EFFECT OF ARTIFICIAL RIPENING AGENTS ON QUALITY AND SHELF LIFE OF MANGO

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CERTIFICATE

This is to certify that the thesis entitled **'Effect of Artificial Ripening Agents on Quality and Shelf life of Mango'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science In Horticulture**, embodies the result of a piece of *bona fide* research work carried out by **Towfiqul Anwar**, Registration number: **08-03035** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

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ABSTRACT

The study was conducted at the laboratory of Sher-e-Bangla Agricultural University, Dhaka during the period from June to August 2014 to study the effect of different artificial ripening agents on quality and shelf life of mango. The experiment comprised of two factors; Factor A: Mango variety (3)- V_1: Lakhanvhog, V_2: Langra, V_3: Himsagar; Factor B: Ripening agents (4 levels)- R_0: No ripening agents (control), R_1: CaC_2 @ 10 g/kg of fruit, R_2: Ethrel @ 1000 ppm and R_3: Ethephon @ 1000 ppm. The study was laid out in a Completely Randomized Design with three replications. In case of variety, at different days after harvest (DAH), all of the studied physical, chemical parameters and microbial characters, V_2 showed the better performance, followed by V_3. The highest shelf life (13.16 days) were recorded from V_2, while the lowest shelf life (11.91 days) from V_1. For different ripening agents, at different DAH, all of the studied physical, chemical parameters and microbial characters, showed suitable performances in R_2 treatment and R_1 treatment showed the lowest performances. The highest shelf life (13.08 days) were recorded from R_0, while the lowest shelf life (11.67 days) from R_1. Due to the combined effect of different variety and ripening agents, at different DAH, all of the studied physical, chemical parameters and microbial characters, the better performance were recorded from V_2R_2 and the lowest performance from V_1R_1. The highest shelf life (13.97 days) were observed from V_2R_0 and the lowest shelf life (11.47 days) from V_1R_1 treatment combination. It was revealed that, ethrel @ 1000 ppm is suitable for ripening agents in consideration of quality and shelf life of mango and among the mango variety langra was superior.

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CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.) is a fleshy stone fruit belonging to the genus *Mangifera* under the family Anacardiaceae is a popular fruit and also called the king of fruit (Salunkhe and Desai, 1984). The mango is native to South Asia, from where it has been distributed worldwide to become the most cultivated fruits in the tropics. Mango has been cultivated for more than 4000 years (Candole, 1984). It is commercially grown in more than 40 countries. Asia accounts for approximately 77% of global mango production and the America and Africa accounts for approximately 13% and 9%, respectively. It grows in native to South-East Asia and consists of 62 species (Anonymous, 2013).

The Mango of Rajshahi and Chapai Nawabgonj is popular in home and abroad. The main mango producing countries of the world are India, Pakistan, Mexico, Brazil, Haiti, Philippines etc. India is the largest mango producer country who alone can produce 9.30 million tons followed by Brazil, Pakistan, Mexico, Philippines, Indonesia, Haiti, China, Bangladesh, Egypt, Sudan, Srilanka and Cuba (Bhuyan, 1995). In Bangladesh, mango ranks first in terms of area and third in terms of production and occupies 34,000 hectares of land and total production is 1,085,000 metric tons (BBS, 2013). Mango is decidedly the most popular fruit among millions of people in the orient and is considered to be the best of all the indigenous fruits of Bangladesh. Mango is acknowledged as the best fruits in the world market because of its great utility, excellent flavor, attractive fragrance, beautiful shades of color, delicious taste and healthful value. Nutritionally, mango is highly important because it has medium calorific value and high nutritional values. Carbohydrate content in ripe mango pulp is 16.9 (Salunkhe and Desai, 1984). Mango help prevent many deficiency diseases because it is a rich source of vitamins, minerals arid total soluble `solids (Purohit, 1985).

Nutritional value per 100 g energy 250 kcal, carbohydrates 15 g, dietary fiber 1.6 g, fat 0.38 g, protein 0.82 g, vitamin A equiv. 54 µg, beta-carotene 640 µg, Vitamin C 36.4 mg, vitamin E 0.9 mg, vitamin K 4.2 µg, calcium 11 mg, Iron 0.16 mg, Magnesium 10 mg, Manganese 0.063 mg, Phosphorus 14 mg, Potassium 168 mg, Sodium 1 mg. (USDA, 2013). The per capita fruit consumption in Bangladesh is far below the minimum requirement. The minimum dietary requirement of fruit/day/head is 85 g, whereas our availability is only 30-35 g, which is much lower than recommended daily requirement (Siddique and Scanlan, 1995). On the other hand, scientist claim that a considerable portion of the world's total food supply and that 30 to 40% at the crop produce harvested in the developing countries never reach to the consumer mainly because of pre and postharvest losses (Miller *et al*., 1986). As estimated by Lashley (1984), approximately 30 to 50% fruits go waste during postharvest handling, storage and ripening.

The magnitude of postharvest losses in fresh fruit was estimated to be 5 to 25% in developed countries and 20 to 50% in developing countries (Khader, 1985). According to Hassan (2010), the postharvest loss of mango in Bangladesh is 27.4%. Srinivasa *et al*. (2002) reported from India that the total post harvest losses of mango cv. Totapuri and Alphonso to be 17.9% (3.5% Orchard field), 4:9% transportation, 4.1% storage and 5:4% retail level and 14.4% (1.9% Orchard 3.7% transportation, 3.7% storage and 5.3% retail level), respectively. Quroshi and Meah (1991) found that post harvest loss of mango fruits varied according to variety from 0 to 16.3% with an average loss 12.5%. It also depends on transport distance from production site to retail location. Mondal *et al*. (1995) estimated that postharvest loss of mango was in the range of 30 to 35% due to late ripening. Therefore, a critical area of examination would be how to reduce these postharvest losses in mango and other fresh fruits through so time ripening. Mango being one of the most important fruits, efforts towards reduction of postharvest losses should be of top priority through shortening ripening period.

Calcium carbide (CaC_2) is the commonly used chemical for ripening of mango fruit, due to its low price and availability in local market, however, use of this chemical in fruit industry is being discouraged worldwide due to dangers of explosion and carryover of toxic materials like arsenic and phosphorus to consumers, thus making the healthy fruit poisonous (Mariappan, 2004). Since no technical knowledge is considered necessary for its anomalous use, higher quantity of calcium carbide needed to ripen immature fruit, makes them tasteless (Subramanian, 2004; Medlicott, 1986; Padmini and Prabha, 1997). Various research literatures indicated that ethrel and ethephon are the two potential chemicals which can be used to ripen mango fruit (Cua and Lizada, 1990; Medlicott *et al.*, 1990; Padmini and Prabha, 1997; Singh and Janes, 2001). There are only few reports about the effectiveness of ethephon as a ripening agent (Nair and Singh, 2003). Mata *et al*. (2007) concluded that ripening reactions controlled by ethylene can be increased by exposure of the fruit to an atmosphere containing ethrel in order to produce homogeneous external color. Sergent *et al.* (1993) reported that immersed mangoes in hot water (52^0C for 2 minutes) and thereafter these mango treated with 2-chloroethyl phosphonic acid (Ethephons) at 1000, 2000 or 4000 mgl^{-1} for 1 or 2 minutes, which increased the production of soluble solids content that correlated with the improved flavor and color and softer texture of mango.

Considering the above all situation, the present study was undertaken to fulfill the following objectives:

- To find out the performance of different mango variety in terms of quality and shelf life using different ripening agents.
- To find out the interaction effect of different mango variety and ripening agents.

CHAPTER I
REVIEW OF LITERATURE

Mango is a nutritious and delicious popular fruit all over the world, however, it is a climacteric in nature and has short shelf life. A lot of work is going on to artificial ripening, improve its quality and reduce its wastage by prolonging its shelf life. But research works related to quality and shelf life of mango due to different ripening materials on different popular variety are limited in Bangladesh as well as the world. The research work so far done in Bangladesh and else where is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related so far been done at home and abroad have been has been cited and discussed below-

Dissa *et al*. (2011) carried out a study to determine the impact of ripeness on drying characteristics of mango by considering different zones on the fruit. The total soluble solids/acidity ratio, color and texture of fruit flesh for each zone was considered and the ripeness was estimated. Also for each zone of ripeness, drying curves and time temperature curves were established both in forced and natural convection. Mass diffusivity (estimated by considering two diffusion regions), thermal diffusivity and drying rates were deduced from these drying curves by considering product shrinkage. Results showed that the time required to reduce moisture content to any given level depended on the ripeness state, being highest for unripe samples and lowest for ripe samples. At each drying moment, temperature of ripe sample was higher than that of unripe sample. Mass diffusivity, thermal diffusivity and drying rates strongly increased with ripeness state. At 60^0C, unripe and ripe fruit mass diffusivities ranged respectively from 1.69 × 10-10 to 9.87 × 10-10 m²/s and 3.38 × 10-10 to 1.77 × 10-9 m²/s. Thermal diffusivities ranged from 2.12 × 10-11 to 6.44 × 10-10 m²/s and 2.74 × 10-10 to 8.05 × 10-10 m²/s, respectively for unripe and ripe samples. In natural convection, drying rates reached maximal values of 0.16 kg m^{-2}/s for unripe

sample and 0.47 kg m^2/s for ripe sample whereas in forced convection they reached respectively 0.43 and 0.67 kg m^2/s.

Jabbar *et al*. (2011) diseases and disordered causes severe losses to mango fruit quality and sometime yielding unmarketable fruit. Also, the risk of fruit fly presence has made it obligatory to use pre-requisite as hot water quarantine treatment (HWQT) for marketing and access to other countries like China and Iran. To differentiate the use of fungicides and hot water quarantine application on mango fruit cv. Samar Bahisht Chaunsa, a study was carried out. The mangoes were stored for 21 days at (13±1^{0}C, 85±5% RH). The results showed that application of Topsin-M fungicide @ 1 g L^{-1} as field dip for 1 min (pre-transport) followed by HWQT @ 48^{0}C for 60 min., showed significantly suppression of postharvest diseases. The HWQT generally lead to increase the internal discoloration as compared with the control. NaOCl alone or with HWQT, caused higher internal discoloration of fruit. All physical treatments induced some degree of soft nose but combination of NaOCl with HWQT was found to accelerate the problem compared to control. The fruits treated with NaOCl @ 2.5 g $10L^{-1}$ and Topsin-M @ 1 gL^{-1} along with HWQT @ 48^{0}C for 60 min gave greater total titratable acidity. However, color, total sugar, non-reducing sugar, total soluble solids contents and organoleptic acceptability of the fruits were found to be non-significantly influenced by the treatments. The postharvest, pre-transport treatment of Topsin-M @ 1 gL^{-1} followed by HWQT (48^{0}C for 60 min) was effective in reducing incidence of postharvest diseases, and fulfilling market access criteria. The higher degree of soft nose development in hot water quarantine treatment fruits.

Ezz and Awad (2011) studied the effect of various treatments of potassium permanganate, hot water treatment under 50^{0}C for 30 minutes and shrink film addition to control shelf life of mango cultivars ‘Hindi Be- Besennara’ (early ripe) and ‘Alphonse’ (mid season) under three levels of temperature including 8, 10 and 13^{0}C and relative humidity of (80-85%) for 30 days. The parameters such as decay, shelf life, weight loss, firmness, titratable acidity, TSS, ascorbic acid,

reducing and total sugars were studied. The data of each parameter was collected at an interval of six days during the storage period. Results showed that the treatment of shrink film at 8^0C was proved the most effective in keeping shelf life of the two cultivars and this also showed better performance of physical and chemical parameters in the two seasons for the two cultivars. It was found that keeping quality in low temperature and decreased with increasing temperature degree. Similarly, the hot water treatment showed the same trend with control in TSS, acidity, reducing and total sugars and also low content in ascorbic acid. All treatments and control had no shelf life in 24 and 30 days in 13^0C. While in the shrink film there was no decay recorded till 24 days under the different temperatures applied.

Venkatesan and Tamilmani (2010) the study was focused on the influence of ethereal on the ripening of off–season fruits of *Mangifera indica* L. var. Neelum. In the experiment the experimental fruits were treated with different concentrations of ethereal (100, 200 and 300 ppm) while the untreated fruits were placed inside the laboratory naturally. They treated the fruits with different concentrations (100, 200 and 300 ppm) of ethereal ripened on 13^{th} day, 11^{th} day and 9^{th} day, respectively after treatment of different concentrations. The color of the treated fruits changed from green greenish to yellow and the fruits were fit to be eaten. Also the color changed from green to greenish yellow to yellow. On the other hand control fruits, partial ripening led to incomplete metabolic changes, which did not change the presence of sourness in the fruits. Consequently, they were unfit for eating. These studies were passed out using the fruit pulp and peel tissues only. The data showed that phenols reduced in ripening, both in the untreated and treated fruits. Activity of enzymes peroxidase, polyphenoloxidase and catalase increased. Comparing the 100, 200 and 300 ppm ethrel treatments, it was found that 200 ppm had the better results of ripening of off–season fruits of *Mangifera indica* L. var. Neelum.

Singh and Singh (2010) studied the effect of post harvest treatment on physiological and chemical properties of mango cultivar Amrapali. They used

seven treatments of postharvest were specified as T_1 (control), T_2 (hot water treatment), T_3 (Frutox wax treatment), T_4 (hot water treatment + FWE), T_5 (ALPF), T_6 (hot water treatment + ALPF), T_7 (FEW + ALPF), T_8 (hot water treatment + FWF + ALPF). The changes in physical, biochemical and organoleptic characteristics of the fruits were encouraged and their determination was noted in Amrapali mango fruit. Physical change viz physiological weight loss percent, specific gravity, size of fruits, percentage of spoilage and ratio of pulp-peel were appreciably different over control. On fifteenth dayof exploration, fruit which was treated with water (hot) + wax and enfold in ALPF showed lowest physiological weight loss.

Islas-Osuna *et al*. (2010) mango is a tropical fruit that ripens rapidly; therefore a continuous effort has been made to increase its shelf life and quality by the postharvest technologies. This technology includes the application of 1-Methylcyclopropene which acts as ethylene receptors inhibitor. They treated the fruits with 1-Methylcyclopropene (750 ml L^{-1}) influenced the physical and chemical characteristics, compounds (bioactive) and activities of cell wall degrading throughout ripening period and storage. The mature green mangoes of Kent cultivar were compared for outer quality, Polygalacturonase phytochemicals and Pectin Methylesterase activities of enzyms in storage by 20°C for two weeks using 1-MCP and those without 1-MCP. The results showed that the concentration of ascorbic acid reduced during the ripening of fruit and losses were reduced in 1-MCP-treated mangoes. The enzymatic activities of pectin methylesterase and Polygalacturonase were decreased in the treated fruits than untreated ones. There was little change observed in the β-carotene in the treated and untreated fruits. It may be concluded that 1-MCP influenced the process of ripening in Kent cultivar of mango fruit by decreasing the ascorbic acid losses, 1-MCP treatment was justified as it maintain nutritional value during its storage.

Le *et al*. (2010) determined the quality changes and control the occurrence of disease; treated the Taiwan native strain mango fruit with hot water (52, 55 and

58^0C); vapor heat (46.5^0C for 40 min) and treatment of hot water + vapor heat pursed cold storage (1, 3, 6, 9, 12, 15 and 20^0C). At 55^0C for 3 (minutes) the hot water reduced the spots and controlled of anthracnose disease for 6 days compared to control. The treatment of vapor heat retained firmness, peel color index and content of total soluble solid at 3^0C of storage time. The disease occurrence of the *Colletotrichum gloeosporiodes and Alternaria alternata* were reduced by hot water and vapor heat treatment application at 3^0C for 3 weeks by storage. The area of *Dothiorella mangiferae* increased during the similar time but did not change the quality. The combined treatment of hot water plus vapor heat with continuous storage at 3^0C for ambient room temperature the highest quality of fruit produced.

Payasi and Sanwal (2010) reported that the final stage of development is fruit ripening, which physiologically and biochemically measures that make fruit tasty and attractive to eat. The ripening of fruit can be retarded by different methods of modified atmosphere and packaging, gamma irradiation treatment and sucrose ester coating etc. The phytohormones, 1 methylenecyclopropene and reducing agents treatments delayed the ripening of fruit. Molecular biology tackle like plants (transgenic) with control of genes concerned in production of ethylene otherwise over appearance of genes for deprivation of ethylene, virus stimulated gene quiet as well as exploitation of transcription aspect have been efficiently used for regulating or controlling ripening of mango fruit.

Rathore *et al*. (2010) recorded significant effect of active packaging in Cardboard Carton (APCC) on overall quality characteristics such as loss in weight, titratable acidity, ascorbic acid, pH and total soluble solids contents of mango (Chaunsa white variety). It was investigated at the ambient temperature ($28\text{-}33^0$C and 56.7-69.7% RH) during storage. The results showed that the uncoated fruit packed in carton had comparatively greater percent weight loss (10.96%) than control (9.39%); however, after use of APCC system same packaging had significantly decreased the percent weight loss up to 6.89%. It was also observed that mango fruit through APCC system showed TSS (16.44-

20.76%), pH (3.98-4.83), had increase, while TA (0.51-0.92%) had slower decrease, and slower increased of AA (23.06- 40.83 mg/100 g) during ripening stage with an average mean of 8.10%, 17.73%, 4.28%, 0.75%, 25.47%, respectively. The control sample (T) had higher weight loss (9.39%), TSS (20.83%), highest pH value (4.91), lowest acidity (0.44%), highest AA (42.06 mg/100 g), respectively at much earlier during storage. It can be concluded from the study that innovative approach of APCC with other protective chemicals such as coating emulsions having fungicide, ethylene absorbent and anti-ripening agent showed an effective role in enhancing the storage life up to 25 days and also controlled the compositional changes due to delayed ripening of the fruits with a minimum quality loss, as compared to control sample which had a greater changes in its composition and qualitative losses during storage at ambient temperature. The unappealing skin, changed color and poor taste the control fruit was perished within two weeks of their storage.

Amin *et al*. (2008) studied the sap burn injury and regarded it as the most threatening to external fruit quality of mango. When the pedicel of a mango fruit is broken, the sap exudes and spread over the fruit peel and causes a serious injury to the skin of mango. They estimated the suitable time of harvesting as well as de-sapping for control of sap burn injury in mango fruits. Australian industry product “Mango Wash” and Lime [Ca $(OH)_2$] at different times of the day including: 7 a.m. (morning), 12 p.m. (noon) and 5 p.m. (evening) were assessed. Lime @ 0.5% and Mango Wash @ 0.4% was used. Results showed that no sap injury (0 score) was recorded in the fruits harvested and de-sapped during morning, while maximum sap injury was found at noon in both the treatments (0.5 score for lime, 0.75 score for Mango Wash). Both the treatments (lime and Mango Wash) showed significantly reduced sap injury as compared with control for all the three times of treatment application. All of the physicochemical characteristics were non-significantly affected except fruit peel color and non-reducing sugar contents. The color of fruit peel was slightly suppressed by the use of Mango Wash. Lime was found to impart attractive

appearance to the fruits; however the skin color was non significantly improved as compared to control. Also the qualitative characteristics were non-significantly influenced by the time of fruit harvest. However, significantly greater TSS was found in the fruit harvested at noon as compared to other times of the day. It can be concluded that lime may be successfully used as an alternate instead of highly expensive Mango Wash for de-sapping of mango fruits.

Anwar *et al*. (2008) carried a study on two major problems related to postharvest of local mango industry. The firstly issue was the use of wooden crates which are being eliminated from the markets. Secondly, for early ripening of mango calcium carbide (CaC_2) is mostly used; due to health hazards caused by CaC_2 its use is being discouraged internationally. To find out an alternative for resolving the above mentioned problems, two experiments were carried out on cv. Samar Bahisht Chaunsa commercial mango. Fruits were packed in traditional wooden packaging with newspaper liner (WP) and corrugated cardboard packaging (CBP) for comparison. In first experiment, two chemicals CaC_2 (2 g kg^{-1} of fruit) and ethylene (C_2H_4) application (100 ppm, 20^0C, 48 h) were compared for ripening of mangoes, followed by ripening at ambient conditions (33 ± 1^0C and 60-65 %RH). The results showed that CBP fruit had significantly lower fresh fruit weight loss (FWL) and better storage life compared with WP fruit treated with or without CaC_2. It was also found that WP fruits with CaC_2 had faster ripening rate and better color of peel color as compared with C_2H_4 treated CBP. In 2nd experiment, WP or CBP fruit were stored (13 ± 1^0C and 85-90% relative humidity) for fifteen days, and allowed for natural ripening at two different temperatures ($28, 33 \pm 1^0$C). Also the performance of mango with C_2H_4 (100 ppm, 48 h) treatment at 25^0C and 30^0C was investigated in CBP fruit. Despite of ripening temperatures and methods, CBP showed significantly decreased in FWL as compared with WP. Ethylene treatment at higher temperature (30^0C) significantly improved quality compared with application at low temperature (25^0C), however, the fruit color was not developed to the desired level. It may be concluded, CBP can be a better substituted for WP due to its demonstrated

benefits; however, more work is needed to develop a precise ripening protocol use of ethylene at different concentrations and temperature etc.

Maqbool and Malik (2008) sap burn injury is a serious problem of mango fruit as it reduces the attraction and downgrade fruit. Management of sap burn in commercial cultivars Sindhri and Chaunsa of Pakistan at physiological maturity were harvested along with 4-5 cm pedicel. After de-stemming, fruits were immediately treated with potential chemical solutions i.e. calcium hydroxide [$Ca(OH)_2$], Tween-80, sodium carboximethyl cellulose (CMC), lauryl sulfate sodium (LS), detergents and vegetable oil. The fruits after treatment with the chemicals were dried in air and packed in boxes (cardboard), and brought in laboratory and were stored at14°C & RH 85% for seven and fourteen days in case of cv. Sindhri and cv. Chaunsa, respectively. Fruits treated with calcium hydroxide showed better results against sap burn injury followed by Tween-80 in both the cultivars. In the follow-up study, the chemicals with better results in experiment 1 were testes along with alum on cv. Chaunsa to verify the results. The fruits after application of chemicals were subjected to different conditions for storage (25^0C and RH 56% and 14^0C & RH 85%). The data on sap burn injury recorded after 24, 48 and 72 hours, showed almost similar results at different temperatures. Treatment with $Ca(OH)_2$ gave 95% sap burn injury control at different temperatures. The same treatment gave higher TSS levels ($Ca(OH)_2$ at 25^0C). At the same temperature total sugars was recorded maximum in fruits treated with simple water (30.80%), while in stored fruits, maximum total sugars (26.70%) were noted with alum treatment. De-stemmed under $Ca(OH)_2$ gave a maximum of total carotenoids in fruits at different storage temperatures. It may be concluded that $Ca(OH)_2$ was the better treatment in reducing sap burn injury and improving the fruit quality at different temperatures.

Ravindra and Goswami (2008) mango fruit has short shelf life after harvesting therefore; studied the important postharvest pre-cooling technique on mango (tropical) fruits. For pre-cooling process the cooling medium of liquid nitrogen

with sufficient potential was used due to their motionlessness of the vaporized gas of nitrogen and high capacity of cooling. In comparison to pre-cooling like air cooling and hydro-cooling techniques for Amrapali mango fruit, the liquid nitrogen was used with the system of mechanical refrigeration like the cooling (medium). The performance of pre-cooling was evaluated for fruit quality like color, firmness of fruit, index of chilling injury, and the cooling coefficient and rate of cooling. They studied the effect of various pre-cooling techniques on mango fruit acidity (titratable), pH and the contents of total soluble solids of the ripened mango The results showed of this study that the system of liquid nitrogen (20.5 kg/h the flow rate of liquid nitrogen; 85^0C of average gas temperature) enhanced the cooling coefficient of the air cooling method by the forty percent and had no unfavorable effect produced on the fruit quality. The control of exposure time and careful plane would facilitate in understand the liquid nitrogen potential in techniques of precooling for mango fruits. This would be useful (practically) in system of control atmosphere storage methods.

Anwar and Malik (2007) determined the effect of hot water treatment on mango (cultivar Sindhri) fruits ripening behavior, shelf life and quality. The fruit of mango was transferred to treatment of hot water at 45^0C-75 minutes and 48^0C in 60 minutes along with wash only (control). A fruit coating, two percent (Fresh Seal P) was also used in combination with treatment of hot water on 48^0C-60 minutes. After application of water (hot) treatment, fruits were ripened without storage at room temperature otherwise were stored on 13 ± 2^0C and relative humidity 85±5 percent. The stored mango fruits were removed after seven, fourteen and twenty days and were ripened at ambient temperature (24 ± 1^0C, relative humidity 68-70 percent). Hot water treatment effects on physical and biochemical properties were estimated. Fruit transferred to hot water treatment at 45^0C-75 minutes and naturally ripened (without storage), indicated non-significant difference for different quality factors than wash only (control) whereas keeping the shelf life of fruits (6 days). Hot water application at 48^0C-60 minutes reduced the period of ripening i.e. 3 days. Whereas, during storage

non-significant differences among treatments indicated that hot water treatment does not influence the post-storage fruit quality. Among various treatments, fruit transferred to hot water treatment at 45^0C-75 minutes created superior results than treatment of water (hot) on 48^0C-60 minutes total carotenoids contents were found maximum in washed only fruits (62.78 µg/g) followed by treatment of hot water on 45^0C-75 minutes (59.39 µg/g). Fruits transferred to higher temperature during hot water treatment developed uniform color and more yellow. The results were non-significant for rests of the treatment.

Maqbool *et al*. (2007) accessed the international market for supply of superior quality mango there are different problems to be surmounted. Sap burn is one of the major problems in Mangoes and different management practices and experiments have been conducted to deal with this problem in Pakistan for various cultivars of Mangoes. In the current study, first experiment was explored the various cultivars of mango fruit for harvest time of a day and for sap quantity. The collected sap from Chaunsa cultivar was 11.89 times more than Sindhri cultivar and early in the morning the exudation of sap quantity was higher as compared to later throughout the day. Secondly it was noted that the effect of late de-stemming (after harvest) on sap quantity was little. But the quantity of total sap was highest in Chaunsa cultivar and lowest in Sindhri cultivar. Spurt and ooze were also tested in the three commercial mango cultivars and the sap burn susceptibility after 24, 48 and 72 hrs at two various storage environment (ambient: 25 ± 1^0C; 14^0C and 85 percent relative humidity). The cultivar of Chaunsa was most vulnerable followed by cultivar Dusehri and Sindhri. The rate of sap burn was higher in Chaunsa cultivar at ambient (room) temperature (25 ± 1^0C) as compared to cold storage (14^0C, 85 percent relative humidity (RH)). The sap burn occurrence was about same in Dusehri and Sindhri cultivars at both the temperatures. With reference to harvest time of the day the severity of sap burn level was investigated. They noted that with the proceeding of daytime the severity of sap burn increased. The severities score of sap burn was lowest in harvested fruits at 8:00 am (0.06) and was highest in

fruits were harvested at 3:00 pm (1.08) after seven days of storage at ambient temperature and in cold storage (13±1^{0}C and 80-85 percent relative humidity). They also determined the optimal de-sapping time and decreased the sap burn injury incidence; for this purpose they placed the fruits on desapping trays for various time phases. The sap burn incidence was lowest in fruits which were kept on de-sapping trays for twenty minutes (0.65) followed by ten minutes (0.73) than untreated (2.54)/fruit harvested by conventional technique after fifteen days of storage (13±1^{0}C and 80-85 percent relative humidity).

Singh *et al*. (2007) reported the fleshy fruits go through textural changes with ripening that lead to tissue firmness loss and subsequent softening due to cell wall take to pieces carried out through various and in particular articulated enzymes. They investigated the effect of different chemical treatments on mango fruit ripening at level of physiologically and biochemically. The changes in firmness, respiration, total soluble sugar, pH and a degrading enzyme of cell wall pectatelyase action, treatment with 1-methylcyclopropene, gibberlic acid, sodium metabisulphite, ascorbic acid and silver nitrate, retarding the process of ripening whereas those of ethereal increased the process. They observed pectatelyase activity of mango fruit was to be inhibited by certain metabolites present in enzyme of dialyzed ammonium sulphate take out and EDTA. The mango pectatelyase activity showed an entire requirement for calcium and an optimal 8.5 pH.

Zheng *et al*. (2007) investigated the oxalic acid effects on ripening and occurrence of decay mango fruit at room temperature (25^{0}C) during storage. The Zill cultivar of mango fruit was dipped in oxalic acid solution (5 mM) for ten minutes at 25^{0}C. The data demonstrated that the ripening of fruit was retarded and decay occurrence was also decreased by treatment of oxalic acid compared to the control. They concluded that reducing production of ethylene was a major provider to delaying the process of ripening by the physiological effect of oxalic acid. The treatment of oxalic acid showed potential technique for mango postharvest storage.

Kaswija *et al*. (2006) studied the organoleptic quality and microbial infectivity on mature green Dodo mango fruit before and during a 3- and 6-day period of ripening by smoked pit ripening, ethylene (fruit generated) pit ripening, untreated pit ripening and room temperature as control technique. The changes of post harvest ripening in the quality parameters of the ripened mango fruit were associated with treatments and compared by same changes in other verities of mango. They concluded that the organoleptic characteristics have significant differences with the employed method. The quality of microbial was significantly different among the treatments, while with aroma profiles there were significant differences of identified compounds of aromatic reflected the most important scores of sensory quality at ripening stage.

Malik *et al*. (2006) explored the advantage of postharvest polyamines application (Spermidine, Spermine and Putrescine) on the shelf life and quality of Kensington Pride mango fruit. Application of polyamine slow down the color development, fruit softness and physiological weight loss was decreased through storage without a significant reduction in ethylene production. Low concentrations of Spermine (0.01 mM), high concentrations of Spermidine (0.5 mM) and Putrescine (1 mM) were more useful in delay fruit softening. Through fruit ripening, Spermine (0.01 mM) showed the lowest amount of respiration compared with the fruit control. The ripe fruit analysis stored for three or four weeks, illustrated that polyamine application appreciably improved the firmness of fruit, ascorbic acid, acidity, while reducing the ratio of TSS/acid and content of total carotenoid compared with the control. The exogenous polyamines application enhanced the shelf life of mango fruit without having harmful result on quality of fruit.

Zeng *et al*. (2006) for disease control treated the Matisu variety of mango fruit with 1 mmol/L salicylic acid solution for two minutes in vacuum diffusion on a low down pressure and for an extra ten minutes at pressure of air. The mango fruit was immunized by anthracnose spore suspension 1×104 CFU m/L when fruit was kept (incubated) at 13^0C and relative humidity 85-95%. At the fourth

day of incubation, in treated (with salicylic acid) fruit the lesions diameter and disease incidence were 20.9 percent and 37.5 percent lesser as compared to control fruit. By treatment of salicylic acid, the action of protection enzymes was notably increased and the action of phenylalanine ammonia-lyase and β-1, 3-glucanase was six/0.9 double higher as compared to control fruit. In treated (salicylic acid) fruit the superoxide radicals and hydrogenperoxide production speed was 79.44 percent and 22.3 percent superior as compared to control fruit on the eight day. They concluded that phenylalanine ammonia-lyase, β-1, 3-glucanase and hydrogen peroxide/superoxide radicals possibly occupied in the disease resistance enhancement in fruit of mango.

Anjum and Ali (2004) studied the post harvest treatment on green mature mango cultivar SS-1 fruits; were immersed for ten minutes in 2.5, 5.0 or 7.5 percent calcium sulphate ($CaSO_4.2H_2O$), calcium ammonium nitrate $\{Ca(NH_4NO_3)_2\}$ and calcium chloride ($CaCl_2.2H_2O$) solutions. A control was also incorporated in which fruits were dipped in fresh water for ten minutes. At ambient temperature (25 ± 3^0C) the fruits were ripened in boxes lined and enclosed with newspaper. Calcium chloride delayed the ripening of fruit about three days as compared to control and resulted in superior aroma of the fruits, however, it stimulate shriveling of skin. Calcium sulphate treatments showed in better color of pulp. The increase in concentration of calcium salts resulted in reduced the ripening but had harmful effect on quality of fruit by rising skin shrinking and decreasing taste and flavor of the fruits. CaC_2 at 5.0 percent delayed the ripening for four days and resulted in better skin and pulp color but with enlarged skin shriveling and poor taste and flavor, showing reduced eating quality.

Santos *et al.* (2004) studied the effect various maturity stages of Rosa cultivar mango with calcium chloride. Fruits were harvested at the mature-green (green yellowish) and pre-climacteric (yellow-greenish) maturity stages. Calcium chloride was applied by 15-cm deep fruit immersion during two hours in solutions contain 0.0 (control); 4.0 and 8.0 percent. The mango fruit was stored at 10 ± 1^0C and 85 percent relative humidity during twenty days, followed by five

day storage at room temperature (24 ± 2^0C). Fruit skin color, weight loss, firmness (scores one to seven), internal and external appearances (scores one to six), total soluble solids and total titratable acidity were evaluated. Calcium chloride was particularly more useful when applied to pre-climacteric fruits. The fruits treated with 4.0 percent calcium chloride demonstrated fruits presented skin black spot, soaked areas, and decay particularly pre-climacteric mangoes. As compared to controls, 8.0 percent calcium chloride treatment provided a five-day enhance in shelf life of mature-green 'Rosa' mango stored at 10 ± 1^0C. The calcium chloride 8.0 percent showed lowest weight losses when transferred to room temperature, while maintaining total soluble solids, titratable acidity, fruit firmness, and best external and internal appearances, even though, no significant delay on skin color progress was noticed.

Nair and Singh (2003) tested the effects of pre-storage ethereal application on chilling injury development, ethylene production, respiration rate and quality of Kensington Pride mango fruit. This mango (mature green) fruit was dipped in aqueous solution including different ethereal application zero, fifty, 250 and 500 mg L^{-1} along with surfactant (Tween 80) 0.01percent for five minutes. These fruits were stored for 4 weeks at 5^0C. At 22^0C, the mango fruit was permitted toward ripening. Chilling injury index, respiration rate and ethylene production was noted throughout the period of ripening from one to nine days. The rots of fruit, acidity, taste, firmness, TSS/acid ratio, total sugars, non-reducing and reducing sugar and total soluble solids were noted from fruit entirely ripe. Chilling injury was decreased significantly among every ethereal treatment. The 500 mg/L ethereal treatment showed to be mainly useful into decreasing the chilling injury. In ethereal treated fruit the ethylene production and respiration rate was also enhanced with ripening period than fruit untreated. The quality of fruit enhanced by the treatment of ethereal with improved sugars, TSS/acid ratio, total soluble solids and decreased the firmness of fruit. They concluded that pre-storage treatment of 500 mg/L ethereal dip for 5 min decreased chilling injury as well as enhanced quality of fruit and taste.

Prusky *et al*. (1999) studied the reduction of postharvest diseases occurrence source by *Alternaria alternata* and increasing the quality of mango fruit. For this purpose combined spray of hot water & brushing of fruit treatment for 15-20s was used. The treatment of hot water effectiveness was investigated at various temperatures (48 to 64^0C), in mixture with treatment of prochloraz plus waxing of fruit. Fruits brushing by hot water considerably decreased the rot progress through *Alternaria alternata*. After storage, the decrease of disease incidence by treatment (hot water brushing and prochloraz @ 900 µg ml^{-1}) for three weeks at 12^0C and another week at 20^0C was more effective than by hot water brushing alone. The treatment of hot water brushing for 15s enhanced the development of fruit color and more useful as compared to common treatment of commercial dip for five minutes on 55^0C. High quality for mango fruits with a lesser amount of decay progress by the combination of hot water brushing and waxing.

Menezes *et al*. (1995) studied the obvious flows of sap squirt out from the point of abscission of the fruit stalk after harvesting. The sap burn produced undesirable aesthetic on the fruit skin due to seepage of sap with considerable economic loss. They discussed the problem of economic significance, the biochemical description of the mango latex and injury of sap burn and some techniques to decrease the injury.

Holmes *et al*. (1993) evaluated the standard harvesting technique to pick the mango fruit with elongated stem and transport them in crates made of plastic to the packing shed. The mango fruit were then de-sapped by removing the pedicel or stem and the fruits were placed stem end down on a conveyor for 20- 30 minutes. This technique still resulted in between 50 and 60 percent of the mango fruit suffering from some extent of sap burn. The current work by officers of the Queensland Department of Primary Industries has verified that these levels could be reduced by various techniques: (1) packing with short stems; (2) de-stemming in a lime solution; (3) treatment with sprays and dips detergent earlier to destemming; (4) picking the fruit without stems on a harvesting support spraying and or dipping detergent on the mango fruit without delay. All techniques

reduced the severity and the sap burn fruit percentage. The harvesting aid proved most useful reducing the total sap burn to 15.9 percent, and resulted in reduction of the pickers' number to almost half and hence a significant saving in the overall cost.

Loveys *et al*. (1992) studied that the skin of mango fruit damage through exuded of sap from the broken or cut pedicel decreased the acceptance of consumer and shelf life of the storage fruit. The Kensington mango fruit are mainly vulnerable to sap burn damage. The sap of fruit separated into two parts by centrifugation. Damage skin was caused mostly through the top non aqueous part. The main factor of this part was terpinolene which provided symptom identical from sap burn damage when applied to the fruit surface. The indistinguishable kind of injury could be stimulated by the terpinolene synthetic application when applied with no added water and diluted in hexane or as an aqueous mixture. The components of non-volatile sap separated by cleansing were not harmful to the skin of mango. The sap exuded from the leaf petioles of mango also enclosed terpinolene, but its application was a lesser amount of than one percent of the application in pedicel sap and this sap has no harmful effect on the fruit skin. Irwin cultivar of Florida is a lesser amount responsible to sap burn damage & in sap the major terpene was recognized as 3-carene. When applied to skin of Kensington mango, 3-carene caused notably less injured than terpinolene. They concluded that the main cause of sap burn in mango is entrance of the sap volatile components for instance terpinolene for the period of lenticels, resultant in injured of browning and tissue of following enzymes.

McCollum *et al.* (1992) studied the effects of individual shrink film wrapping on mango fruit shelf life and quality. Mango fruit were wrapped with shrink film in Rd 106 film and other left non wrapped. The wrapped and non wrapped fruit was held at 21^0C frequently and used to measure the in package application of oxygen, CO_2 and ethylene as well as CO_2 and ethylene evolution from fruit subsequent removal of the wrap in one set. The fruit was stored at 12^0C for one or two weeks after which they were shifted to 21^0C for ripening and then quality

was estimated in second set. The concentration of CO_2 within the warp series from about five to eight percent and concentration of oxygen was about twelve percent at 21^0C. The taking away of the film, respiration of the fruit were same to non wrapped controls; though, ethylene evolution increased with increased period of wrapping. The increased ethylene was most dissimilar between wrapped and non wrapped fruit. The wrapped fruit had more decomposed and inferior fruit quality when compared with non wrapped fruit. They concluded from this study individual shrink film wrapping of mango fruit does not showed to be useful.

Yuniarti and Suhardi (1992) minimized the postharvest losses during transportation by applying different methods for retarding ripening process in mangoes (cv. Arumanis). For this purpose mango fruit was harvested at optimal maturity and treated with (1) 2, 4, 6 percent solution of $CaCl_2$; (2) 4, 5, 6 or 7 percent wax emulsion; (3) perforated polyethylene bags wrapping have KMnO4 as an absorbent of ethylene (2.5, 5.0, 7.5, 7.5 or 10.0 percent); (4) sealed polyethylene bags wrapping with $KMnO_4$ as in (3); or (4) control untreated. The mango fruits were placed perforated cartons and these cartons were transported for 36 hours. At room temperature analyzed these samples for soluble solids contents, texture, weight loss and days taken to reach the best possible ripeness or the condition of over-ripe. Emulsion of wax at six or seven percent had the maximum result in slow down the ripening process (by eleven days) and the stage of over-ripe (by nine days), and was compared by control fruits, and resulted weight loss was lowest. The soluble solids contents (14.8 percent after transportation subsequent 6% wax treatment) were also lowest by treatment of wax emulsion as compared to control.

CHAPTER III

MATERIALS AND METHODS

The investigation was conducted to study the effect of artificial ripening agents on quality and shelf life of mango. The materials and methods were used for conducting the study has been presented in this chapter under the following headings-

3.1 Description of the study location

3.1.1 Period of the study

The study was conducted during the period from June to August 2014.

3.1.2 Description of the study area site

The study was conducted at the laboratory of the Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in $24^0 09^/$N latitude and $90^0 26^/$E longitudes. The altitude of the location was 8 m above from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.1.3 Physical condition of the storage room

The temperature and relative humidity of the storage rooms were recorded daily basis with a digital temperature and humidity meter. The maximum temperature of the storage room was 36^0C and relative humidity 83%. Details of the temperature and humidity of storage room has been presented in Appendix I.

3.2 Details of the study

3.2.1 Experimental materials

Three (3) popular varieties of Mango i.e. Lakhanvhog , Langra and Himsagar were used as experimental materials for the study. These mango at matured stage were collected from mango orchard of Volahat, Chapainawbgonj. Fruit were treated with different ripening agents i.e. CaC_2, Ethrel and Ethephon. All of these ripening agents were collected from local market.

3.2.2 Design and layout of the study

The study was laid out in a Completely Randomized Design (CRD) with three replications. Sixteen uniform sized mango fruits were kept in each treatment. A total of 192 fruits of more or less similar shape and size and free of visible disease symptoms were collected. The skin adherences, dots and latex were cleaned by gently wiping the fruits with moist and clean towel.

3.2.3 Treatments of the experiment

The experiment comprised of two factors

Factor A: Mango variety (3 varieties)

i) V_1: Lakhanvhog
ii) V_2: Langra
iii) V_3: Himsagar

Factor B: Ripening agents (4 levels)

i) R_0: No ripening agents i.e. control
ii) R_1: CaC_2 @ 10 g/kg of fruit
iii) R_2: Ethrel @ 1000 ppm
iv) R_3: Ethephon @ 1000 ppm

There were total 12 (3×4) treatment combinations as, V_1R_0, V_1R_1, V_1R_2, V_1R_3, V_2R_0, V_2R_1, V_2R_2, V_2R_3, V_3R_0, V_3R_1, V_3R_2 and V_4R_3.

3.2.4 Application of ripening materials

3.2.4.1 Application of CaC_2

Calcium carbide (CaC_2) is the commonly used chemical for ripening of mango fruit, due to its low price and availability in local market, however, use of this chemical in fruit industry is being discouraged worldwide due to dangers of explosion and carryover of toxic materials like Arsenic and phosphorus to consumers, thus making the healthy fruit poisonous. For arsenic test 4 samples were sent to Bangladesh Council of Scientific and Industrial Research (BCSIR)

for laboratory analysis to find out the amount of Arsenic. For this purposes only Langra variety was used and only 4 samples (control, 5 g/kg, 10 g/ka and 15 g/kg CaC_2) were sent to BCSIR. Calcium carbide (CaC_2) was applied in solid form. The mangoes were weighted in a digital machine and accordingly CaC_2 were applied @ 10 g/kg of fruits in a plastic bucket and warped the bucket with a polythene paper and kept for 3 days.

3.2.4.2 Preparation of ethrel solution

'Ripen-15' was the trade name of ethrel which was collected from local market. Ripen-15 had the ethrel concentration of 39%. So, to prepare 1000 ppm ethrel solution, 2.6 ml of Ripen-15 was added to 1 liter of distilled water. After preparing the solution the mangoes were dipped in ethrel solution for 10 minutes.

3.2.4.3 Preparation of ethephon

2-chloroethylphosphonic acid was the trade name of ethephon which was collected from local market. To prepare 1000 ppm ethephon solution, 1.7 ml of 2-chloroethylphosphonic acid was added to 1 liter of distilled water. After preparing the solution the mangoes were dipped in ethephon solution for 10 minutes.

3.3 Parameters studied

In this experiment the following parameters were studied:

3.3.1 Physical parameters

- Firmness
- Weight loss
- Dry matter content

3.3.2 Chemical parameters

- TSS (Total soluble solids)
- TA (Titratable acidity)

- Vitamin C

3.3.3 Microbial characters

- Disease incidence (%)

3.3.4 Shelf life

3.4 Observation

During the entire period of storage, the fruits used in the experiment were observed every day. Data were recorded at an interval of 2 days starting from 3 Days after harvest (DAH) is influenced by different varieties and ripening materials.

3.5 Methods of studying parameters listed earlier

3.5. 1 Physical parameters

3.5.1.1 Firmness

Days required to reach different stages of firmness during storage and ripening were determined using numerical rating scale of ,1-6, where 1 = mature hard, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe, 5 = over ripe, 6= totally unfit for consumption. Similar rating scale was used by Hassan (2006).

3.5.1.2 Estimation of total weight loss

The fruits of each treatment were individually weight by using electric balance and kept for storage. Percent total weight loss was calculated at an interval of 3 days during storage by using the following formula:

$$\text{Weight loss (\%)} = \frac{\text{IW-FW}}{\text{IW}} \times 100$$

Where,

IW= Initial fruit weights (g) and

FW= Final fruit weight (g)

3.5.1.3 Estimation of dry matter content

Ten (10) gram of fruit pulp was weighed in a porcelain crucible (which was previously cleaned, dried and weighed) from each treatment and replications. The crucible was placed in electric oven at 80^0C for 72 hours until the weight became constant. It was then cooled in desiccators and weighed again. Percent moisture content was calculated by using the formula:

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

Where,

IW= Initial weight of fruit pulp (g) and

FW= Final weight of oven dried fruit pulp (g)

Percent dry matter content of the pulp was calculated from the data obtained during moisture estimation using the following formula:

Dry matter (%) = 100 - % moisture content.

3.5.2 Chemical parameters

3.5.2.1 Estimation of total soluble solids content

Total soluble solids content of mango pulp was estimated by using Abbes, Refractometer. A drop of mango juice squeezed from the fruit pulp on the prism of the refractometer. Percent TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods described by Ranganna (1979).

3.5.2.1 Titratable acidity (TA)

Titratable acidity was estimated by chemical analysis process using mango pulp stored in refrigerator. The titratable acidity of mango pulp was determined by method of Ranganna (1979). The following reagents were used for the determination of titratable acidity.

i) Standard NaOH solution (0.1 N)

ii) 1% phenolphthalein solution

Extraction of mango juice

Ten (10) gram of fresh mango pulp was taken in a 500 ml beaker and then it was homogenized with distilled water in blender. The blender materials were then filtered and transferred to 500 ml volumetric flask and the volume was made up to the mark with distilled water.

Procedure

Five milliliters (5 ml) of pulp solution was taken in a conical flask. Two to three drops of phenolphthalein indicator solution was added and then the conical flask was shaken vigorously. It was then titrated immediately with 0.1 N NaOH solution from a burette till a permanent pink color was appeared. The volume of NaOH solution required for the titration was noted from burette reading. Percent titratable acidity was calculated by using the following formula:

$$\text{Titratable acidity (\%)} = \frac{T \times N \times V_1 \times E}{V_2 \times W \times 1000} \times 100$$

Where,

T= Titre

N= Normality of NaOH

V_1= Volume made up

E= Equivalent weight of acid

V_2= Volume of sample taken for estimation

W= Weight of sample taken

3.5.2.3 Vitamin C content

Ascorbic acid content was determined according to the method of Ranganna (1979). The following reagents were used for the estimation of ascorbic acid content.

i) Three percent (3%) metaphosphoric acid (HPO_3)

It was prepared by dissolving the sticks of HPO_3 in distilled water.

ii) Standard ascorbic solution

Ten milligram percent (10 mg%) of L-ascorbic acid solution was prepared by dissolving ascorbic acid in 3% metaphosphoric acid solution.

iii) Dye solution

It was prepared by dissolving 50 mg of the sodium salt of 2, 6-dichlorophenol indophenol in approximately 50 ml of hot distilled water containing 42 mg of sodium bicarbonate. It was then cooled and diluted to 100 ml with distilled water.

The following steps were followed for the estimation of ascorbic acid:

Standardization of dye solution

Ten milliliters (10 ml) of standard ascorbic acid solution was taken in a conical flask and 5 ml of metaphosphoric acid HPO_3 was added to it. A micro burette was filed with the dye solution. The content of the conical flask was titrated with dye solution. The content of conical flask was titrated with dye till the pink-colored end point appeared. The milliliters of dye solution required to complete the titration was recorded. Dye factor was calculated using the following formula:

$$\text{Dye factor (\%)} = \frac{0.5}{\text{Titre}} \times 100$$

Preparation of sample

About five grams (5 g) of fresh fruit and 35 ml of 3% metaphosphoric acid solution was taken in a blender and homogenized for 2 minutes. After blending it was filtered and centrifuged at about 2000 ppm for 5 minutes. The supernatant homogenized liquid was transferred to a 50 ml volumetric flask and the volume was made up with 3% metaphosphoric acid.

Procedure

Ten milliliters (10 ml) of the aliquot was taken in a conical flask and titrated with dye solution. The ascorbic acid content of the samples was calculated by using the following formula:

$$\text{Ascorbic acid content (mg/100g)} = \frac{T \times D \times V_1}{V_2 \times W} \times 100$$

Where,

T = Titre;

D = Dye factor;

V_1 = Volume made up (ml);

V_2 = Volume of extract used for titration;

W = Weight of sample (g)

3.5. 3 Microbial characters

3.5.3.1 Assessment of disease incidence

The fruits were critically examined one day later for the appearance of rot. The incidence of fruit rot was recorded after one day. The first count was made at the 3 days after harvest. Diseases incidence means percentage of fruits infected with disease. This is measured by calculating the percentage of fruits infected in each replication of each treatment. The diseased fruits were identified symptomatically. The disease incidence was calculated as follow:

$$\text{Disease incidence (\%)} = \frac{\text{Number of infested fruits in each replication}}{\text{Total number of fruits in each replication}} \times 100$$

3.5.4 Estimation of shelf life

Shelf life of mango fruits as influenced by variety and ripening agents was calculated by counting the days required to ripe fully as to retaining, optimum marketing and eating qualities.

3.6 Statistical analyses

The data on quality and shelf life of mango were statistically analyzed to find out the significant differences for different variety and ripening materials. The mean values of all the characters were calculated and analyses of variance were performed by the ‘F’ (variance ratio) test using MSTAT-C software. The significance of the differences among the mean values of treatment in respect of different parameters was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprised presentation and discussion of the results obtained from the study on the effect of different variety and ripening agents on quality and shelf life of mango. The analyses of variance (ANOVA) of the data on quality and shelf life of mango are presented in Appendix II-VIII. The results which are influenced by different treatments have been presented and discussed under the following headings:

4.1 Physical parameters

4.1.1 Firmness score

Firmness score of mango at 3, 5, 7, 9 and 11 days after harvest (DAH) varied significantly due to different variety (Appendix II). At 3, 5, 7, 9 and 11 DAH, the highest firmness score (2.42, 3.46, 4.96, 5.71 and 5.78, respectively) were recorded from V_3 which were followed (2.28, 3.28, 4.45, 5.15 and 5.43 respectively) by V_1, while the lowest firmness score (1.47, 2.98, 3.92, 4.07 and 4.83, respectively) was recorded from V_2 (Table 1).

Different ripening agents showed statistically significant differences in terms of firmness score of mango at 3, 5, 7, 9 and 11 DAH (Appendix II). At 3, 5, 7, 9 and 11 DAH, the highest firmness score (2.50, 3.41, 4.62, 5.58 and 5.77, respectively) were recorded from R_0, which were followed (1.90, 3.42, 4.46, 4.63 and 5.21, respectively) by R_1, whereas the lowest firmness score (1.44, 2.66, 4.11, 4.24 and 4.68, respectively) were found from R_2 (Table 1).

Statistically significant variation was recorded due to the combined effect of different variety and ripening agents in terms of firmness score of mango at 3, 5, 7, 9 and 11 DAH (Appendix II). At 3, 5, 7, 9 and 11 DAH, the highest firmness score (2.90, 3.87, 5.52, 6.33 and 6.40, respectively) were recorded from V_3R_0 and the lowest firmness score (1.10, 2.43, 3.50, 4.33 and 4.40, respectively) were recorded from V_2R_2 treatment combination (Table 2).

Table 1. Effect of different variety and ripening agents on firmness score of mango at different days after harvest (DAH)

Treatment	Firmness score at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
Mango variety					
V_1	2.28	3.28	4.45	5.15	5.43
V_2	1.47	2.98	3.92	4.07	4.83
V_3	2.42	3.46	4.96	5.71	5.78
$LSD_{(0.05)}$	0.156	0.158	0.319	0.402	0.484
Level of significance	0.01	0.01	0.01	0.01	0.01
Ripening agents					
R_0	2.50	3.41	4.62	5.58	5.77
R_1	1.90	3.42	4.46	4.63	5.21
R_2	1.44	2.66	4.11	4.24	4.68
R_3	1.89	3.08	4.18	4.46	4.72
$LSD_{(0.05)}$	0.180	0.183	0.368	0.464	0.559
Level of significance	0.01	0.01	0.05	0.01	0.01
CV(%)	6.02	4.42	6.92	6.79	7.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Firmness scores: 1 = mature hard, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe, 5 = over ripe, 6= totally unfit for consumption.

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Table 2. Combined effect of different variety and ripening agents on firmness score of mango at different days after harvest (DAH)

Treatment	Firmness score at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	2.83	3.57	4.55	5.87	6.10
V_1R_1	2.17	3.50	4.47	4.87	5.37
V_1R_2	1.43	2.63	4.23	4.40	4.53
V_1R_3	2.20	3.03	4.13	4.67	4.70
V_2R_0	1.77	2.80	3.79	4.17	4.80
V_2R_1	1.37	3.37	4.24	4.03	4.67
V_2R_2	1.10	2.43	3.50	4.33	4.40
V_2R_3	1.13	2.93	3.77	3.77	4.47
V_3R_0	2.90	3.87	5.52	6.33	6.40
V_3R_1	2.17	3.40	4.67	5.00	5.60
V_3R_2	1.80	2.90	4.60	5.20	5.10
V_3R_3	2.33	3.27	4.63	4.93	5.00
$LSD_{(0.05)}$	0.312	0.317	0.638	0.803	0.968
Level of significance	0.05	0.01	0.05	0.05	0.05
CV(%)	6.02	4.42	6.92	6.79	7.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Firmness scores: 1 = mature hard, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe, 5 = over ripe, 6= totally unfit for consumption.

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

4.1.2 Weight loss

Statistically significant variation was recorded in terms of weight loss of mango at 3, 5, 7, 9 and 11 DAH due to different variety (Appendix III). At 3, 5, 7, 9 and 11 DAH, the highest weight loss (5.60, 7.19, 9.32, 12.00 and 14.85%, respectively) were found from V_1 which were statistically similar (5.32, 6.88, 8.55, 11.67 and 13.40%, respectively) to V_3, while the lowest weight loss (3.88, 5.14, 7.10, 10.53 and 11.68%, respectively) was observed from V_2 (Figure 1).

Weight loss of mango at 3, 5, 7, 9 and 11 DAH showed statistically significant differences for different ripening agents (Appendix III). At 3, 5, 7, 9 and 11 DAH, the highest weight loss (5.31, 7.09, 9.47, 13.27 and 15.60%, respectively) were observed from R_0, which were statistically similar (5.18, 6.99, 9.29, 12.62 and 15.47%, respectively) to R_3 and closely followed (5.04, 6.24, 8.44, 11.71 and 13.56%, respectively) by R_1, whereas the lowest weight loss (4.20, 5.29, 6.09, 8.00 and 8.62%, respectively) were recorded from R_2 (Figure 2).

Combined effect of different variety and ripening agents showed statistically significant variation in terms of weight loss of mango at 3, 5, 7, 9 and 11 DAH (Appendix III). At 3, 5, 7, 9 and 11 DAH, the highest weight loss (6.47, 8.40, 11.13, 14.27 and 18.40%, respectively) were found from V_1R_0 and the lowest weight loss (4.20, 5.47, 6.20, 8.27 and 8.60%, respectively) were recorded from V_2R_2 treatment combination (Table 3).

4.1.3 Dry matter content

Different variety varied significantly in terms of dry matter content of mango at 3, 5, 7, 9 and 11 DAH (Appendix IV). At 3, 5, 7, 9 and 11 DAH, the highest dry matter content (16.95, 18.27, 19.88, 21.50 and 23.87%, respectively) were observed from V_2 which were statistically similar (15.59, 17.95, 19.15, 20.76 and 22.69%, respectively) to V_3, while the lowest dry matter content (14.24, 16.21, 16.61, 17.28 and 19.29%, respectively) was found from V_1 (Table 4).

Table 3. Combined effect of different variety and ripening agents on weight loss of mango at different days after harvest (DAH)

Treatment	Weight loss (%) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	6.47	8.40	11.13	14.27	18.40
V_1R_1	5.73	6.93	9.47	12.27	14.87
V_1R_2	4.40	5.53	6.53	8.20	9.33
V_1R_3	5.80	7.90	10.13	13.27	16.80
V_2R_0	3.27	4.73	7.00	11.60	11.47
V_2R_1	3.93	5.20	7.20	10.87	12.20
V_2R_2	4.20	5.47	6.20	8.27	8.60
V_2R_3	4.13	5.17	8.00	11.40	14.47
V_3R_0	6.20	8.13	10.27	13.93	16.93
V_3R_1	5.47	6.60	8.67	12.00	13.60
V_3R_2	4.00	4.87	5.53	7.53	7.93
V_3R_3	5.60	7.90	9.73	13.20	15.13
$LSD_{(0.05)}$	0.800	1.015	1.070	0.995	2.452
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	9.57	8.09	5.13	6.58	9.46

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Table 4. Effect of different variety and ripening agents on dry matter content of mango at different days after harvest (DAH)

Treatment	Dry matter content (%) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
Mango variety					
V_1	14.24	16.21	16.61	17.28	19.29
V_2	16.95	18.27	19.88	21.50	23.87
V_3	15.59	17.95	19.15	20.76	22.69
$LSD_{(0.05)}$	1.021	1.119	1.773	2.105	2.637
Level of significance	0.01	0.01	0.01	0.01	0.01
Ripening agents					
R_0	12.78	14.83	17.37	17.97	18.79
R_1	15.51	17.31	18.23	20.32	23.43
R_2	17.78	19.56	21.22	22.80	24.75
R_3	16.30	18.22	20.36	21.30	23.84
$LSD_{(0.05)}$	1.179	1.293	2.047	2.431	3.038
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.58	4.34	4.14	5.96	4.72

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Statistically significant variation was recorded due to different ripening agents in terms of dry matter content of mango at 3, 5, 7, 9 and 11 DAH (Appendix IV). At 3, 5, 7, 9 and 11 DAH, the highest dry matter content (17.78, 19.56, 21.22, 22.80 and 24.75%, respectively) were found from R_2, which were statistically similar (16.30, 18.22, 20.36, 21.30 and 23.84%, respectively) to R_3 and closely followed (15.51, 17.31, 18.23, 20.32 and 23.43%, respectively) by R_1, whereas the lowest dry matter content (12.78, 14.83, 17.37, 17.97 and 18.79%, respectively) were recorded from R_0 (Table 4).

Dry matter content of mango at 3, 5, 7, 9 and 11 DAH showed statistically significant variation due to the combined effect of different variety and ripening agents (Appendix IV). At 3, 5, 7, 9 and 11 DAH, the highest dry matter content (20.04, 20.96, 22.30, 23.07 and 25.48 respectively) were recorded from V_2R_2 and the lowest dry matter content (12.20, 14.14, 14.61, 15.77 and 16.10 respectively) were observed from V_1R_0 treatment combination (Table 5).

4.2 Chemical parameters

4.2.1 Total soluble solids

Total soluble solids of mango at 3, 5, 7, 9 and 11 DAH varied significantly due to different variety (Appendix V). At 3, 5, 7, 9 and 11 DAH, the highest total soluble solids (15.59, 17.87, 20.63, 22.91 and 26.69%, respectively) were recorded from V_2 which were statistically similar (15.35, 17.66, 19.53, 21.96 and 25.39%, respectively) to V_3, while the lowest total soluble solids (14.46, 15.30, 17.12, 18.70 and 22.82%, respectively) was found from V_1 (Figure 3).

Table 5. Effect of different variety and ripening agents on dry matter content of mango at different days after harvest (DAH)

Treatment	Dry matter content (%) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	12.20	14.14	14.61	15.77	16.10
V_1R_1	13.77	16.21	17.05	18.22	19.89
V_1R_2	16.24	17.84	18.98	19.63	19.76
V_1R_3	14.74	16.65	19.78	20.51	22.43
V_2R_0	13.18	15.56	15.79	16.34	17.93
V_2R_1	17.66	18.52	20.93	22.02	24.85
V_2R_2	20.04	20.96	22.30	23.07	25.48
V_2R_3	16.93	18.05	19.49	21.60	23.25
V_3R_0	12.97	14.79	15.71	16.80	17.34
V_3R_1	15.10	17.18	18.71	19.73	21.55
V_3R_2	17.07	19.88	20.38	21.71	22.02
V_3R_3	17.23	19.95	21.82	22.78	24.84
$LSD_{(0.05)}$	2.042	2.239	3.546	4.211	5.274
Level of significance	0.05	0.05	0.05	0.05	0.05
CV(%)	5.58	4.34	4.14	5.96	4.72

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Different ripening agents showed statistically significant differences in terms of total soluble solids of mango at 3, 5, 7, 9 and 11 DAH (Appendix V). At 3, 5, 7, 9 and 11 DAH, the highest total soluble solids (15.89, 18.35, 21.31, 23.03 and 27.98%, respectively) were observed from R_2, which were statistically similar (15.03, 17.38, 19.16, 22.34 and 26.26%, respectively) to R_3 and closely followed (14.35, 14.65, 16.08, 16.67 and 18.27%, respectively) by R_1, whereas the lowest total soluble solids (15.26, 17.39, 19.81, 22.72 and 27.37%, respectively) were found from R_0 (Figure 4). Sergent *et al.* (1993) reported that immersed mangoes in hot water (52^0C for 2 mins) and thereafter these mango treated with 2-chloroethylphosphonic acid (Ethephons) at 1000, 2000 or 4000 mgl^{-1} for 1 or 2 minutes, which increased the production of soluble solids content that correlated with the improved flavor and color and softer texture of mango.

Combined effect of different variety and ripening agents showed statistically significant variation in terms of total soluble solids of mango at 3, 5, 7, 9 and 11 DAH (Appendix V). At 3, 5, 7, 9 and 11 DAH, the highest total soluble solids (16.06, 17.71, 21.36, 23.32 and 27.49%, respectively) were found from V_2R_2 and the lowest total soluble solids (15.30, 15.54, 18.63, 21.18 and 26.47%, respectively) were recorded from V_1R_0 treatment combination (Table 6).

4.2.2 Titrable acidity

Statistically significant variation was recorded in terms of titrable acidity of mango at 3, 5, 7, 9 and 11 DAH due to different variety (Appendix VI). At 3, 5, 7, 9 and 11 DAH, the highest titrable acidity (1.45, 1.29, 0.865, 0.656 and 0.431%, respectively) were found from V_2 which were statistically similar (1.43, 1.27, 0.842, 0.621 and 0.415%, respectively) to V_3, while the lowest titrable acidity (1.38, 1.23, 0.816, 0.559 and 0.406%, respectively) was recorded from V_1 (Table 7).

Table 6. Combined effect of different variety and ripening agents on total soluble solids (TSS) of mango at different days after harvest (DAH)

Treatment	Total soluble solids-TSS (%) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	15.30	15.54	18.63	21.18	26.47
V_1R_1	13.35	14.13	15.01	16.67	18.31
V_1R_2	14.18	15.76	17.43	18.56	23.88
V_1R_3	15.02	15.78	17.39	20.37	24.62
V_2R_0	15.53	19.41	20.99	22.57	27.14
V_2R_1	14.91	15.62	16.38	19.80	21.13
V_2R_2	16.06	17.71	21.36	23.32	27.49
V_2R_3	14.91	17.88	19.38	22.16	25.78
V_3R_0	14.95	17.22	19.81	24.42	28.49
V_3R_1	14.80	15.21	16.84	18.55	19.35
V_3R_2	17.44	20.57	22.16	25.20	27.58
V_3R_3	15.16	18.49	20.72	24.48	28.37
$LSD_{(0.05)}$	1.386	2.837	2.820	3.549	3.975
Level of significance	0.05	0.05	0.05	0.05	0.05
CV(%)	5.07	6.22	4.61	5.09	5.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Table 7. Effect of different variety and ripening agents on titrable acidity of mango at different days after harvest (DAH)

Treatment	Titrable acidity (%) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
Mango variety					
V_1	1.38	1.23	0.816	0.559	0.406
V_2	1.45	1.29	0.865	0.656	0.431
V_3	1.43	1.27	0.842	0.621	0.415
$LSD_{(0.05)}$	0.027	0.009	0.009	0.028	0.009
Level of significance	1.01	0.01	0.01	0.01	0.01
Ripening agents					
R_0	1.37	1.22	0.807	0.561	0.404
R_1	1.41	1.25	0.831	0.599	0.412
R_2	1.45	1.30	0.870	0.648	0.433
R_3	1.44	1.28	0.855	0.639	0.420
$LSD_{(0.05)}$	0.031	0.010	0.010	0.031	0.0010
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	6.80	8.84	4.74	6.89	4.37

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Titrable acidity of mango at 3, 5, 7, 9 and 11 DAH showed statistically significant differences for different ripening agents (Appendix VI). At 3, 5, 7, 9 and 11 DAH, the highest titrable acidity (1.45, 1.30, 0.870, 0.684 and 0.433%, respectively) were recorded from R_2, which were statistically similar (1.44, 1.28, 0.855, 0.639 and 0.420%, respectively) to R_3 and closely followed (1.41, 1.25, 0.831, 0.599 and 0.412%, respectively) by R_1, whereas the lowest titrable acidity (1.37, 1.22, 0.807, 0.561 and 0.404%, respectively) were observed from R_0 (Table 7).

Statistically significant variation was recorded due to the combined effect of different variety and ripening agents in terms of titrable acidity of mango at 3, 5, 7, 9 and 11 DAH (Appendix VI). At 3, 5, 7, 9 and 11 DAH, the highest titrable acidity (1.49, 1.38, 0.919, 0.709 and 0.451%, respectively) were recorded from V_2R_2 and the lowest titrable acidity (1.35, 1.22, 0.805, 0.552 and 0.333%, respectively) from V_1R_0 treatment combination (Table 8).

4.2.3 Vitamin C content

Vitamin C content of mango at 3, 5, 7, 9 and 11 DAH varied significantly due to different variety (Appendix VII). At 3, 5, 7, 9 and 11 DAH, the highest vitamin C content (20.46, 20.20, 17.47, 17.50 and 14.78 mg/100 g, respectively) were recorded from V_1 which were statistically similar (20.22, 18.74, 17.19, 16.21 and 14.05 mg/100 g, respectively) to V_3, while the lowest vitamin C content (19.33, 17.58, 15.12, 12.95 and 10.79 mg/100 g, respectively) was recorded from V_2 (Figure 5).

Different ripening agents showed statistically significant differences in terms of vitamin C content of mango at 3, 5, 7, 9 and 11 DAH (Appendix VII). At 3, 5, 7, 9 and 11 DAH, the highest vitamin C content (20.76, 19.65, 18.65, 17.80 and 15.54 mg/100 g, respectively) were recorded from R_2, which were statistically similar (20.13, 19.51, 17.37, 16.06 and 14.92 mg/100 g, respectively) to R_3 and closely followed (19.90, 19.05, 16.72, 15.67 and 13.81 mg/100 g, respectively) by R_1, whereas the lowest (19.22, 17.16, 13.64, 12.67 and 10.56 mg/100 g, respectively) from R_0 (Figure 6).

Table 8. Combined effect of different variety and ripening agents on titrable acidity of mango at different days after harvest (DAH)

Treatment	Titrable acidity (%) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	1.35	1.22	0.805	0.552	0.333
V_1R_1	1.41	1.24	0.806	0.549	0.405
V_1R_2	1.38	1.23	0.819	0.574	0.419
V_1R_3	1.37	1.22	0.835	0.560	0.407
V_2R_0	1.39	1.24	0.807	0.562	0.413
V_2R_1	1.43	1.25	0.853	0.653	0.425
V_2R_2	1.49	1.38	0.919	0.709	0.451
V_2R_3	1.48	1.30	0.879	0.700	0.4 35
V_3R_0	1.37	1.21	0.808	0.570	0.405
V_3R_1	1.40	1.26	0.834	0.597	0.407
V_3R_2	1.47	1.30	0.874	0.660	0.430
V_3R_3	1.46	1.30	0.852	0.658	0.419
$LSD_{(0.05)}$	0.054	0.017	0.017	0.005	0.0017
Level of significance	0.05	0.01	0.01	0.01	0.05
CV(%)	6.80	8.84	4.74	6.89	4.37

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Combined effect of different variety and ripening agents varied significantly in terms of vitamin C content of mango at 3, 5, 7, 9 and 11 DAH (Appendix VII). At 3, 5, 7, 9 and 11 DAH, the highest vitamin C content (22.31, 21.57, 19.49, 18.54 and 17.58 mg/100 g, respectively) were recorded from V_1R_2 and the lowest vitamin C content (18.22, 16.79, 13.01, 11.67 and 11.19 mg/100 g, respectively) were recorded from V_2R_0 treatment combination (Table 9).

4.3 Microbial parameters

4.3.1 Disease incidence

Statistically significant variation was recorded in terms of disease incidence of mango at 5, 7, 9 and 11 DAH due to different variety (Appendix VIII). At 5, 7, 9 and 11 DAH, the highest disease incidence (13.92, 33.75, 61.92 and 86.33%, respectively) were recorded from V_1 which were statistically similar (12.58, 31.50, 59.58 and 83.50%, respectively) to V_3, while the lowest disease incidence (10.75, 24.58, 52.33 and 76.33%, respectively) was recorded from V_2 (Table 10).

Disease incidence of mango at 5, 7, 9 and 11 DAH showed statistically significant differences due to different ripening agents (Appendix VIII). At 5, 7, 9 and 11 DAH, the highest disease incidence (19.11, 35.33, 62.00 and 86.89%, respectively) were recorded from R_0, which were statistically similar (17.11, 31.78, 59.33 and 85.67%, respectively) to R_1 and closely followed (10.00, 30.44, 58.89 and 82.11%, respectively) by R_3, whereas the lowest disease incidence (3.44, 22.22, 51.56 and 73.56%, respectively) were found from R_2 (Table 10).

Statistically significant differences was recorded due to the combined effect of different variety and ripening agents in terms of disease incidence of mango at 5, 7, 9 and 11 DAH (Appendix VIII). At 7, 9 and 11 DAH, the highest disease incidence (23.33, 41.33, 70.00 and 94.67%, respectively) were recorded from V_1R_0 and the lowest disease incidence (2.00, 17.00, 47.67 and 73.00, respectively) were recorded from V_2R_2 treatment combination (Table 11).

Table 9. Combined effect of different variety and ripening agents on Vitamin C content of mango at different days after harvest (DAH)

Treatment	Vitamin C (mg/100 g) at				
	3 DAH	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	19.67	18.08	13.84	15.55	11.68
V_1R_1	20.03	20.49	17.72	16.48	14.37
V_1R_2	22.31	21.57	19.49	18.54	17.58
V_1R_3	19.82	18.67	16.81	16.42	14.49
V_2R_0	18.22	16.79	13.01	11.67	11.19
V_2R_1	19.89	17.78	15.39	14.37	12.62
V_2R_2	19.05	17.76	15.43	13.56	11.88
V_2R_3	20.17	17.99	16.63	15.18	14.47
V_3R_0	19.78	16.62	14.05	13.80	10.80
V_3R_1	19.78	18.88	17.05	16.16	14.45
V_3R_2	20.93	18.61	16.02	15.32	15.15
V_3R_3	20.40	19.86	17.66	16.57	15.81
$LSD_{(0.05)}$	1.386	2.784	3.850	5.923	6.182
Level of significance	0.05	0.05	0.05	0.05	0.05
CV(%)	4.09	6.23	4.02	5.96	4.92

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Table 10. Effect of different variety and ripening agents on disease incidence (%) of mango at different days after harvest (DAH)

Treatment	Disease incidence (%) at			
	5 DAH	7 DAH	9 DAH	11 DAH
Mango variety				
V_1	13.92	33.75	61.92	86.33
V_2	10.75	24.58	52.33	76.33
V_3	12.58	31.50	59.58	83.50
$LSD_{(0.05)}$	1.568	2.259	4.907	3.918
Level of significance	0.01	0.01	0.01	0.01
Ripening agents				
R_0	19.11	35.33	62.00	86.89
R_1	17.11	31.78	59.33	85.67
R_2	3.44	22.22	51.56	73.56
R_3	10.00	30.44	58.89	82.11
$LSD_{(0.05)}$	1.811	2.608	5.666	4.524
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.60	5.93	7.53	5.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

Table 11. Combined effect of different variety and ripening agents on disease incidence (%) of mango at different days after harvest (DAH)

Treatment	Disease incidence (%) at			
	5 DAH	7 DAH	9 DAH	11 DAH
V_1R_0	23.33	41.33	70.00	94.67
V_1R_1	15.00	33.00	61.33	87.33
V_1R_2	3.33	25.00	51.33	75.67
V_1R_3	14.00	35.67	65.00	87.67
V_2R_0	17.33	29.67	55.33	79.33
V_2R_1	17.67	28.00	55.33	80.00
V_2R_2	2.00	17.00	47.67	73.00
V_2R_3	6.00	23.67	51.00	73.00
V_3R_0	6.67	35.00	60.67	86.67
V_3R_1	18.67	34.33	61.33	89.67
V_3R_2	5.00	14.67	55.67	72.00
V_3R_3	10.00	32.00	60.67	85.67
$LSD_{(0.05)}$	3.137	4.518	9.814	7.836
Level of significance	0.01	0.05	0.05	0.05
CV(%)	6.60	5.93	7.53	5.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Lakhanvhog
V_2: Langra
V_3: Himsagar

R_0: No ripening agents i.e. control
R_1: CaC_2 @ 10 g/kg of fruit
R_2: Ethrel @ 1000 ppm
R_3: Ethephon @ 1000 ppm

4.4 Shelf life

Shelf life of mango varied significantly due to different variety (Appendix VIII). The highest shelf life (13.16 days) were recorded from V_2 which was statistically similar (12.96 days) to V_3, while the lowest shelf life (11.91 days) was recorded from V_1 (Figure 7).

Statistically significant variation was recorded due to different ripening agents in terms of shelf life of mango (Appendix VIII). The highest shelf life (13.08 days) were recorded from R_0, which was statistically similar (13.01 days and 12.94 days) to R_2 and R_3, while the lowest shelf life (11.67 days) were found from R_1 (Figure 8).

Combined effect of different variety and ripening agents showed statistically significant difference in terms of shelf life of mango (Appendix VIII). The highest shelf life (13.97 days) were recorded from V_2R_0 and the lowest shelf life (11.47 days) was recorded from V_1R_1 treatment combination (Figure 9).

4.5 Laboratory analysis for Arsenic (As)

Sample mango from CaC_2 treatments were collected and sent to Bangladesh Council of Scientific and Industrial Research (BCSIR) for laboratory analysis to find out the amount of Arsenic. But the analysis report revealed that there were no significant amounts of Arsenic in treated mango (Plate 1) with CaC_2. The application of CaC_2 was in solid form and that might be the reason that there was no affect of CaC_2 on mango (i.e. Arsenic). If CaC_2 would be applied with dissolved water then Arsenic may be found which also reported by earlier experiment (Asif, 2012). So in depth research may be required in this issue as because it is proved through several research.

Form No. QSF-22 Revision No. 06 Revision Date: 22 July, 2012

জীবনের জন্য বিজ্ঞান

Institute of National Analytical Research and Service
BCSIR LABORATORIES, DHAKA
বাংলাদেশ বিজ্ঞান ও শিল্প গবেষণা পরিষদ
BANGLADESH COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

ANALYSIS REPORT

Ref. No. : i) 532 of BCSIR Lab. Dhaka dt. 13/07/2014
: ii) D-532 of Analytical Service Cell, BCSIR. 13/07/2014

Lab ID : A-708 to A-711

Name and address of Customer : তৌফিকুল আনোয়ার
এম. এস
উদ্যানতত্ত্ব বিভাগ
শেরেবাংলা কৃষি বিশ্ববিদ্যালয়।

Work order details : এম, এস এর থিসীসের গবেষণার নমুনা সমূহে আর্সেনিক উপস্থিতি এবং পরিমাণ নির্ণয় করা প্রসঙ্গে, তারিখঃ ১০ জুলাই, ২০১৪ ইং।

Type of sample* : Mango

Quantity of sample : 200 gm/Mango (4 Mangoes)

Packing and marking : Polyethylene Pack

Date of receipt : 14/07/2014

Period of analysis : 14/07/2014 to 07/08/2014

Visual observation/Remarks : Green

Lab ID	Particulars of supplied sample	Parameters	Concentration
A-708	Sample - 01	Arsenic (AS)	Less than 0.01 mg/kg
A-709	Sample - 02	Arsenic (AS)	Less than 0.01 mg/kg
A-710	Sample - 03	Arsenic (AS)	Less than 0.01 mg/kg
A-711	Sample - 04	Arsenic (AS)	Less than 0.01 mg/kg

07-08-2014
Sig, and Name of the Validator
Md. Aminul Ansan
Principal Scientific Officer
Institute of National Analytical Research & Service (INARS)
BCSIR Laboratories, Dhaka

10.08.14
Counter Signature
(Research Coordinator)
Dr. Pizush Kanti Biswas
Principal Scientific Officer
Analytical Service Cell
BCSIR, Dhaka.

10.8.14
Counter Signature
(Director)
Dr. Husna Parvin Nur
Director
BCSIR Laboratories, Dhaka
Dr. Qudrat-e-Khuda Road
Dhaka-1205.

Page 1 of 1

*The results relate only to the items tested.

Dr, Qudrat-I-Khuda Road, Dhanmondi, Dhaka-1205, Tel.: 88-02-8621741; Fax: 880-2-8613022;
PABX: 8611057-61, 8625038-9, 8626034-5, 8626032, Ext. /325; E-mail: directordl@yahoo.com, bcsir@bangla.net

Plate 1. Analysis report of mango treated with CaC_2 to estimate the presence of Arsenic

4.6 Limitations of research

Because of limitation of time, resources and raw materials (mango) it was not possible to repeat the experiment to confirm the result.

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at the laboratory field of Horticulture at Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from June to August 2014 to study the effect of different ripening agents on quality and shelf life of mango. The experiment comprised of two factors; Factor A: Mango variety (3 varieties)- V_1: Lakhanvhog, V_2: Langra, V_3: Himsagar; Factor B: Ripening agents (4 levels)- R_0: No ripening (control), R_1: CaC_2 @ 10 g/kg of fruit, R_2: Ethrel @ 1000 ppm and R_3: Ethephon @ 1000 ppm. The study was laid out in a Completely Randomized Design (CRD) with three replications.

In case of variety, at 3, 5, 7, 9 and 11 DAH, the highest firmness score (2.42, 3.46, 4.96, 5.71 and 5.78, respectively) were recorded from V_3, while the lowest firmness score (1.47, 2.98, 3.92, 4.07 and 4.83, respectively) from V_2. At 3, 5, 7, 9 and 11 DAH, the highest weight loss (5.60, 7.19, 9.32, 12.00 and 14.85%, respectively) were recorded from V_1, while the lowest weight loss (3.88, 5.14, 7.10, 10.53 and 11.68%, respectively) from V_2. At 3, 5, 7, 9 and 11 DAH, the highest dry matter content (16.95, 18.27, 19.88, 21.50 and 23.87%, respectively) were recorded from V_2, while the lowest (14.24, 16.21, 16.61, 17.28 and 19.29%, respectively) from V_1. At 3, 5, 7, 9 and 11 DAH, the highest total soluble solids (15.59, 17.87, 20.63, 22.91 and 26.69%, respectively) were recorded from V_2, while the lowest total soluble solids (14.46, 15.30, 17.12, 18.70 and 22.82%, respectively) from V_1. At 3, 5, 7, 9 and 11 DAH, the highest titrable acidity (1.45, 1.29, 0.865, 0.656 and 0.431%, respectively) were recorded from V_2, while the lowest titrable acidity (1.38, 1.23, 0.816, 0.559 and 0.406%, respectively) from V_1. At 3, 5, 7, 9 and 11 DAH, the highest vitamin C content (20.46, 20.20, 17.47, 17.50 and 14.78 mg/100 g, respectively) were recorded from V_1, while the lowest vitamin C content (19.33, 17.58, 15.12, 12.95 and 10.79 mg/100 g, respectively) from V_2. At 5, 7, 9 and 11 DAH, the highest disease incidence (13.92, 33.75, 61.92 and 86.33%, respectively) were

recorded from V_1, while the lowest disease incidence (10.75, 24.58, 52.33 and 76.33%, respectively) from V_2. The highest shelf life (13.16 days) were recorded from V_2, while the lowest shelf life (11.91 days) from V_1.

For different ripening agents, at 3, 5, 7, 9 and 11 DAH, the highest firmness score (2.50, 3.41, 4.62, 5.58 and 5.77, respectively) were observed from R_0, whereas the lowest firmness score (1.44, 2.66, 4.11, 4.24 and 4.68, respectively) from R_2. At 3, 5, 7, 9 and 11 DAH, the highest weight loss (5.31, 7.09, 9.47, 13.27 and 15.60%, respectively) were observed from R_0, whereas the lowest weight loss (4.20, 5.29, 6.09, 8.00 and 8.62%, respectively) from R_2. At 3, 5, 7, 9 and 11 DAH, the highest dry matter content (17.78, 19.56, 21.22, 22.80 and 24.75%, respectively) were observed from R_2, whereas the lowest (12.78, 14.83, 17.37, 17.97 and 18.79%, respectively) from R_0. At 3, 5, 7, 9 and 11 DAH, the highest total soluble solids (15.89, 18.35, 21.31, 23.03 and 27.98%, respectively) were observed from R_2, whereas the lowest (15.26, 17.39, 19.81, 22.72 and 27.37%, respectively) from R_0. At 3, 5, 7, 9 and 11 DAH, the highest titrable acidity (1.45, 1.30, 0.870, 0.684 and 0.433%, respectively) were observed from R_2, whereas the lowest (1.37, 1.22, 0.807, 0.561 and 0.404%, respectively) from R_0. At 3, 5, 7, 9 and 11 DAH, the highest vitamin C content (20.76, 19.65, 18.65, 17.80 and 15.54 mg/100 g, respectively) were observed from R_2, whereas the lowest (19.22, 17.16, 13.64, 12.67 and 10.56 mg/100 g, respectively) from R_0. At 5, 7, 9 and 11 DAH, the highest disease incidence (19.11, 35.33, 62.00 and 86.89%, respectively) were observed from R_0, whereas the lowest (3.44, 22.22, 51.56 and 73.56%, respectively) from R_2. The highest shelf life (13.08 days) were observed from R_0, while the lowest shelf life (11.67 days) from R_1.

Due to the combined effect of different variety and ripening agents, at 3, 5, 7, 9 and 11 DAH, the highest firmness score (2.90, 3.87, 5.52, 6.33 and 6.40, respectively) were observed from V_3R_0 and the lowest firmness score (1.10, 2.43, 3.50, 4.33 and 4.40, respectively) from V_2R_2. At 3, 5, 7, 9 and 11 DAH, the highest weight loss (6.47, 8.40, 11.13, 14.27 and 18.40%, respectively) were

observed from V_1R_0 and the lowest weight loss (4.20, 5.47, 6.20, 8.27 and 8.60%, respectively) from V_2R_2. At 3, 5, 7, 9 and 11 DAH, the highest dry matter content (20.04, 20.96, 22.30, 23.07 and 25.48%, respectively) were observed from V_2R_2 and the lowest dry matter content (12.20, 14.14, 14.61, 15.77 and 16.10%, respectively) were recorded from V_1R_0. At 3, 5, 7, 9 and 11 DAH, the highest total soluble solids (16.06, 17.71, 21.36, 23.32 and 27.49%, respectively) were observed from V_2R_2 and the lowest total soluble solids (15.30, 15.54, 18.63, 21.18 and 26.47%, respectively) were recorded from V_1R_0. At 3, 5, 7, 9 and 11 DAH, the highest titrable acidity (1.49, 1.38, 0.919, 0.709 and 0.451%, respectively) were observed from V_2R_2 and the lowest titrable acidity (1.35, 1.22, 0.805, 0.552 and 0.333%, respectively) were recorded from V_1R_0. At 3, 5, 7, 9 and 11 DAH, the highest vitamin C content (22.31, 21.57, 19.49, 18.54 and 17.58 mg/100 g, respectively) were observed from V_1R_2 and the lowest (18.22, 16.79, 13.01, 11.67 and 11.19 mg/100 g, respectively) from V_2R_0. At 7, 9 and 11 DAH, the highest disease incidence (23.33, 41.33, 70.00 and 94.67%, respectively) were observed from V_1R_0 and the lowest disease incidence (2.00, 17.00, 47.67 and 73.00%, respectively) from V_2R_2. The highest shelf life (13.97 days) were observed from V_2R_0 and the lowest shelf life (11.47 days) was recorded from V_1R_1 treatment combination.

Conclusion:

From the findings, it was revealed that Ethrel @ 1000 ppm is suitable for ripening agents in consideration of quality and shelf life of mango and among the mango variety langra was superior.

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