinkage and spoilage, lower percentage of weight loss, higher percentage of marketable fruits and decreased rate of increase in total soluble solids, acidity, ascorbic acid and sugar content.

Girdhay and Anurag Payasi, (2007) reported that the ripe banana fruits were subjected to dip treatment for 4 h using chemicals, plant extracts or their combinations, and shelf life of treated fruits stored at room temperature was monitored by assaying fruit firmness. The treatment of fruit with 1% garlic clove extract or 10% onion bulb extract and adjusting the pH to 4.5 extended the shelf life by 4–5 days when compared with untreated fruit. Treatment with a combination of 1% garlic extract and 1 mm sodium metabisulphite and adjusting the pH to 4.5 prolonged the shelf life of ripe banana to 13–14 days when compared with 6–7 days for the untreated fruit. The treatment delayed the fruit softening by diminishing the rate of starch and pectin degradation. The rate of increase in b-amylase and polygalacturonase activities along with softness was also retarded in treated fruits when compared with control fruits.

Singh *et al.* (2003) also reported the effect of various plant extracts such as neem leaves, castor oil and neem oil on citrus fruits and identified neem leaf extract as the best in retaining most of the biochemical characteristics and shelf life.

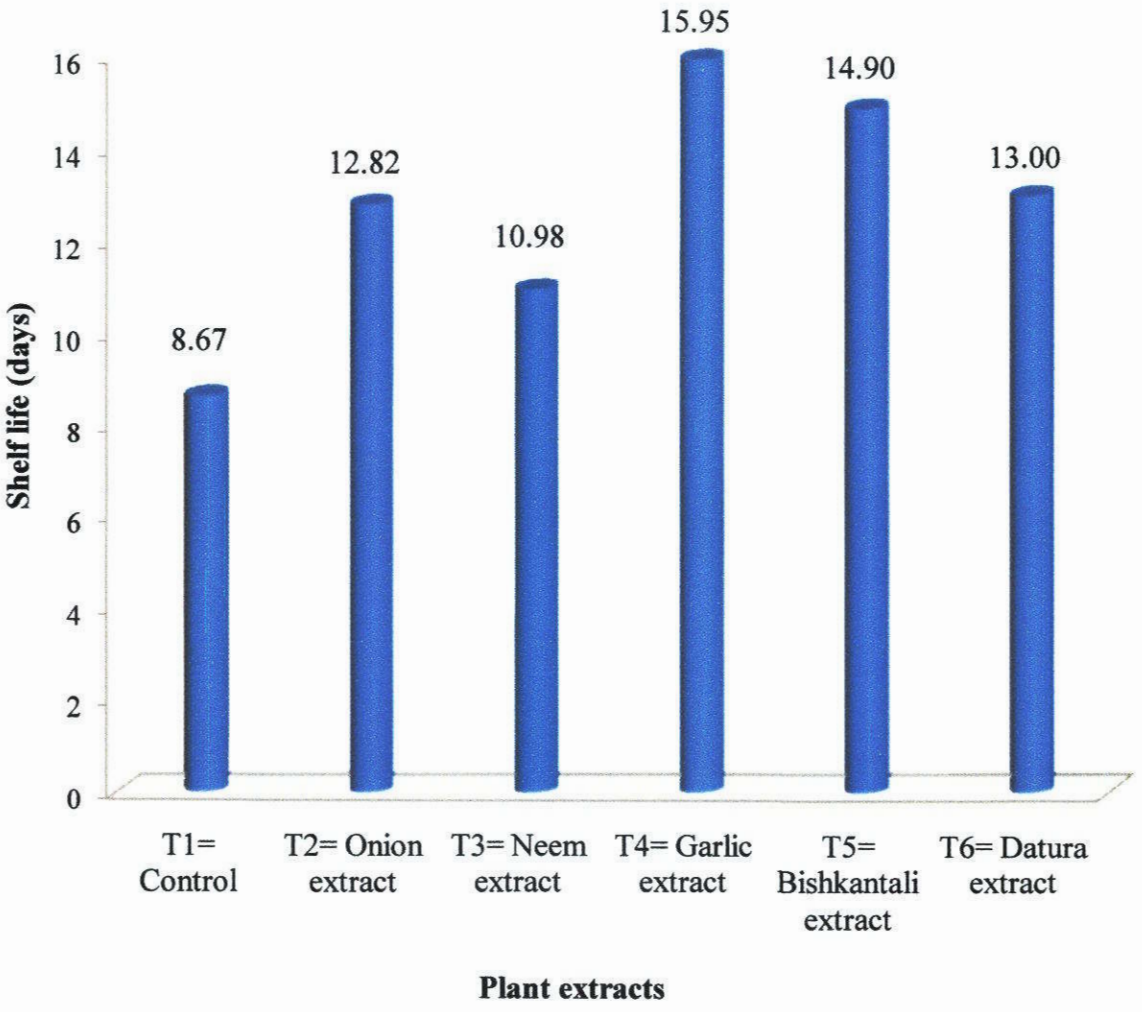

Fig. 3. Effect of plant extracts on shelf life at different days after storage of papaya.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Germplasm Centre of the Discipline of Agrotechnology, Khulna University, Khulna during the period from April to May, 2013, to investigate the effect of different postharvest treatments of plant extract on fruit characteristics, physico-chemical changes, disease incidence and severity and shelf life of papaya fruits cv. Shahi. The experiment comprised of six plant extracts included control viz., control (T_1), onion (T_2), neem (T_3), garlic (T_4), biskantali (T_5), datura (T_6) extracts. The single-factor experiment was laid out in completely randomized design (CRD) with three replications. Observations were made on external and internal fruit attributes shelf life, physico-chemical properties such as total weight loss, per cent moisture content, per cent dry matter content, total soluble solid, pulp to peel ratio and disease incidence and disease severity. The physico-chemical data were recorded at three days interval during storage. The collected data were analyzed statistically.

Postharvest storage treatments of plant extract was significantly influenced on total weight loss, per cent moisture content, per cent dry matter content, total soluble solid where, the maximum (54.19%) weight loss occurred in the control treatment and the minimum (36.18%) weight loss occurred in the garlic extract treatment at 12 days after storage. The maximum (10.49%, 21.98% and 33.53%) weight loss was recorded from datura where the minimum was from garlic (7.98%, 12.81% and 22.56%) at 3rd, 6th and 9th days after storage, respectively. Moisture content in the pulp of papaya was the highest (85.33%) at 3 (DAS) due to the use of onion extract. On the other hand, at 3 (DAS) the lowest moisture content (80.67%) was found in bishkantali extract treated fruits. At 6 (DAS) the highest

value of moisture content was (82.67%) in neem treated fruit where the lowest (76.33%) was in bishkantali treated fruits. In case of 9 and 12 (DAS) the highest moisture content was (80.33% and 76.67%) in datura treated fruits and the lowest was (73.33% and 70.33%) in bishkantali treated fruits.It was observed that the per cent dry matter content increased with the increase in storage duration. Bishkantali extract treated fruits showed the highest (19.33, 23.67, 26.67 and 29.67%) dry matter content throughout the whole storage period (3, 6, 9, 12 DAS respectively). On the other hand at 3 DAS onion treated fruits showed 14.67% , at 6 DAS neem treated fruits showed 17.33%, at 9 and 12 DAS datura treated fruits showed 19.67% and 23.33% dry matter content which were the lowest.The higher TSS content (9.67% Brix) was recorded in control treated fruits where the lowest (8.57%) was noticed in garlic extract treated fruits of Shahi papaya at 3 days after storage. Similarly, at 6 DAS, the higher and the lower TSS content was also observed in control fruits (10.43%) and the fruits kept in garlic and onion extract (9.33%), respectively. The higher (12.83%) and the lower (10.17%) TSS content was obtained in control fruits and the fruits kept in garlic treatment, respectively at 9 DAS. On the other hand, at the 12 days after storage, the highest (14.27%) TSS content was also observed in control fruits and the lower (11.27%) in garlic extract. Among the postharvest treatments of plant extract, garlic extract produced the maximum pulp to peel ratio (6.01) and the minimum (4.67) was recorded in control treatment at 3 DAS. At 6 DAS, the maximum pulp to peel ratio (5.88) was also obtained from the garlic treated fruit where the minimum (4.43) was recorded in bishkantali treatment. On the other hand, pulp to peel ratio was the maximum (4.81 and 3.82) in garlic extract and the minimum (3.19 and 3.02) was observed in control treatment at 9 and 12 days after storage, respectively. The effect of different postharvest treatments of plant extract under natural storage temperature on shelf life, fruit

quality characters and disease incidence and severity was significant. The longest shelf life (15.95 days) was recorded in fruits with garlic extract whereas minimum shelf life (8.67 days) was recorded in untreated fruits preceded by those of kept in neem (10.98 days), onion (12.82 days), datura (13.00 days), and biskantali (14.90 days) respectively.

Considering the results of the present study, it can be concluded that botanical extracts exert a positive effect on fruit quality characteristics, physico-chemical properties, disease incidence, disease severity and shelf life of papaya. Among the various extracts, garlic extract maintained quality characters moderately, reduced disease incidence and severity and extended shelf life of papaya significantly. It seems that garlic extract may be considered as an ideal one for postharvest storage of papaya.

Further studies required to carry out the possible effects of other promising botanical extracts with series of concentrations on shelf life and quality of papaya fruits in Bangladesh. Several low cost treatments such as hot water treatment, poly bag packaging, leaf extract of papaya, combination of different plant extracts etc. can be applied for longer shelf life of papaya. Even we can modify the time and duration of applying botanical extracts to see the results before any final recommendation.

REFERENCES

Abd-El-Aziz, S. A. and F. S. Mansour. 2006. Some safe treatment for controlling post-harvest diseases of Valencia orange (*Citrus sinensus* L.) fruits. Ann. Agric. Sci., 44: 135-146.

Abd El-Naby and S. K. M. 2010. Effect of postharvest treatments on quality aspect of Maghrabi Banana fruits. American-Eurasian J. Agri. Environ. Sci., 8(5): 582-587.

Aborisade, A. T. and Ajibade A. A. 2010. Effect of prestorage curing on storage life, internal and external qualities of sweet orange (*Citrus sinensis*). Revista Brasileira de Fruticultura, 32: 910-915.

Aguaya, E., Escalona, V. and Artes, E. 2004. Quality of fresh cut papaya as affected by type of cut, packaging, temperature and storage time. Eur. Food Res. Tech., 219: 492-499.

Alam, M. S. 2003. Effects of packaging materials and growth regulators on quality and shelf life of papaya (cv. Ranchi). M.S. Thesis, Dept. of Horticulture,BAU. Mymensingh.pp 37-80.

Alam, M. M. 1990. Neem in nematode control. In Nematode biocontrol (aspect and prospects) Delhi, India. CBS. Pub-and Distributors Pvt. Ltd. 51-55 [HelminthAbstr.,] 46: 72.

Arriola, M. C., Calzada, J. F., Menchu, J. F., Role, C. and Garcia, R.1980. Papaya *In*: Nagy, S. and Shaw, P.E. (eds). Tropical and Sub-Tropical Fruits. AVI, Westport, Connecticut, USA, pp. 316-340.

Ashrafuzzaman, M.H., and Khan, A. R. 1992. Antifungal activity *in vitro* of some plant extracts on *Rhizoctnia solani*. Bangladesh J. Sci. Res., 10(2): 243-244.

Aziz, A. B. A., El-Nabawy, S. M. and Zaki, H. A. 1975. Effect of different temperatures on the storage of papaya fruits and respirational activity during storage. Scientia Hort., 3(2): 173–177.

Aykroyed, W. R. 1951. The nutritive value of Indian Food and the planning of satisfactory diets. Govt. of India Res., New Delhi.

Badillo, V. M. 1971. Monografia de la familie Caricaceae. Associacionde Profesores, Universidad Central de Venezuela, Maracay, Venezuela.

Bagwan, N. B. 2001. Anthracnose of banana fruits and its management with plant extracts. Aerobiology, Mycology and Pathology Laboratory, Department of Botany, M.U. College, India Current Research University of Agriculture Science Bangalore. 30(11/12): 197-198.

Barakat, M. R., M. A. A. Mohamed, M. A. Essa and Zeinab A. Zaki. 2012. Effect of Using Some Biological Post Harvest Treatments on Storability of Washington Navel Orange Fruits Compared with Imazalil Post Harvest Chemical Treatments. J. Hort. Sci. Ornam Plants. 4(1): 50-57.

Benjawan, C., C. Prasit, Chutichudet B. and Chutichudet P. 1997. Studies on prolonging storage life of papaya fruit. Khon-kaen Agric. J., 25(3): 120-131[Rev. Plant Path. 1999. 57(5): 592].

Bhardwaj, R. L. and Sen, N. Z. 2003. Zero energy cool chamber storage of Mandarin (*Citrus reticulate* cv. Nagpur Santra). J. Food Sci. Tech., 40 (6): 669-672.

Bisen, A., Pandey, S. K. and Patel, N. 2011. Effect of skin coatings on prolonging shelf life of kagzi lime fruits (*Citrus aurantifolia* Swingle). J. Food Sci Technol., (online available at: http://www.springerlink.com/content/m5xlk 13j658n5817/)

Borase, S. S., S. P. Singh and A. K. Joshi. 2004. Efficacy of postharvest treatments on shelf life and quality of papaya (*Carica papaya* Linn.). Orissa J.of Hort.,32(2): 57-60.

Bose, T. K. and Mitra S. K. (eds). 1996. Fruits: Tropical and Subtropical. Naya Prokash, 206 Bidhan Sarani, Calcuta. p. 272.

Bose, T. K. 1985. Fruits of India Tropical and Subtropical Naya Prakash, Bidhan Sarani, Calcutta, India. p. 320.

Chadha, K. L., Melanta, K. R., Lodh and Selvaraj, Y. 1972. Biochemical changes associated with growth and development of pineapple variety Kew. I. Changes in physico-chemical constituents. Indian Hort., 29(1): 53-57.

Correa, S. F., Pereira, G., Alves, V. L. and Vargas, H. 2008. Fetermination of thermal diffu -seeveity in papaya pulp as a fuction of maturation satge. Revista Brassileira de Fruticultura 30(3): 325-330 .

Dantas, S. A. F., Oliveira, S. M. A., Michereff, S. J., Nascimento, L. C., Gurgel, L. M. S. and Pessoa, W. R. L. S. 2003. Post harvest fungal diseases in papaya and orange marketed in the Distribution Centre of Recife. Fitopatologia Brasileira., 28(5): 528-533. [Cited from CAB abstr. Vol. Id. IA 084, SP-0012-0146].

Dhali, D. D. 2006. Determination of effective dose of garlic and allamanda tablets for controlling *phomopsis* blight and fruit rot of eggplant. An MS thesis submitted of the Department of Plant Pathology, BAU, Mymensingh. pp. 1-20.

Echerenwa, M. C. and Umechuruba, C. I. 2004. Postharvest fungal diseases of papaya *(Carica papaya* L.) fruits and seeds in Nigeria. Global J. Pure App. Sci., 10(1): 69-73.

Eisa, N. A., El-Habbaa, G. M., Fouad, N. A. and Ahmed, Z. H. 2001. Controlling post harvest decay of Navel orange fruits. Ann. Agric. Sci., 39: 1531-1550.

Emeruwa, A. C. 1982. Antibacterial substance from carica papaya fruit extract. J. Natural Prod., 45(2): 123-127.

Eno, A. E., Owo O. I., Itam, E. H. and Konya, R. S. 2000. Blood pressure depression by the fruit juice of *Carica papaya* (L.) in renal and DOCA-induced hypertension in the rat. Phytother. Res., 14: 235-239.

Fakir, G. A., and Khan, A. A. 1992. Control of some selected seed borne fungal pathogens of jute by seed treatment with garlic extract. BAU Res. Prog., 6A: 176-180.

FAOSTAT (Food and Agriculture Organization Statistics Division). 2013. Report on Worldwide Crop Production. Rome, Italy, (online available at:http://faostat3.fao. org/download/Q/QC/E).

Firmin. A. 1997. Physico-chemical changes in papaya during storage. Trop. Sci., 37(1): 49-51.

Geetha, P. and Thirumaran, A. S. 2010. Increasing the shelf-life of papaya through vacuum packing. Acta Hort., 851: 527-532.

Ghanta, P. K. 1994. Physico-chemical changes in papaya cv. Ranchi during fruit development and maturity. South Indian Hort., 42(4): 131-235.

Girdhay, G. Sanwal and A. Payasi. 2007. Garlic extract plus sodium metabisulphite enhances shelf life of ripe banana fruit. Intl. J. Food Sci. Tech., 42: 303–311.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. Jon Wiley and sons. Inc, New York. P. 67-215.

Hami, M. A. 1960. Papaya cultivation and production of papain. Food and Agriculture Council, Ministry of Food and Agriculture, Govt. of Pakistan, Karachi. p. 51.

Haque, M. A. 1985. Ripening time and weight loss during ripening of "Amritasagar" banana. Bangladesh J. Agril. Res., 10(2): 156-158.

Hayes, W. B. 1993. Fruit Growing in India, Kitabistan, Allahabad, India. P. 307.

Hernandez-Castro, E., Utrera-Landa, V., Villanueva-Jiménez, J. A., Rodríguez-Lagunes, D. A. and Ojeda-Ramírez, M. M. 2005. Neem extracts on Aphis nerii behavior and papaya ringspot virus transmission. J. Agric. Univ. Puerto Rico, 89(1-2): 75-84.

Hossain, M. S. 2007. Garlic tablet for controlling *Phomopsis* blight and fruit rot of Brinjal. An MS thesis submitted of the Department of Plant Pathology, BAU, Mymensingh. pp. 1-15.

Ines, M. C., Pascua, G. S., and Pasccua, G. F. S. 2008. Botanical materials as alternative control against anthracnose. PCARRD Highlights. P. 312.. 78-88.

Janisiewicz, W. J. and Korsten L. 2002. Biological control of postharvest diseases of fruit. Ann. Rev. Phytopath., 40: 411-444.

Khan, N. U. 1999. Studies on epidemiology, seed-borne nature and management of *Phomopsis* fruit rot of brinjal. Unpublished [MS Thesis], Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh, pp. 38-68.

Lurie, S. K. and Ben, A. R. 1990. Physiological changes in diphenyl treated 'Granny Smith' apples. Israel J. Bot., 38(34): 199-207.

Maqbool, M., Ali, A., Alderson, P.G., Mohamed, M. T. M., Siddiqui, Y. and Zahid, N. 2011. Postharvest application of gum arabic and essential oils for controlling anthracnose and quality of banana and papaya during cold storage. Postharvest Biol. Tech., 62(1): 71-76.

Meah, M. B., Hossain, M. D. and Islam, M. R. 2002. Development of an Integrated Approach for Management of *Phomopsis* Blight and Fruit Rot of Eggplant in Bangladesh: Annual research report (2001-2002), Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh, Bangladesh. 25 pp.

Meah, M. B. 2007. Development of an integrated approach for management of *Phomopsis* blight/fruit rot of eggplant in Bangladesh. Final Research Report (2001-2006). Department of Plant Pathology, BAU, Mymensingh. p.86

Mia, B. 2003. Studies on postharvest behavior of papaya. MS thesis, Department of Horticulture, BAU, Mymensingh. pp. 40-96.

Mondal, M. F. 2000. Production and storage of fruits (in Bangl). Published by Mrs. Afia Mondal. BAU campus, Mymensingh- 2202. P. 312.

Mondal, M. F. and Bose, S. K. 2007. Physico-chemical changes in papaya fruits during storage. J. Bangladesh Soc. Agric. Sci. Tech., 4(3 and 4): 145-148.

Mootoo, A. 1991. Effect of postharvest calcium chloride dips on ripening changes in fruits in Julie mangoes. Trop. Sci., 31(3): 243-248.

Morton, J. F. 1987. Fruits of Warm Climates; J. F. Morton Publisher: Miami, FL, USA. pp. 18-23.

Muniz, M. F. S., Rocha, D. F., Silveira, N. S. S. and Menezes, M. 2003. Identification of fungi causal agents of postharvest diseases on commercialized fruits in Alagoas, Brazil. Summa Phytopathologica., 29(1): 38-42.

Naher, N. 2000. Physico-chemical changes of papaya under different storage conditions. M.S. Thesis, Dept. of Horticulture, BAU. Mymensingh. pp. 60-93

Nakasone, H. Y. and Paull, R. E. 1998. Tropical Fruits, Oxford University Press, USA. P. 445.

Narayana, C. K., Mustafa, M. M. and Sathiamoorthy, S. 2002. Effect of packaging and storage on shelf-life and quality of banana cv. Karpuravalli; Indian J. Hort., 59(2):113-117.

Obagwu, J. and Korsten, L. 2003. Control of citrus green and blue moulds with garlic extracts. Euro. J. Plant Path., 109: 221-225.

Osuna-Garcia, J. A., Beltran, J. A. and Barraza, M. H. P. 2005. Improvement of shelf life and quality of papaya 'Maradol' with 1-methylcyclopropene (1-MCP). Revista Chapingo Serie Hort., 11(1): 7-12. [Cited from CAB Abstr. Vol. Id. IA. 012 SP-0012-0148].

Pathmanaban, G., M. Nagarajan, K. Manian and Annamalainathan K. 1995. Effect of fused calcium salts on postharvest preservation in fruits. Madras Agril. J.,82(1): 47-50.

Pesis, E., Marinansky R. and Subhadrabandhu S. 1992. Influence of fruit coating on quality. International symposium on tropical fruit: frontier in tropical fruit research, Pattaya City, Thailand, 20-24 May 1991. Acta Hort., 321:659-666.

Purseglove, J. W. 1985. Tropical Crops: Monocotyledons. English Language Book Society, London. 1(1&2): 75-91.

Raheja, S. and Thakore, B. B. L. 2002. Effect of physical factor, plant extracts and bio-agent on *Colletotrichum gloeosporioides* Penz., the causal organism of anthracnose of Yam. J. Mycol. Pl. Path., 32: 293-294.

Rahman, M. A., Quddus, M. A. and Haque, M. S. 1979. Studies on pineapple: Part III- The effect of different physical treatments on the changes in physiological and biochemical characteristics in stored pineapples. Bangladesh J. Sci. Ind. Res., 14(1-2): 109-118.

Ran Singh, Sharma, R. K. and Kumar, J. 1989. Effect of some chemicals on shelf life of kinnow mandarin. Res. Dev. Rep., 6(1): 87-91.

Ranganna, S. 1979. Manual of Analysis of Fruit and Vegetable products. Tata McGraw - Hill Pub.Co.Ltd., New Delhi, p. 634.

Reni, M., Sheela, K. B. and Raju, V. K. 2000. Storage stability of pulp of different papaya varieties. Indian J. Hort., 57(11): 295-299.

Rohrbach, K. and Phillips, D. J. 1990. Postharvest diseases of pineapple. Acta Hort. 269: 503-508.

Romero, P., Rodrigo, M. J., Alferez, F., Zacarias, L. and Lafuente, M. T. 2011. Transcripto -mic responses of Navelate orange (*Citrus sinensis* L. Osbeck) fruit to water stress. Acta Hort., 892: 351-356.

Roy, R. R. 2003. Shelf life and diseases of papaya as influenced by different postharvest treatments. MS Thesis, Dept. of Horticulture, BAU, Mymensingh. pp. 24-25.

Salunkhe, D. K. and Desai, B. B. 1984. Postharvest Biotechnology of fruit.Vol 1. CRC press, Inc. Boca Raton, Florida. pp. 77-94.

Samson, J. A. 1986. Tropical Fruits (2nd Edition). Longman Scientific & Technical, Longman Group, England. pp. 199-215.

Selvaraj Y, Pal D. K. (1982) Changes in the chemical composition of papaya (Thailand variety) during growth and development. J. Food Sci. Technol. 19:257-259.

Shakila, A. and Anburani, A. 2009. Effect of storage temperatures on the quality and shelf life of papaya. International Symposium on Papaya held on 7-8 August, Leuven, Belgium. pp. 25-29.

Shindem, G. S., Viradia, R. R., Patil, S. A. and Kakade, D. K. 2009. Effect of post harvest treatments of natural plant extract and wrapping material on storage behavior of mango (cv. KESAR). Intl. J. Agril. Sci., 5(2) 420-423.

Shirshikar, G. S. 2002 Studies on fruit rots of mango (*Mangifera indica* L.) caused by *Botryodiplodia theobromae* Pat. and *Colletotrichum gloeosporioides* Penz. and their management. M.Sc. (Agri) Thesis, KKV, Dapoli, Maharashtra, India.

Sing, Z., Janes J., Suresh N., Sing Z., Ben A.R. and Hadas S.P. 2001. Packaging materia -ls affect physiological weight loss fruit colour and quality of mango during storage. Acta Hort., 2(1): 603-604.

Sing, R. K. and Dwivedi, R. S. 1987. Fungitoxicity of different plant species against Sclerotium rolfsii Sace. Nat. Sci. Lett., 10(3): 89-91.

Singh Dinesh, D., Thakur, R. K. and Singh, D. 2003. Effect of pre-harvest sprays of fungicides and calcium nitrate on postharvest of Kinnw in low temperature storage. Plant disease Res. 18(1): 9-11.

Singh, I. N. G., Dhuique-Mayer, C., and Lozano, Y. 2000. Physico-Chemical changes during enzymatic liquefaction of Mango Pulp (*cv. Keitt*) J. Food Proc. Pres., 24(1): 73-85.

Singh, H., Korpraditskul, V. and Singh, P. P. 1999. Evaluation of some plant extracts for the control of *Collitotrichum capsici* (SYD). Butler and Bishy, the causal agent of chilli anthracnose. Mora Institute of Tech., Perlis campus, Malaysia Azadirachta indica Juss., 12: 131-138.

Singh, I. D. 1990. Papaya, Oxford and IBH Publishing Company Private Limited, New Delhi, p. 192.

Thompson, A. K. and Lee G. R. 1971. Factors affecting the storage behaviour of papaya fruit. J. Hort. Sci, 46(4): 511-516.

Tripathi, V. K., Ram, H. B., Jain, S. P. and Singh, S. 1981. Changes in developing banana fruit. Prog. Hort., 13(1): 45-53.

Uddin, M. N. and Hossain, A. K. M. A. 1993. Study on the storage of pineapple. Bangladesh Hort., 21(2): 7-12.

Villegas, V. N. 1997. Edible fruits and nuts - *Carica papaya* L. In: *EWM Verheij*, RE Coronel, (eds.) Volume 2. Wageningen University, The Netherlands Waller, JM, 1992, Colletotrichum diseases of perennial and other cash crops. Colletotrichum: biology, pathology and control, pp. 167-185.

Waller, J. M. 1992. Colletotrichum disease of perennial and other cash crops. Colletotrichum; biology, pathology and control, pp. 167-185.

Watson, B. 1997. Agronomy agroclimatology notes for the production of papaya. MAFFA, Australia. P. 230

Wijewardane, R. M. N. A. and Guleria, S. P. S. 2009. Combined Effects of Pre-cooling, Application of Natural Extracts and Packaging on the Storage Quality of Apple (*Malus domestica*) cv. Royal Delicious. Tropical Agril. Res., 21(1): 10-20.

Yusof, S. and Salleh M. 1992. Physico-chemical Response of papaya to waxing. Acta Hort., 223-292.

APPENDICES

Appendix I. Daily average temperature and relative humidity during the storage period from 21 April to 04 May, 2013

Day	Room Temperature (^{0}C)		Average	Relative Humidity (%)		Average
	Maximum	Minimum		Maximum	Minimum	
21-04-13	29.5	25.4	27.5	98	83	82
22-04-13	31.4	26.1	28.7	94	73	87
23-04-13	32.7	25.8	29.3	95	70	86
24-04-13	33.0	27.2	30.1	95	70	84
25-04-13	33.5	27.0	30.3	95	72	88
26-04-13	32.0	27.4	29.7	95	84	91
27-04-13	29.0	26.2	27.6	97	88	94
28-04-13	33.2	25.7	29.5	92	67	81
29-04-13	31.0	27.0	29.0	95	79	88
30-04-13	29.5	26.2	27.9	95	83	91
01-05-13	30.1	26.0	28.0	98	87	95
02-05-13	29.2	26.0	27.6	98	86	94
03-05-13	30.0	24.0	27.0	98	93	96
04-05-13	28.0	24.0	26.0	97	90	94
02-05-13	30.0	24.6	27.3	97	78	90
03-05-13	27.5	25.0	26.3	97	92	94
04-05-13	29.8	24.7	27.3	95	79	89

Appendix II. Analysis of variance (mean square) results for weight loss (%) of papaya at different days after storage

Source of variation	Degrees of freedom	Mean square of weight loss (%) at different DAS			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	5	2.975**	28.59**	50.85**	138.14**
Error	12	0.388	3.34	3.19	2.49
Total	17				

**= Significant at 1% level of probability.

Appendix III. Analysis of variance (mean square) results for TSS (%Brix) of papaya at different days after storage

Source of variation	Degrees of freedom	Mean square of TSS (%Brix) at different DAS			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	5	0.544**	0.521**	3.658**	5.11*
Error	12	0.065	0.055	0.120	1.29
Total	17				

**= Significant at 1% level of probability; * = Significant at 5% level of probability.

Appendix IV. Analysis of variance (mean square) results for pulp to peel ratio of papaya at different days after storage

Source of variation	Degrees of freedom	Mean square of Pulp to peel ratio at different DAS			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	5	0.593**	0.933**	1.127**	0.286**
Error	12	0.035	0.041	0.033	0.029
Total	17				

**= Significant at 1% level of probability.

Appendix V. Analysis of variance (mean square) results for moisture content (%) of papaya at different days after storage

Source of variation	Degrees of freedom	Mean square of moisture content (%) at different DAS			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	5	10.73**	17.76**	21.30**	16.13**
Error	12	1.70	2.35	2.97	2.29
Total	17				

**= Significant at 1% level of probability.

Appendix VI. Analysis of variance (mean square) results for dry matter content (%) of papaya at different days after storage

Source of variation	Degrees of freedom	Mean square of dry matter content (%) at different DAS			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	5	10.73**	17.760**	21.30**	16.13**
Error	12	1.48	0.358	1.09	1.33
Total	17				

**= Significant at 1% level of probability.

Appendix VII. Analysis of variance (mean square) results for disease incidence (%) of papaya at different days after storage

Source of variation	Degrees of freedom	Mean square of disease incidence (%) at different DAS			
		3 DAS	6 DAS	9 DAS	12 DAS
Treatment	5	453.390**	1071.14**	1232.02**	1039.63**
Error	12	0.628	1.43	3.85	9.79
Total	17				

**= Significant at 1% level of probability.