EFFECTS OF PACKAGING METHODS, TEMPERATURE AND ETHYLENE ON SHELF LIFE AND QUALITY OF BANANA

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EFFECTS OF PACKAGING METHODS, TEMPERATURE AND ETHYLENE ON SHELF LIFE AND QUALITY OF BANANA

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECTS OF PACKAGING METHODS, TEMPERATURE AND ETHYLENE ON SHELF LIFE AND QUALITY OF BANANA"** 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 (MS)** in **HORTICULTURE** embodies the result of a piece of bona fide research work carried out by **PRODIP KUMAR SARKAR** Registration No. 23924/00171 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

Date:

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DEDICATED TO
MY
BELOVED PARENTS

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The Author

ABSTRACT

The study was conducted at the laboratories of the Horticulture Research Centre, Bangladesh Agriculture Research Institute, Joydebpur, Gazipur and cold storage of Bangladesh Agricultural Development Corporation, Airport, Dhaka during the period from April 14 to June 15, 2005. The objectives of the experiment were to evaluate the effects of temperature, packaging methods and ethylene on quality of banana during storage. Two experiments were conducted: first effect of packaging methods and temperature on the shelf life of banana. There were ten treatment combinations comprising two levels of temperature i.e room temperature (28-30°C), low temperature (14-15°C) and five packaging methods viz. control, banavac, banavac with ethylene absorbent [$KMnO_4$], perforated polythene and non-perforated polybags. Second experiment effect of ethylene and type of banana on ripening fruits. There were two types of banana viz. fresh banana and stored banana and four dosages of ethylene such as 0 (Control), 250 ppm, 500 ppm and 750 ppm.

In the first experiment, weight loss (7.99%) was lower at low temperature than that of room temperature irrespective of packaging methods. Banavac and banavac with $KMnO_4$ packages at low temperature (14-15°C) was the best method for lengthening shelf life of green banana. Banana also kept fresh, green and hard for 21 days at both room temperature (28-30°C) and low temperature (14-15°C) in banavac and banavac with $KMnO_4$ packages.

In the second experiment, reducing sugar (9.20%), non-reducing sugar (6.10%), total sugar (15.30%), P^H (5.31) and TSS (25.10%) of stored fruit were higher than that of fresh banana. Total acid content (0.31%) of stored banana was lower that of fresh banana (0.36%).

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ABBREVIATIONS AND ACRONYMS

SAU	Sher-e-Bangla Agricultural University
BARI	Bangladesh Agricultural Research Institute
HRC	Horticulture Research Centre
BBS	Bangladesh Bureau of Statistics
°C	Degree Celsius
TSS	Total Soluble Solids
DMRT	Duncan's Multiple Range Test
ppm	Parts Per Million
MA	Modified Atmosphere
BADC	Bangladesh Agricultural Development Corporation

Chapter 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Banana (*Musa spp.*) is one of the cheapest, most plentiful and nutritious fruits in Bangladesh (Khader *et al.*, 1996). It belongs to the family *Musaceae*. The actual place where it had originated can not be precisely circumscribed but generally agreed that all the edible bananas and plantains are indigenous to the warm, moist region of tropical Asia, probably in the mountainous regions where Assam, Myanmar, Thailand, Indo-China meet (Singh, 1990). Now a days, it is found in most of the tropical countries among which Brazil, India, Philippines, Thailand, Indonesia, Mexico, Honduras, Colombia, Costa-Rica and Panama are the major producing countries.

The climate and soil of Bangladesh are congenial for banana cultivation. Hence, banana is growing throughout the year although there is a distinct harvesting season from September to November. During this period production is surplus and market price fall down. Banana is a very popular fruit in Bangladesh with a total production of 650 thousand metric tons in an area of 45 thousand hectare (BBS 2005). In respect of total production, it ranks top position among the major fruits grown in Bangladesh and comprises about 42% of the total production. The fruit is a highly perishable commodity. Hence, losses are also very high even under normal temperature. Losses of banana occur between harvest and consumption. Banana takes 6-8 days during summer and 13-15 days during winter to ripen. It indicates that temperature plays an important role in postharvest life of banana. Ideal temperature for storage of banana is 13-15°C. Lower temperature causes chilling injury. Higher temperature (up to 25°C) accelerates ripening and much higher temperature causes heat injury.

The magnitude of post harvest losses in fresh fruits and vegetables is estimated to be 5 to 25% in developed countries and 20 to 50% in developing countries, depending upon the commodity (Khader, 1991).

Banana fruits are usually harvested at physiologically mature stage. It does not ripe adequately and uniformly on the tree because of climacteric respiration. Non-uniformly ripened fruits are characterized by poor external color, texture, taste and odor. Therefore, banana needs to be ripened artificially either by using ethylene or heat treatment.

Ethylene, a naturally produced plant hormone is responsible for ripening and senescence. Ethylene has several effects including breakdown of starch to sugars, breakdown of chlorophyll and the synthesis of other pigments such as carotenoid and anthocyanin, synthesis of aromatic volatile etc. Various techniques have been developed in different countries to delay ripening and to extend the shelf life of banana.

The optimum ripening conditions using ethylene gas a temperature of 17-24°C for 24-72 hours. Among the techniques 'Banavac' is a method created for banana which involves the creation of a Modified Atmosphere (MA). MA involves the reduction of O_2 and /or increase of CO_2 conc. around the commodity. MA has several advantages including reduction of metabolic activity, reduction of synthesis and action of ethylene, alleviation of chilling injury, control of some decay organisms and insects. Therefore, they are very effective for delaying ripening and senescence, preserving and reducing losses (Yahia, 1998). Actually the factors that inhibit either the synthesis or the action of ethylene can delay ripening and senescence of fresh horticultural crops and can prolong their lives. Potassium per manganate oxidizes ethylene and eliminates into the atmosphere around the crop (Scott *et al.*, 1970). Banavac is a commonly used procedure during commercial transportation of banana. Ventilation is very important during the ripening process to reduce the accumulation of CO_2 gas and therefore to avoid the inhibition of ethylene action. Moreover, there is no known technique to the growers/traders of Bangladesh to extend the shelf-life of banana. It is not only to extend the shelf life but also to reduce the postharvest losses. As a result, huge quantity of it goes waste due to its perishable character. In Bangladesh a huge amount of banana is spoiled due to prevailing high temperature, humidity, inappropriate postharvest handling and due to inadequate knowledge in the field of postharvest technology. This spoilage of the fruit is attributed to adverse physiological changes, namely loss of weight due to respiration and transpiration, loss of flesh hardness and loss of resistance to microbial attack. Various loss reduction technologies have been devised to minimize the postharvest deterioration of banana. Rao and Rao (1979) opined that for reducing the postharvest losses, banana fruits should be harvested at appropriate degree of maturity compatible with the transport, handling and storage envisaged. It is necessary to delay ripening for distant markets and then enhance ripening for retail sale. Providing good storage condition is also very important technique to minimize postharvest losses of fruits. Storage quality is an important factor for regulating biochemical changes during storage and ripening of banana. Ethylene is used in many countries to ripen banana but it has not yet been standardized.

Banana is being exported in small quantity in ethnic markets of Middle-East countries. Traders are thinking to export it in European countries to get more money but the technologies are not available. Technology is needed to keep the fruits green and disease free for 3-4 weeks to reach to those destinations.

Therefore, it is necessary to study and understand storage technique for lengthening storage period and maintaining the quality of banana. Keeping these views in mind, the present investigation was undertaken to fulfill the following objectives:

1. To find out the optimum packaging method for long term storage
2. To determine optimum temperature for lengthening of postharvest life of green mature banana.
3. To know the interaction effects of packaging methods and temperature on shelf life of banana.
4. To know the effect of ethylene on quality of fresh and low temperature stored banana.

Chapter 2

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

This chapter presented a brief review of the past studies and opinions of researchers related to the current study. Available literatures on the related studies were gathered from theses, books, journals, reports and other form of publication.

2.1 Perforated and non-perforated polythene bags on shelf life of banana

Chillet *et al.* (1997) recommended that anthracnose caused by *colletotrichum musae* is the main factor responsible for the post harvest decay of bananas. They found that rates of fungal rot development and fruit ripening were considerably slowed down when polybags were kept sealed for 28 days at 13.5°C.

Elzayat (1996) found that banana cultivar Magrabi when pretreated with Thiobendazol (400 ppm) associated with polythene packing in cartons found that all packaged fruits were in good condition in storage for one month and had a shelf life of 5-6 days in ambient condition. These fruits ripened normally following storage in respect of TSS, moisture content, acidity and organoleptic traits.

Momen *et al.* (1993) studied some physical measures like perforated and non-perforated polythene with or without Dithane M-45 on the shelf life of banana (cv. Sabri and Amritasagar). They opined that non-perforated polythene cover delayed ripening and increased the storage life of banana significantly, whereas perforated polythene cover had no significant effect.

Sen *et al.* (1978) mentioned that mature banana fruits of cv. Kalibabu, when packed in polythene bag and held at room temperature had a higher shelf life of 3 days. They further observed slower changes in chlorophyll and carotenoid contents of the skin.

Hossain (1999) reported that the shelf life of Amritsagar banana could be extended 12.67 days without deteriorating the quality by non-perforated polythene cover.

Patwary (2001) also noted that the shelf life of banana cv. Amritsagar and Sabri could be extended up to 26.54 days by $KMnO_4$ in non-perforated transparent polythene cover.

Liu (1970) reported that pre-climacteric banana fruits in the sealed polythene bags were observed to have an increased shelf life.

Scott *et al.* (1971a) commented that ripening of banana fruits were delayed when stored in sealed polythene bags. Similar phenomenon had been described by Scott and Robert (1966) where they reported that normally control fruits ripened in 5 to 6 days, whereas the bagged fruits were still green.

Ndubizu (1976) stated that mature green plantains remained green and hard for 3-4 weeks before the ripening started and they were full ripe after about 5 weeks, when they were packed in polythene bags containing an ethylene absorbent. On the contrary, fruits stored in open cartoons ripen within a week.

Patil and Magar (1975) showed that purofil reduces the ethylene concentration and calcium hydroxide reduces the CO_2 concentration in the sealed polythene bags containing pre-climacteric bananas. Further they suggested the use of both purofil and calcium hydroxide in the ratio of 1:1 to increase the shelf life of banana.

Scott and Gandanegara (1974) found that storage life of bananas over a range of temperature from 10-17°C was considerably increased by packing the fruit in sealed polythene bag.

Zica and Brune (1973) did experiment with Parta cultivar of banana and commented that fruits ripened normally after 35 days when they were removed from the bag containing an ethylene absorbent and were stored between 25-29°C, while the fruits in control were completely rotten. They also observed that ripening can be delayed by about 5 days, when fruits were stored in perforated polythene bags at room temperature.

Hardenburg (1971) suggested the use of film packages for reduction of weight loss of fruits. Further he opined that the reduced loss of weight was due to reduction in the rate of transpiration. He suggested that by increasing the number of perforation of polythene bags the chances of rotting fruits, which was due to increased humidity inside the bags, could be avoided.

Use of ethylene absorbent is reported to prolong the shelf life of banana fruits in sealed polythene bags by delaying the onset of ripening (Scott *et al.*, 1970).

Chiang (1970) observed that brominated carbon and potassium permanganate on a carrier of either vermiculite or activated alumina doubled the storage life of banana in sealed polythene bags.

Treatment of banana fruits stored in polythene bags with Thiobendazole (TBZ) was reported to have controlled black end and crown rot as reported by Burdan (1969)

El-Mahmoudi and Eisawi (1968) found that loss of weight occurred in dwarf Cavendish banana during ripening. Scott *et al.* (1971b) reported that there was a reduction of weight of banana fruits packed in polybags. Thompson *et al.* (1974) observed that plantain stored in carton without a packing material lost weight rapidly during ripening and became black and shriveled.

In an experiment it was observed that green fruits of Lacatan and Dwarf Cavendish banana can successfully be stored in perforated and sealed polythene bags under refrigerated conditions for 7-10 days, it was also observed that, safe period of storage was only 2 weeks and any extension would result in excessive decay of the stored fruit (Smock, 1967).

Tomkins (1962) recommended the use of perforated polythene bags to overcome the toxic effect of higher CO_2 concentration in the sealed polythene bags.

2.2 Ethylene for ripening of banana

Ethylene (C_2H_4) is the simplest chemical compound known to cause a significant physiological effect and the only known plant hormone in the form of gas.

Characteristics:

1. A gas produced naturally by all plants and some other organs.
2. Causes ripening/senescence of plant tissues
3. Acts with very low concentrations (ppm, ppb)
4. Low temperature decreases production and action
5. High temperature (<35°C) increases production and action
6. Stress (physical damage, decay etc.) increases production.

Mode of action:

Ethylene
↓
Took for receptor protein
↓
Binding with receptor
↓
Goes to nucleus
↓
DNA
↓
Duplication of DNA
↓
mRNA
↓
Protein synthesis
↓
Activate enzyme
↓
Effect e.g. Breakdown chlorophyll, pectin etc. by enzymes.

Kende (1993) cited that ethylene plays an important regulatory role in the physiology of plants and in particular, the senescence and postharvest physiology of fruits, flower and vegetables, but it is specially important during the ripening of climacteric fruits.

Bananas are typical climateric fruits which ripen with the increase of respiration and ethylene production (Palmer, 1971). The natural ripening of banana fruit (pulp softening, starch/sugar conversion and pigment changes) is coordinated by the increased production of ethylene by the fruit pulp (Vendrell and McGlasson, 1971, Dominguez and Vendrell, 1994).

Banana coated with coating materials delayed initiation of ethylene reproduction and significantly delayed ripening (Momen *et al.*, 1997a). This coating material modified the internal conc. of O_2 and suggested that internal low O_2 conc. possibly reduced the activity of ACC oxidase (Momen *et al.*, 1997b).

Modified atmosphere with low O_2 conc. slows down deterioration of fruits by depressing respiration, ethylene production and tissue sensitivity to ethylene (Kader *et al.*, 1989).

Ethylene treated and non-treated bananas (*Musa* AAA group) and plantain (*Musa* AAB group) were stored at temperature of 13-25°C and 90% relative humidity for 8 days.

In an experiment of banana cv. Champa, results clearly revealed that the ripening process was enhanced rapidly by either dipping fruits in or spraying them with 1000 ppm ethylene. In respect of storage condition, the results clearly showed that banana fruits sprayed with 500 ppm ethylene, when stored under conditions with adequate oxygen availability registered better color development and the required softness (Ghosh, 1998).

2.3 Fungicide application against diseases

Subramanyan *et al.* (1972) concluded that polythene bag package delays the ripening, but due to accumulation of excessive humidity, the fruits become more susceptible to diseases. This problem is solved when the fruits are given pre storage dips in 1000 ppm conc. of TBZ. Further they not only recorded 75% reduction in the incidence of out end infection both under cold storage and room temperature storage conditions but recorded higher shelf life by 20 days.

According to Shillingford (1970), Benomyl and Thiobendazole are very effective in minimizing decay of banana fruits even at low concentration of 200 to 300 ppm.

2.4 Effect of Temperature on shelf life of banana

Muthuswamy *et al.* (1971) made an investigation on common and refrigerated storage of banana cv. Dwarf Cavendish. They found that whole bunches could be held in refrigerated storage at 14.4°C for about 25 days, compared with 2-7 days at room temperature (29-35°C). Detached hand ripened within 7 days at room temperature and reached fully ripe stage after 18 days at 14.4°C.

Raman *et al.* (1971) experimented with banana cv. Dwarf Cavendish and Robusta hands and at the three quarters full stage they were stored at 14.5°C ±1°C and 80-90 RH. After 4 weeks 64% Robusta fruits were fully ripe and Dwarf Cavendish was over ripe.

According to PCARRD (1988), keeping fruits under low temperature is still the most effective way of prolonging their shelf life. Optimum storage condition for most bananas, either mature green or ripe, is 13 to 14°C and 95% relative humidity. Shelf life can be extended by about two or more weeks. However, storing fruits below the optimum temperature will result in chilling injury.

In an experiment Rippon and Trochoulian (1976) commented that the life of banana fruit after ripening was mainly determined by the temperature, at which ripening was commenced and holding temperature after ripening had little influence on shelf life. Fruit was adversely affected when ripened at 15 to 17°C and subsequently removed to temperature 10°C or more above the ripening temperature. Ripening at 17°C proved best.

Krishnamurthy (1989) experimented with banana cv. Robusta and concluded that green unripe banana could be held at 15°C and 20°C for one to four weeks, followed by proper ripening at ambient conditions. Fruits remain green, firm and unripe for two to three weeks at these temperatures.

2.5 Modified Atmosphere on shelf life of banana

The technology of modified and controlled atmosphere is widely used for the storage, transport and packaging of several types of foods. Modified atmosphere (MA) refers to any atmosphere that is different than the air (20-21% O_2, about 0.03% CO_2, about 79% N_2 and trace quantities of other gases), while control atmosphere (CA) refers to atmosphere different than normal air and strictly controlled during all the time. MA and CA usually involve an atmosphere with reduce concentration of O_2 and/or an elevated concentration of CO_2.

Banana responds very well to MA/CA, especially when the fruit is green (pre-climateric). Most adequate atmospheres depend on the variety and range between 1-5% O_2 and 4-6% CO_2. Concentrations lower than 1% O_2 and higher than 10% CO_2 cause fruit injury. Transport of bananas in MA has been practiced for more than two decades and use of CA has recently been implemented. The BANAVAC system developed by United Fruit Company consist of packing green pre-climateric fruits in polythene liners (about 0.04 mm thickness). Vacuum is applied and bags are sealed. Atmosphere developed inside the bags consist of about 1-4% O_2 and 4-6% CO_2. This system can maintain the fruit in good quality for about 30 days. Better result can be obtained by using ethylene absorbers such as potassium permanganate.

Ghosh *et al.* (1998) in an experiment with banana cv. Champa reported that the ripening process was enhanced rapidly by either dipping fruits in or spraying them with 1000 ppm ethylene. Ethylene at 500 ppm was also found equally effective in inducing ripening in fruits, though the ripening was slower. In respect of storage condition, the results clearly showed that the banana fruit sprayed with 500 ppm ethylene, when stored under conditions with adequate oxygen availability registered better color development and required softness.

Saranda *et al.* (1997) found that the effect of low O_2 levels (1, 3, 5 and 7% compared with a control atmospheric level of 21%) on the quality (assessed as weight loss, storage life, external appearance, eating quality, incidence of crown rot) of 12 weeks old banana cv. Embul fruits, stored at 13.5°C for 20 or 30 days were investigated. After 20 or 30 days, weight loss was lower following storage in O_2 at 1, 3 and 5% compared with control and 7% O_2 treatments. Storage life, external appearance and eating quality of fruits were similar for the 1, 3 and 5% O_2 treatments.

Elzayat (1997) stated that the effect of pretreatment (dipping thiobendazole at 400 ppm or 5% quinolate), storage temperature (13 or 15°C) and packaging (wrapping in polyethylene before packing in cartoons) on the storage quality of bananas cv. Magrabi (green fruit harvested at three-quarter stage from Kanater Experiment station, Egypt) were investigated in 1992 and 1993. Fruits were stored for one month.

Cox (1997) noted that bananas are affected by crown rot, caused by *Colletotrichum* spp and *Fusarium* spp which can be controlled by the postharvest application of imazalil and thiobendazole.

Haque (1985) found Amritasagar banana to loose weight. Mature Amritasagar bunches harvested in mid-August registered 4.7% reduction of weight in 5 days time. The weight loss in bunches harvested in October were 2.36% in 5 days and 4.04% in 7 days.

Ogazi (1966) pointed out that by using 200 ppm of the chemical thiobendazole (TBZ), the fruits can be kept green for 25 days under refrigeration (15°C).

Samches Nieva *et al.* (1970) found that the storage of plantain is also extended by packing in sealed polythene bags with ethylene absorbent.

2.6 Ripening and prevention of ripening

When bananas begin to ripen, the process can be delayed but the climacteric once initiated is irreversible. Therefore, bananas are shipped and stored green until the chosen time for moving the fruit to the produce shelves for sale.

Bananas will ripe naturally and develop a pale yellow color at ambient tropical temperature. If left on the tree, ripening became uneven and fruit fell from the stem when they became over ripe. To be assured of a firm pulp texture, good color and flavour, fruit must be ripened at controlled temperatures. The ripening process has been divided into seven stages as indicated by color changes (plate 5). These are from 1 to 7 as follows: 1. green; 2. green with a trace of yellow; 3. more green than yellow; 4. more yellow than green; 5. only a green tip remaining; 6. all yellow; 7. yellow flecked with brown. Ethylene gas should be applied when pulp temperatures are between 14 and 18°C at a rate of 1000 ppm. Ethylene is explosive at a concentration of 3 percent in air. After applying ethylene the rooms should remain closed for 24 hours and then the doors are opened daily for 20 minutes for aeration. Once the fruit reaches color stage 4 the pulp temperatures should be kept at 13-14°C. Other compounds that stimulate ripening are acetylene, calcium carbide and ethephon (500-1000 ppm) (Liu 1978).

Defective ripening is caused by too high or too low temperatures. High temperature disorders ('cooked fruit') are indicated by soft, ripe pulp with a greenish-yellow skin color, weak necks, slit peel and brown flecks on a greenish-yellow peel. Temperatures below 13°C cause 'chilling'. Mildly chilled fruit has a greyish-yellow color due to the discoloration of the latex vessels in the peel.

Severely chilled fruit will not ripe. Uneven ripening can be caused by low temperatures and insufficient ethylene.

Ripening can be delayed by using a controlled atmosphere in polyethylene bags of specified thickness. 'Banavac' bags are 0.015 in (0.4 mm) thick which increases the carbon dioxide to about 5 percent and decreases the oxygen to around 2 percent (Badran 1969). The insertion of potassium permanganate, an ethylene absorbent, in the bag is very effective in delaying ripening (Scott *et al.,* 1970). Another method of delaying ripening is the use of sub-atmospheric pressure (Apelbaum *et al.*, 1977). Gamma radiation at 35-50 krad inhibited the ripening of preclimacteric fruit (Maxie *et al.*; 1968). Gibberellins will delay ripening for 5-10 days (Vendrell, 1970; Desai and Deshpande, 1978). The only recommended method used commercially is the 'Banavac' bag.

Chapter 3

MATERIALS AND METHODS

CHAPTER-3

MATERIALS AND METHODS

3.1 Experimental site

The study on effect of packaging methods, temperature and ethylene on shelf life and quality of banana was carried out at room temperature in the laboratory of Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur and cold storage of Bangladesh Agricultural Development Corporation, Airport, Dhaka during the period from April 14 to June 15, 2005.
Two experiments were conducted:

Experiment 1: Effect of packaging methods and temperature on the shelf life of banana

Experiment 2: Effect of ethylene and type of banana on ripening of fruits

The main objectives of the study were:

(a) to determine the proper packaging method and temperature for long time storage and

(b) to know the quality of banana following storage with ethylene treatment

3.2 Experiment 1: Effect of packaging methods and temperature on the shelf life of banana

3.2.1 Materials

Banana (BARI Kola-1)**:** The mature fruits of BARI Kola-1 were collected directly from the farmers' field on April 13, 2005. Maturity was indicated by rounding of the fingers and dropping off the stylar ends. The characteristics of the variety BARI Kola-1 are given below as described by Hoque (2004).

BARI Kola-1 (AAA) is the leading commercial variety of banana in Bangladesh. The plants are short in stature. A bunch contains 150 fruits weighing 25 kg on an average. There are 10-11 hands per bunch; each bunch contains 14-20 fingers.

The fingers are long and distinctly curved in the middle with blunted apex. The skin is thick. The bananas are yellow in color when ripe, sweet in taste, soft and completely seedless.

Carton box: The cartoon box of size 40 cm × 30 cm × 15 cm was prepared from paper. There were six holes (2.54 cm in diameter) on the sides of the carton box for ventilation.

Polythene: Clear polythene of 0.05 mm thickness was used as bag for banana.

Vacuum Cleaner: Vacuum cleaner was used for sucking air from polybags to make BANAVAC. Actually air consists of 77.16% N_2, 20.60% O_2, 1.40% moisture, 0.04% CO_2 and 0.80% other gases.

Fungicide: Solution of fungicide Thiobendazole (TBZ) at the rate of 20 g/20 litre water was prepared and the banana hands were dipped in it for a period of 5 minutes and then placed on the floor of the laboratory for drying water from the surface of the fruits.

Clotech: Clotech is sodium hypochloride used in banana as disinfectant against bacteria. Solution was prepared at the rate of 1 litre clotech /10 litre water. The banana hands were dipped into the solution for 5 minutes and then air dried in the laboratory.

3.2.2 Methods

Treatments: The experiment consisted of two factors which are as follows:

Factor A: Packaging methods

T_0= control (open in carton)

T_1=Banana kept in banavac

T_2=Banana kept in banavac with ethylene absorbent ($KMnO_4$)

T_3=Banana kept in carton covered by perforated polybags

T_4=Banana in non-perforated polybags

Factor B: Temperature

1. Room temperature (28-30°C) denoted by R
2. Low temperature (16-17°C) denoted by C

Experimental design: The two factorial experiments were laid out in the completely randomized design (CRD) with three replications.

Application of the treatments

The details of the postharvest treatments were as follows-

1. **Control (T_0):** The banana hands were put in open carton box.

2. **Banavac (T_1):** The banavac (banana vacuum) was created with a vacuum cleaner by sucking the air from the polybag (0.05 mm thick) until the polybag was tied to the fruits.

3. **Banavac with ethylene absorbent (T_2):** Potassium per manganate ($KMnO_4$) was used in banavac as an ethylene absorbent. About 20g $KMnO_4$ were taken in a piece of cloth and then kept along with banana hands into banavac. The polybag was tied with string.

4. **Perforated polythene sheet (T_3):** Polythene sheets were perforated by a punching machine.

5. **Non-perforated polythene bag (T_4):** The banana hands were kept into the polybags and the top of the bag was tied with thread by hands.

3.2.3 Temperature

The bananas were kept in two temperature treatments viz. at room temperature (28-30°C) and low temperature (16-17°C).

3.2.4 Collection of data

The data were collected at seven days interval during storage period to know the shelf life and the quality of banana.

3.2.5 Parameters studied

1. Initial weight (g): Weight of banana was taken before packing with the help of top balance.
2. Final weight (g): Weight of bananas was taken by top balance after ripening.
3. Weight loss (g): Weight loss was determined by substrating final weight from initial weight.
4. Weight loss (%): Weight loss was converted into percentage.
5. Days of ripen: Days required to ripen banana fully from the date of respective observation date.
6. Disease infection: Absence or presence of fungal diseases was recorded at the time of ripening or at the storage period.
7. Organoleptic taste: Organoleptic taste in respect of skin color, skin peeling, sweetness, pulp texture and taste of the fruits were done by a panel of judges of different professions. The members of the panel recorded their preferential comments in the supplied questionnaire (Appendix).
8. Total soluble solids (TSS) of the pulp
9. Total Acid (TA) of the pulp
10. P^H of the pulp

3.3 Experiment 2: Effect of ethylene and type of banana on ripening of fruits

3.3.1 Materials

Fresh and storage banana, Ripen-15 (ripening hormone), bucket, water, measuring cylinder and carton box

3.3.2 Methods

Treatment: Two factors were included in this experiment.

Factor A: Type of Banana

Levels: F: Fresh banana

C: Storage banana

Factor B: Dosage of ethylene

Levels: E_0: Control (no ethylene)

E_1: Ethylene 250 ppm

E_2: Ethylene 500 ppm

E_3: Ethylene 750 ppm

Experimental design

The two factor experiment was conducted in Completely Randomized Design (CRD) with three replications.

Application of the treatments

Banana sample: Storage banana sample was taken from first experimental materials. Twenty one days stored bananas kept in banavac in cold storage of BADC, Airport were taken for this experiment. The bananas were kept at 16-17°C temperature in cold storage. Actually the place where the banana samples were kept in the cold storage was the pre-cooling area. Banana requires 14°C temperature for long time storage. But no room was available in the cold storage for maintaining that temperature. The banavac bananas looked fresh, green and hard at the time of setting experiment for ripening. Fresh bananas were collected from the farmers' field.

Ethylene

The ripening hormone is available in the market in different trade names such as Ripen-15, Axithrel, Tomtom, Ethrel etc. formulated by different companies. Ripen-15 was used in this experiment which contained 48 % ethyphone.

Preparation of ethylene solution: Ethylene solution of 250 ppm, 500 ppm and 750 ppm were prepared by dissolving 5.2 ml, 10.4 ml and 15.6 ml Ripen-15 in 10 litre water, respectively.

3.3.3 Collection of data

After setting experiment fruits were observed daily for collecting data.

3.3.4 Parameters studied

1. Days required to reach different stages of ripening
2. Days required to ripen
3. Organoleptic taste
4. P^H
5. Reducing sugar
6. Non-reducing sugar
7. Total sugar
8. Total soluble solids (TSS)

Biochemical constituents

For biochemical analysis, a composite sample of fruit was prepared from uniformly ripen fruits and sample was homogenized with distilled water. The homogenized solution was centrifuged and filtered to remove solid materials. The filtrate was used for estimation of P^H, total acid, reducing sugar, non reducing sugar and total sugar. Triplicate experiments were done for every determination for each sample.

Total organic acid

The extract 10 ml was passed through cation exchange resin (CGIR-120). The column was washed repeatedly with water for collecting the extract. Similarly as free organic acid, one drop of phenopthelein (1%) was added to it as indicator. Finally it was titrated with 0.05N NaOH solution. Then total organic acid was measured as per the procedure described by Shiraishi (1980).

Estimation of sugar

Sugar contents (reducing, non-reducing and total sugar) were estimated as per method described by Somogyi (1952).

Reducing sugar

At first 2ml of the prepared extract was taken in a 50ml conical flask. Then 10 ml each of Bertrand A (40g of $CuSO_4$, $5H_2O$ dissolved in water and dilute in one liter) and Bertrand B (200g of $C_4H_4O_6KNa$, $4H_2O$ of NaOH dissolved in water and diluted to one liter) solution were added to it. After that the flask was placed on a hot plate, boiled for three minutes and over night. The supernatant was decanted and discarded very carefully by keeping the precipitation. The precipitation was washed repeatedly until blue color disappeared remaining. Then 10ml of Bertrand C [50mg of $Fe(SO_4)_2$] and 115ml of H_2SO_4(conc.) dissolved in water and dilute to 1 liter) solution was added to dissolve the precipitation (Cu_2O). Finally, it was titrated with 0.4% $KMnO_4$ solution. This was repeated thrice and then reducing sugar (g/100g) was calculated.

Total sugar

Two ml of the extract was taken into a 100 ml conical flask and 4-5 drops of 2N HCl was added to it. Then the flask was boiled for 30 minutes on a hot plate. After cooling, the extract was neutralized with NaOH solution and made up to the mark with water. Then 10 ml of neutralized extract solution was taken into a 50 ml conical flask and 10 ml of both Bertrand A and Bertrand B solution were added to it and continued as reducing sugar method.

Non reducing sugar

The non reducing sugar was calculated by deduction of reducing sugar from total sugar.

% Non-reducing sugar = % Total sugar - % reducing sugar

Total soluble solids (TSS)

Total soluble solid (TSS) content of banana fruit pulp was estimated by using ATAGO Hand Refractometer. A drop of banana juice squeezed from the fruit pulp was placed on the prism of the refractometer. Temperature corrections were made by using the methods described by Ranganna (1979).

P^H of banana

Sample of 10g fresh pulp was homogenized in 10 ml of distilled and de-ionized water (P^H 7.0) and the P^H of homogenate was measured with a P^H meter.

Organoleptic taste

Organoleptic taste in respect of skin color, skin peeling, sweetness, pulp texture and taste of the fruits were done by a panel of judges of different professions. The members of the panel recorded their preferential comments in the supplied questionnaire (appendix XI).

3.4 Statistical analysis

The collected data on various parameters were statistically analysed. The means for all the treatments were calculated and analysis of variance for all the characters was performed by F test. The significance of difference between the pairs of means was compared by LSD test at 1% and 5% levels of probability (Gomez & Gomez, 1984).

Chapter 4

RESULTS AND DISCUSSION

CHAPTER-4

RESULTS AND DISSCUSSION

The results obtained from the present study in respect of shelf life and quality of banana fruits have been described and discussed character-wise under separate heading in this chapter.

4.1 Experiment 1: Effect of packaging methods and temperature on the shelf life of banana

4.1.1 Weight loss

Weight loss of banana was significantly influenced by temperature. Weight loss of fruit was higher (8.73%) in room temperature than that of fruits stored at low temperature (7.99%) on 7^{th} day of storage. Lower weight loss of banana was due to high humidity (85-90%) in low temperature storage (Table 1).

The packaging methods used in this investigation had significant effect on weight loss of fruit. The highest weight loss of banana (9.12%) was found in control treatment followed by perforated polythene treatment (8.64%). The lowest weight loss of banana (7.87%) was observed in non-perforated polybag closely followed by banavac (7.97%) and banavac with $KMnO_4$ (8.19%) treatments. The higher weight loss in control and perforated polythene was due to evaporation in open and through perforated polythene sheet, respectively. On the other hand, banana in other treatments were within the polythene bag which helped protection of evaporation causing lower weight loss.

Interaction effect of temperature and packaging methods on weight loss of banana was also found significant (table 2). The highest weight loss of banana was recorded in control (10.06%) at room temperature while lowest in Banavac with $KMnO_4$ package (7.83%) closely followed by Banavac (7.89%) and non-perforated polybag (7.86%) packages at low temperature.

Table 1. Main effect of temperature and packaging methods on weight loss of banana (7 days storage)

Treatment	Weight loss (%)
Temperature	
Room temperature (28-30°C)	8.73
Low temperature (14-15°C)	7.99
Packaging method	
Control	9.12 a
Banavac	7.97 c
Banavac with $KMnO_4$	8.19 c
Perforated polythene	8.64 b
Non-perforated polybag	7.87 c

Table 2. Combined effect of temperature and packaging methods on weight loss of banana (7 days storage)

Treatment		Weight loss (%)
Temperature	**Packaging method**	
Room temperature	Control	10.06 a
	Banavac	8.04 cd
	Banavac with $KMnO_4$	8.55 bc
	Perforated polythene	9.12 b
	Non-perforated polybag	7.94 d
Low temperature	Control	8.17 cd
	Banavac	7.89 d
	Banavac with $KMnO_4$	7.83 d
	Perforated polythene	8.15 cd
	Non-perforated polybag	7.86 d

Table 3 showed the per cent weight loss of banana at 14, 21, and 28 days of storage in both room and low temperature in comparison to 7 days storage. The higher weight loss was found in all the treatments for longer period of storage at both room and low temperature. Actually bananas in banavac at low temperature and in banavac with $KMnO_4$ package at both room and low temperature remained for 28 days.

Table 3. Effect of storage period on weight loss of banana

Treatment		Storage period (days)			
Temp	Packaging method	7	14	21	28
		Weight loss (%)			
Room	Control	10.06	-	-	-
	Banavac	8.04	8.18	8.27	-
	Banavac with $KMnO_4$	8.55	8.60	8.78	8.84
	Perforated polythene	9.12	-	-	-
	Non-perforated polybag	7.94	7.98	-	-
Low	Control	8.17	8.23	-	-
	Banavac	7.89	8.15	8.23	8.26
	Banavac with $KMnO_4$	7.83	7.96	8.11	8.36
	Perforated polythene	8.15	8.19	-	-
	Non-perforated polybag	7.86	8.14	8.17	-

4.1.2 Days required to ripen

The results on days required to ripen banana after 7, 14, 21 and 28 days of storage both at room and low temperatures were presented in Table 4. Fruits taken after 7 days storage at room temperature required 7 days for banavac and banavac with $KMnO_4$ packages while it was 9 days of low temperature. Fruits of control treatment at room temperature ripened within 7 days that is, it did not require additional days whereas low temperature treated fruits required additional 7 days to ripen. In case of perforated package, the fruits required 2 days at room temperature and 7 days at low temperature storage for ripening. Fruits of non-perforated package required 3 and 8 days in case of 7 days storage at room and low temperature, respectively.

After 14 days storage, fruits of banavac package required 5 to 7 days at room temperature whereas 8 to 9 days in case of low temperature storage. Fruits of perforated and non-perforated packages took additional 7 days for ripening in case of low temperature storage only. After 21 days storage fruits of banavac packages required 4-6 and 7-8 days in case of room and low temperature storage, respectively. In case of 28 days storage, fruits of banavac with $KMnO_4$ package at room temperature required 4 days while it took 5 to 7 days to ripen in case of low temperature storage, respectively. The results indicated that longer the days of storage, shorter the days required for ripening banana. Low temperature storage of banana required longer duration to ripen than that of room temperature. It may be concluded that banavac and banavac with $KMnO_4$ kept at room temperature were the best packages for long time storage of banana.

Table 4. Effect on time required to ripen

Treatment		Days to ripen			
Temp	**Packaging method**	**7 days storage**	**14 days storage**	**21 days storage**	**28 days storage**
Room	Control	0	-	-	-
	Banavac	7	5	4	-
	Banavac with $KMnO_4$	7	7	6	4
	Perforated polythene	2	-	-	-
	Non-perforated polybag	3	1	-	-
Low	Control	7	-	-	-
	Banavac	9	8	7	5
	Banavac with $KMnO_4$	9	9	8	7
	Perforated polythene	7	7	-	-
	Non-perforated polybag	8	7	7	-

Note: '-' means fruits were not available

4.1.3 Skin color and pulp texture

The results on skin color and pulp texture of banana at different storage period were presented in Table 5 and plate 1-4. On the day of preparation for storage, the bananas were green and hard in texture. Thereafter then banana behaved differently on skin color and pulp texture at different storage period. On 7th day, yellowish colored, soft textured edible bananas were found in both control and perforated polythene bag at room temperature. Perforated poly bag partially allowed O_2 and CO_2 movement during storage period. Banana in Banavac were found green and hard even on 21st day of storage at room temperature. It might be due to less oxygen for respiration and less ethylene production in Banavac. Similarly banana in Banavac with $KMnO_4$ package was found green and hard and not edible up to the experimental period i.e., 28 days of storage. In $KMnO_4$ package, $KMnO_4$ absorbed ethylene gas produced by banana inside the bag resulting in lengthening of green life. The bananas kept in non perforated bag were found yellowish, soft and edible on 14th day of storage. It might be due to higher amount of O_2 within the bag for respiration and production of ethylene gas for ripening in comparison to Banavac. In Banavac only 2-5% O_2 remained inside the bag while in non-perforated polybag, it was higher than Banavac, because O_2 was not removed from the bag. Higher shelf life of banana in non-perforated polybag than perforated bag was observed by Momen *et al.* (1993), Sen *et al.* (1978) and Liu (1970) in their studies. In case of low temperature storage bananas were found yellowish, soft and edible both in control and perforated polybag treatment on 14th day of storage. It might be due to less respiration at low temperature. Banana kept in Banavac and $KMnO_4$ packages were found green and hard on 28^{th} day of storage at low temperature. The results are in agreement with the findings of Krishnamurthy (1989) who reported that fruits remained green, firm and unripe for two to three weeks at low temperature (15-20°C). In case of non-perforated polybag package, about 60% bananas were found green and hard

Table 5. Effect of temperature and storage period on skin color and pulp texture of banana at different storage period

Treatment		Skin color and pulp texture			
Temp	Packaging method	7 days storage	14 days storage	21 days storage	28 days storage
Room	Control	yellowish, soft, edible	–	–	–
	Banavac	green, hard, not edible	green, hard, not edible	green, hard, not edible	–
	Banavac + $KMnO_4$	green, hard, not edible	green, hard, not edible	green, hard, not edible	green, hard, not edible
	Perforated polythene	yellowish, soft, edible	–	–	–
	Non-perforated polybag	green, hard, not edible	Yellowish, Soft, Edible	–	–
Low	Control	green, hard, not edible	yellowish, soft, edible	–	–
	Banavac	green, hard, not edible	green, hard, not edible	green, hard, not edible	green, hard, not edible
	Banavac + $KMnO_4$	green, hard, not edible	green, hard, not edible	green, hard, not edible	green, hard, not edible
	Perforated polythene	green, hard, not edible	yellowish, soft, edible	–	–
	Non perforated polybag	green, hard, not edible	Green, hard, not edible	green, hard, not edible	–

on 21st day of storage. Storage at low temperature was found better than that of room temperature to keep the bananas green and hard for longer period irrespective of packaging methods. Hossain and Hoque (2001) and Ndubizu (1976) also observed the fruits to be green, hard and unripe in their experiments kept at low temperature for 21 days. Similar results were observed by Zica and Brune (1973), Scott *et al.* (1970), Raman *et al.* (1971), Muthuswamy *et al.* (1971), Elzayat (1996, 1997) and Ogazi (1996). Among the methods, Banavac and Banavac with $KMnO_4$ were found better than others. This technology will be helpful to the traders/businessmen to export their banana in different countries of the world. Banana will remain green for 28 or more days during shipment in Banavac maintaining low temperature 14-15°C for all the time.

4.1.4 Disease status of banana

Banana is a soft, fleshy and sweet fruit. Fungus grows well on it. It is a climacteric fruit. The characteristic of climacteric fruit is sharp rise of respiration to the peak and sudden fall. At the peak the fruits become edible and taste sweet. After that peak deterioration begins rapidly. During deterioration, fungus grows very rapidly. Banana ripen on 7th day did not show fungal infection in any treatment irrespective of temperature and packaging methods (Table 6). On 14th day of storage, fungal infection was observed only in non-perforated package at room temperature. On 21st day, banana kept at room temperature showed fungal infection in both banavac treatments. On the other hand, the fruits of banavac at low temperature storage condition were found fungus free. On 28th day of observation, bananas kept in banavac and banavac with $KMnO_4$ package were also found free from fungal infection. Similar results were observed by Chillet *et al.* (1997). Considering the disease infection during storage, banavac packaging at low temperature was the best method to keep the fruits disease free for longer period. It is fact that high temperature encourages fungal spore development while low temperature suppresses its activity.

Table 6. Disease status of banana during storage period

Treatment		Disease status			
Temp	Packaging method	7 days storage	14 days storage	21 days storage	28 days storage
Room	Control	No	–	–	–
	Banavac	No	No	Yes	–
	Banavac + $KMnO_4$	No	No	Yes	–
	Perforated polythene	No	–	–	–
	Non-perforated polybag	No	Yes	–	–
Low	Control	No	No	–	–
	Banavac	No	No	No	No
	Banavac + $KMnO_4$	No	No	No	No
	Perforated polythene	No	No	No	–
	Non-perforated polybag	No	No	No	–

Note: 'No' means no fugal infection and 'Yes' means presence of fugal infection

4.1.5 Organoleptic taste

Consumer's acceptability of banana depends on color and taste. Hence, organoleptic tastes were done on skin color, sweetness, pulp texture and skin peeling of banana.

Skin color during ripening: Both temperature and packaging methods did not have any effect on skin color of banana. The fruits of all the treatments were bright yellow at the time of ripening. The pigment chlorophyll was lost due to chlorophylase (enzyme) activities during ripening.

Pulp texture: Softening is an important change with the ripening of fruits. Cell wall degradating enzymes play major role in this process. The softening is also associated with hydrolysis of cell contents. As such, pectolytic enzyme activities induce solubilization of pectic substances found in middle lamellae. In this experiment neither temperature nor the packaging methods had any effect on pulp texture. The pulp texture was soft in all the treatments.

Sweetness: Sweetness of banana depends on conversion of starch to sugar. According to Forsyth (1980), starch declines from 20-23 percent to 1-2 percent in fully ripe fruit and at the same time the soluble sugar increases from less than 1 percent to 20 percent. During ripening starch hydrolysis occurs due to enzymes and converted into sucrose, glucose and fructose.

In this study, sweetness of banana varied when kept at room temperature and low temperature storage. The fruits at room temperature storage were sweet to taste whereas it was very sweet at low temperature storage. It might be due to slow conversion of starch to sugar during ripening in case of low temperature storage.

Skin peeling: Peeling quality is an important character in case of banana during eating. Easy peeling is usually preferred by the consumers. In this study, easy peeling was observed in all the treatments irrespective of temperature and packaging methods.

4.1.6 Total soluble solids, P^H and total acids

Twenty one days stored fruits were taken for these analysis. Because it might be the maximum duration (days) needed to export banana in green stage in any country of the world. The results on total soluble solids, P^H and total acids of 21 days stored banana fruits were presented in table 8.

Total soluble solids (TSS)

Statistical analysis of the data on TSS was not done as the fruits of some of the treatments became ripe before 21 days. Total soluble solids is a good indicator of the sugar content of fruit. TSS of fruits in banavac and $KMnO_4$ packages were recorded 25.0% and 24.3%, respectively at room temperature. In case of low temperature storage, TSS of fruits of banavac, $KMnO_4$ and non-perforated packages were recorded 25.0%, 26.0% and 24.5%, respectively. No fruits remained for 21 days in other treatments in both room and low temperature storage condition. The higher TSS was found in fruits stored at low temperature than that of room temperature.

P^H of the fruit

The P^H of the fruits of banavac and $KMnO_4$ packages at room temperature and banavac, $KMnO_4$ and non-perforated packages at low temperature storage for 21 days were 5.47, 5.62, 5.22, 5.08 and 5.45, respectively. Fruits were not allowed remain in other treatments up to 21 days in both the cases.

Total Acid

Total acid of the fruits of banavac and $KMnO_4$ packages was 0.2048 and 0.2028% in case of room temperature while at low temperature storage, TSS of the fruits of banavac, $KMnO_4$ and non-perforated packages were found to be 0.2102, 0.1995 and 0.2083%, respectively.

Table 7. Effects of Total Soluble Solids, P^H and total acid of storage banana (after 21 days)

Temp	Method	TSS (%)	P^H	Total Acid (%)
Room	Control	-	-	-
	Banavac	25.0	5.47	0.2048
	Banavac + $KMnO_4$	24.3	5.62	0.2028
	Perforated polythene	-	-	-
	Non-perforated polybag	-	-	-
low	Control	-	-	-
	Banavac	25.0	5.22	0.2102
	Banavac + $KMnO_4$	26.0	5.08	0.1995
	Perforated polythene	-	-	-
	Non-perforated polybag	24.5	5.45	0.2083

Note: '-' means fruits were not available after 21 days

4.2 Experiment 2: Effect of ethylene and type of banana on ripening of fruits

4.2.1 Change of skin color during ripening

Banana fruits are usually harvested at physiologically mature green stage. Because it does not ripe adequately and uniformly on the tree. Non-uniformly ripened fruits are characterised by poor external color, texture, taste and odour. Ethylene is used in many countries for uniform ripening of banana.

Bananas are typical climacteric fruits which ripen with the increase of respiration and ethylene production (Palmer, 1971). The natural ripening of banana fruits (pulp softening, starch/sugar conversion and pigment changes) is coordinated by the increased production of ethylene by the fruit pulp (Vendrell and McGlasson, 1971; Dominguez and Vendrell, 1994).

Skin color during ripening is an important consideration in case of banana. The ripening process of banana was divided into seven stages as indicated by color changes. For this purpose the color chart was developed by Del Monte Banana Company, Miami, Florida shown in plate 5. In this color chart 1-7 indices were used.

Index 1= green

2= green with a trace of yellow

3= more green than yellow

4= more yellow than green

5= only a green tip or pedicel remaining (ideal color for retail display)

6= all yellow (suitable for sale and consumption)

7= yellow flecked with brown (completely ripe, best flavour and highest nutritive value).

The color stage of fresh and stored banana as affected by ethylene was presented in table 8. Ethylene was applied on freshly harvested and 21 days stored banana at green stage to ripen the fruits quickly. On first day after treatment, fruits of all the treatments were green in color (Index 1) except ethylene 500 and 750 ppm where 3 to 4 stages were observed. On the second day, ethylene treated fruits of both types reached 4 to 6 stages of ripening. On the other hand, non treated fruits in control treatment took 7 days to reach the optimum 6 stages of ripening.

On the third day of observation, both fresh and storage banana treated with 250 ppm ethylene reached stage 6. The results indicated that higher dose of ethylene accelerated ripening of banana while lower dose (250 ppm) acted slowly. For faster or early ripening higher dose of ethylene is desirable but it might cause hazard to human health and environmental pollution. Considering the points one day later ripening through lower dose of ethylene (250 ppm) is congenial. Hence, the results indicated that 250 ppm ethylene was the best dose for ripening of banana.

Table 8. Effect of ethylene treatment on color stage of fresh and storage banana (1-7 stage according to color index)

Treatment	Color stage						
	Day						
	1st	2nd	3rd	4th	5th	6th	7th
F 0ppm	1	1	1	2	3	5	6
F 250ppm	1	4	6	–	–	–	–
F 500ppm	3	6	–	–	–	–	–
F 750ppm	4	6	–	–	–	–	–
C 0ppm	1	1	1	2	3	5	6
C 250ppm	1	4	6	–	–	–	–
C 500ppm	1	4	6	–	–	–	–
C 750ppm	4	6	–	–	–	–	–

4.2.2 Days to ripening of banana treated with ethylene

Ethylene had effect on ripening of both fresh and stored banana (fig.1). Non-treated fruits required 7 days while the ethylene treated fruits of all the treatments took 2 to 3 days to ripen. Among the treatments higher doses of ethylene showed minimum time (2 days) to ripen. No remarkable difference on days to ripen due to ethylene was observed between two types of banana (fresh and stored).

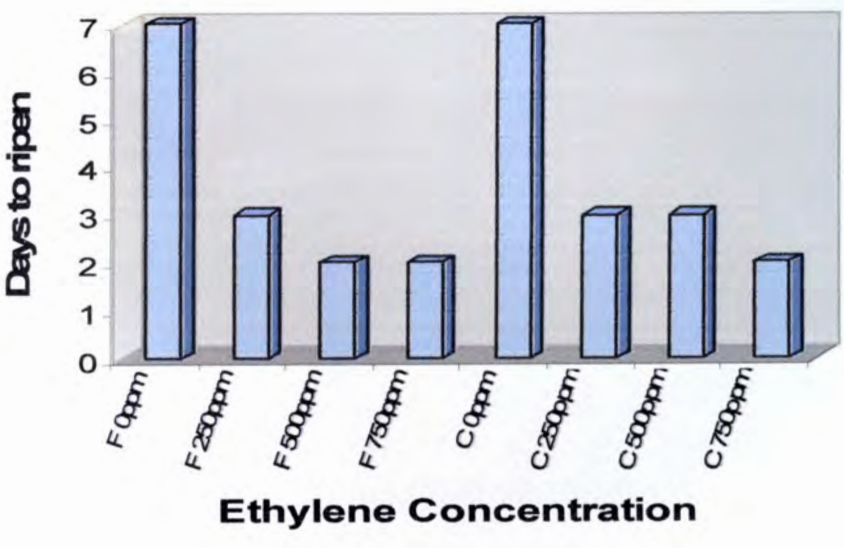

Fig.1. Effect of ethylene on ripening of fresh and low temperature stored banana ('F' means Fresh banana & 'C' means Clod Storage banana)

Plate1. Photography of banana fruits stored for 7 days.

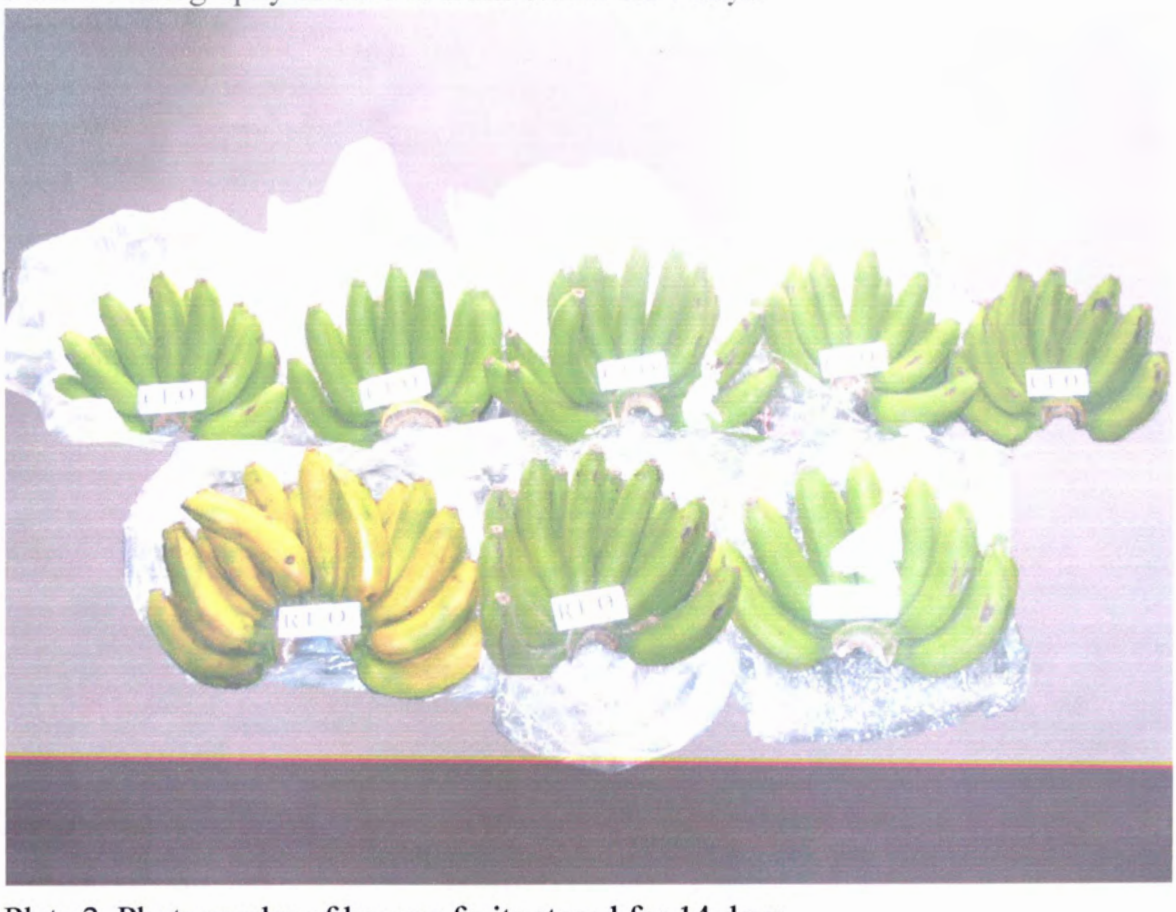

Plate 2. Photography of banana fruits stored for 14 days.

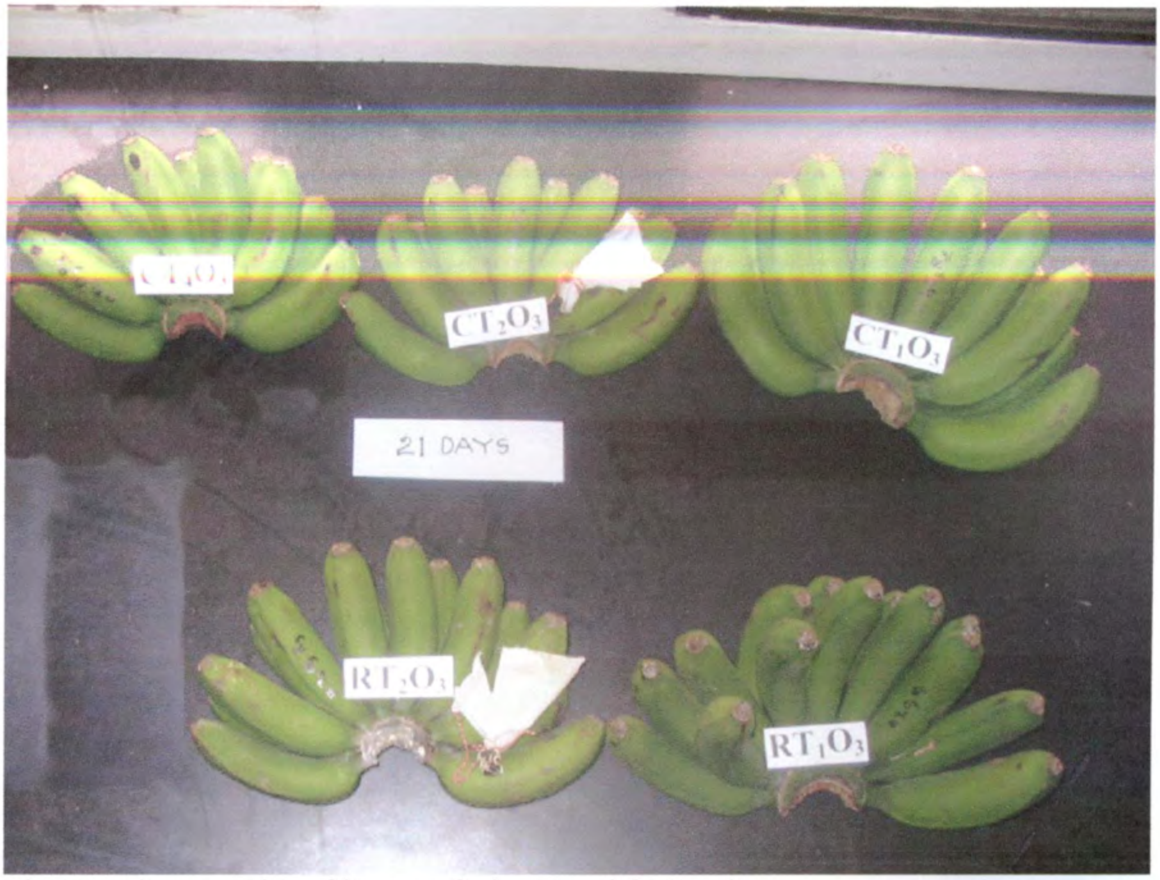

Plate 3. Photography of banana fruits stored for 21 days.

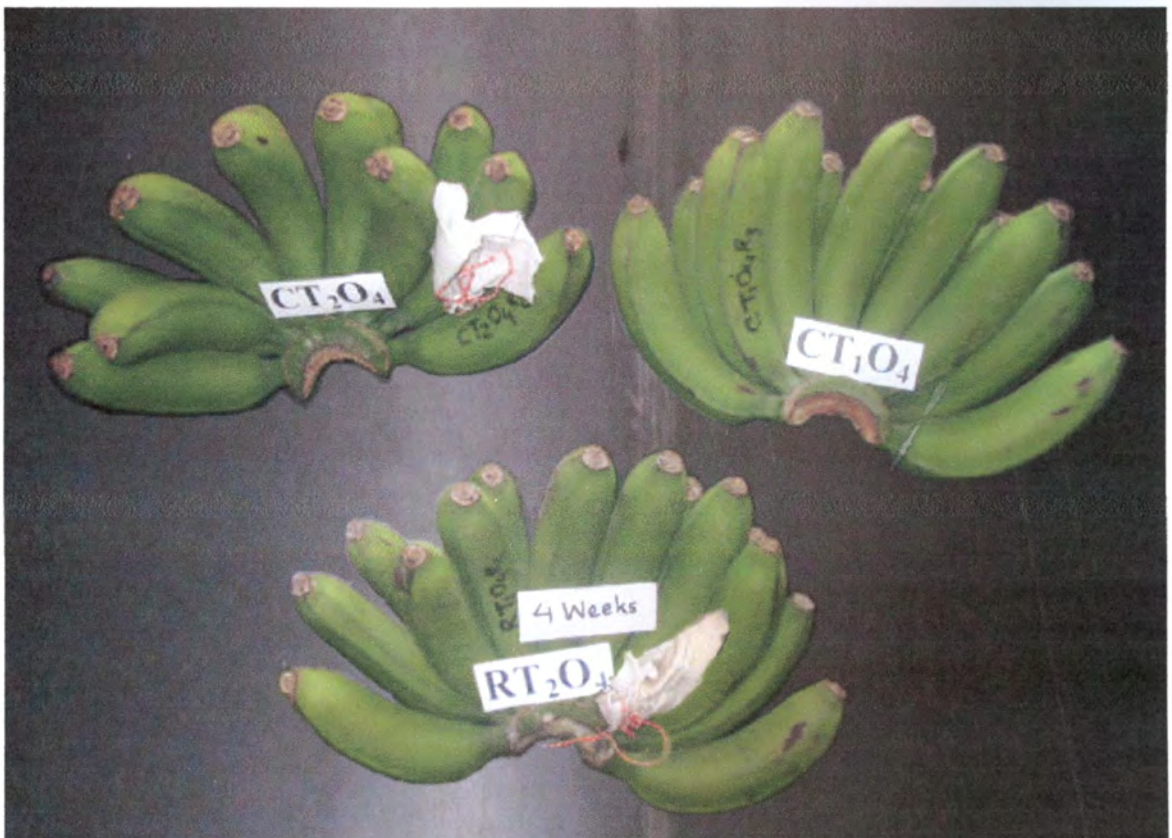

Plate 4. Photography of banana fruits stored for 28 days.

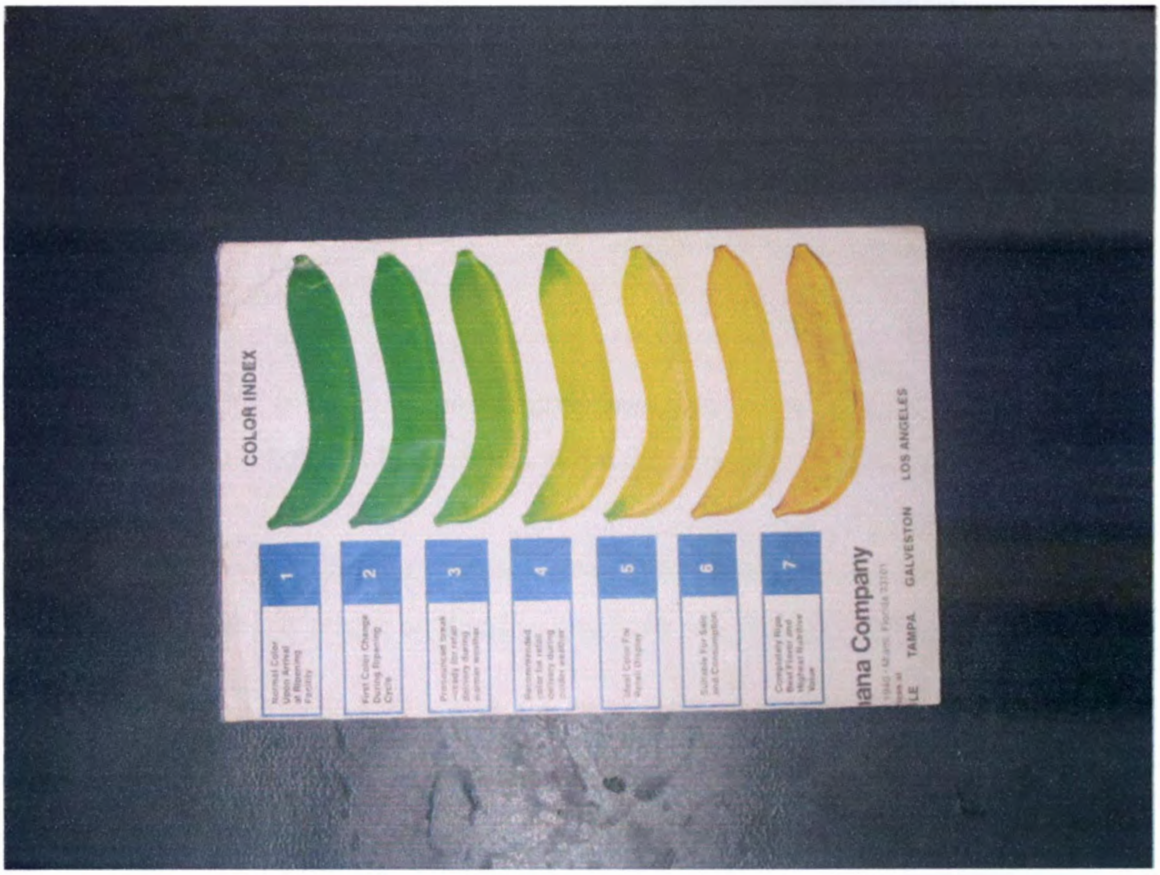

Plate 5. Photography on ripening stages of banana.

4.2.3 Organoleptic Taste

The organoleptic taste results of both fresh and stored banana after ripening by ethylene were presented in table 10. Banana fruits of both freshly harvested and 21 days stored in low temperature were found bright yellow at the time of ripening. Freshly harvested and stored fruits showed easy peeling in all the treatments except the treatment C750 ppm where peeling was difficult. In this experiment, the pulp and skin became soft to very soft causing peeling difficult. It might be due to the application of higher dose of ethylene (750 ppm) for ripening. Fresh bananas whether treated or not treated with ethylene and non treated cold storage bananas were found soft in texture at the time of ripening. The cold storage bananas treated with ethylene were very soft. The freshly harvested fruits of all the treatments were found sweet to taste whereas the storage fruits tasted very sweet.

The pulp color of both fresh and storage banana was not affected by artificial ripening. The pulp color of banana was yellowish in all the treatments.

The fresh fruits were good at the time of ripening while the storage fruits were very good to taste. It might be due to slow conversion of starch to sugar at low temperature.

Table 9. Organoleptic taste of fresh and cold storage banana treated with ethylene

Treatment	Skin color at ripen	Peeling	Texture	Sweetness	Pulp color	Taste
F 0ppm	bright yellow	easy	soft	sweet	yellowish	good
F 250ppm	bright yellow	easy	soft	sweet	yellowish	good
F 500ppm	bright yellow	easy	soft	sweet	yellowish	good
F 750ppm	bright yellow	easy	soft	sweet	yellowish	good
C 0ppm	bright yellow	easy	soft	very sweet	yellowish	very good
C 250ppm	bright yellow	easy	very soft	very sweet	yellowish	very good
C 500ppm	bright yellow	easy	very soft	very sweet	yellowish	very good
C 750ppm	bright yellow	difficult	very soft	very sweet	yellowish	very good

4.2.4 Reducing and non-reducing and total sugar

Reducing, non-reducing and total sugar of banana as affected by type of banana and ethylene were shown in Table 10.

Reducing sugar

A significant variation in reducing sugar content was recorded in both fresh and low temperature stored bananas (table 10). Low temperature stored bananas had higher percentage of reducing sugar (9.20%) than that of fresh bananas (8.63%).

But ethylene had no significant effect on reducing sugar content of the fruits which varied from 8.79 to 9.00%.

Interaction effect between type of banana and ethylene was found insignificant on reducing sugar content of banana (table 11).

Non-reducing sugar

Non-reducing sugar also showed variation between fresh and low temperature stored bananas under study. The higher value of non-reducing sugar was recorded in low temperature stored bananas (6.10%) than that of fresh ones (5.74%). No significant effect of ethylene was observed on non-reducing sugar content of fruits.

Table 10. Effect of type of banana and ethylene on reducing, non-reducing and total sugar of banana

Treatment	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
Type of banana			
Fresh banana (F)	8.63 b	5.74 b	14.37 b
Low temp stored (C)	9.20 a	6.10 a	15.30 a
Ethylene doses			
0 ppm	8.79 a	5.94 a	14.73 a
250 ppm	8.94 a	5.96 a	14.90 a
500 ppm	9.00 a	5.87 a	14.87 a
750 ppm	8.93 a	5.91 a	14.84 a

Note: Means followed by the same letter(s) in a column under the same factor are not significantly different at 5% level

Total sugar

Total sugar is a combination of reducing and non-reducing sugars. Low temperature stored bananas had significantly higher amount of total sugar (15.30%) than that of fresh banana (14.37%). But no significant variation was observed among the ethylene treatments on total sugar content. The interaction between type of banana and ethylene treatments was insignificant on total sugar content.

Table 11. Interaction effect of fresh and stored banana on reducing sugar, non-reducing sugar and total sugar

Treatment		Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)
Banana	Ethylene			
Fresh	0 ppm	8.45 a	5.78 a	14.23 a
	250 ppm	8.64 a	5.76 a	14.40 a
	500 ppm	8.75 a	5.60 a	14.35 a
	750 ppm	8.68 a	5.80 a	14.48 a
Low temp. stored	0 ppm	9.13 a	6.10 a	15.23 a
	250 ppm	9.24 a	6.16 a	15.40 a
	500 ppm	9.25 a	6.13 a	15.38 a
	750 ppm	9.18 a	6.01 a	15.19 a

Note: Means followed by the same letter(s) in a column under the same factor are not significantly different at 5% level

4.2.5 Total acid, P^H and TSS of fruits

The results on total acid, P^H and total soluble solids of fruits were presented in Table 12.

Total acid

No significant effect on total acid was observed between fresh and low temperature stored bananas. Similarly, the ethylene treatments did not show any significant effect on total acid of the fruits. The value of total acid ranged from 0.28 to 0.37%. The interaction effect between type of banana and ethylene doses on total acid content of the fruits was also found statistically significant.

P^H of the fruit

Analysis of variance showed that type of banana had significant effect on P^H of the fruits. The higher P^H 5.31 was observed in low temperature stored fruits than that of fresh fruits (5.22). No significant effect of ethylene was observed on P^H of the fruits which ranged from 5.19 to 5.44. Numerically highest P^H was observed in fruits of control treatment (no ethylene).

Interaction effect between type of banana and ethylene on P^H of the fruit was found significant (table 14). The highest P^H value (5.55) was recorded on ethylene non-treated fresh banana while the lowest in fresh banana treated with 250 ppm ethylene. Low temperature stored banana treated with ethylene showed medium range (5.28 to 5.32).

Total soluble solids (TSS)

TSS is a good indicator of the sugar content of the fruit; however, sweetness sensation depends also on the acid content. Ethylene has significant effect on TSS content of the fruits in case of both fresh and low temperature stored bananas. Low temperature bananas showed higher TSS (25.10%) than that of room temperature (24.11%). In case of ethylene treatment, no significant effect on TSS was observed, the value of which ranged from 24.50 to 24.68%.

The interaction effect between type of banana and ethylene doses was found significant on TSS content of the fruits (table 14). Higher TSS was observed in low temperature stored bananas treated with ethylene. The value of this ranged from 25.00 to 25.15%. Ethylene doses had no effect on TSS content of the fruits.

Table 12. Effect of type of banana and ethylene on total acid, P^H and total soluble solids of banana

Treatment	TA (%)	P^H	TSS (%)
Type of banana			
Fresh banana	0.36 a	5.22 b	24.11 b
Low temp stored	0.31 a	5.31 a	25.10 a
Ethylene doses			
0 ppm	0.28 a	5.44 a	24.59 a
250 ppm	0.34 a	5.21 a	24.50 a
500 ppm	0.37 a	5.22 a	24.65 a
750 ppm	0.35 a	5.19 a	24.68 a

Note: Means followed by the same letter(s) in a column under the same factor are not significantly different at 5% level

Table 13. Interaction effect of type of banana and ethylene on total acid, P^H and total soluble solids content

Treatment		Total acid (%)	P^H	TSS (%)
Banana	**Ethylene**			
Fresh	0 ppm	0.24 a	5.55 a	24.08 bc
	250 ppm	0.38 a	5.10 c	24.00 c
	500 ppm	0.41 a	5.15 bc	24.14 bc
	750 ppm	0.40 a	5.08 c	24.22 b
Low temp. stored	0 ppm	0.32 a	5.32 b	25.10 a
	250 ppm	0.28 a	5.32 b	25.00 a
	500 ppm	0.31 a	5.28 b	25.15 a
	750 ppm	0.29 a	5.30 b	25.13 a

Note: Means followed by the same letter(s) in a column under the same factor are not significantly different at 5% level

Chapter 5
SUMMARY

CHAPTER 5

SUMMARY

The study on shelf life and quality of storage banana as affected by temperature, packaging methods and ethylene were carried out in the laboratory of Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur and Cold storage of Bangladesh Agricultural Development Corporation, Airport, Dhaka during the period from 14th April to 15th June 2005. Two experiments were conducted on this aspect. First experiment was effect of packaging methods and temperature on the shelf life of banana. There were 10 treatment combinations comprising of two levels of temperature: room temperature (28-30°C) and low temperature (14-15°C) and five levels of packaging methods (control, banavac, banavac with $KMnO_4$, perforated polythene and non-perforated polybag). Second experiment was effect of ethylene and type of banana on ripening fruits. There were eight treatment combination comprising of two types of banana (fresh and 21 days stored) and four dosage of ethylene (control, 250 ppm, 500 ppm and 750 ppm). The experiment was laid out in Completely Randomized Design (CRD) with three replications. The mature fruits of BARI kola-1 were collected from the farmers' field. Observations were made on weight loss, days required to ripen, diseases, organoleptic taste, TSS, sugar, acid and P^H content of the fruits. The data were collected at 7 days interval and were analyzed statistically following DMRT.

Weight loss of fruits was significantly influenced by temperature. It was higher (8.73%) in room temperature than that of low temperature (7.99%) on 7th day of storage. Among the packaging methods, non-perforated polybag was found to be the best in respect of reduction of weight loss of fruits closely followed by banavac and banavac with $KMnO_4$ packages.

Fruits taken after 7 days from banavac and banavac with $KMnO_4$ packages kept at room temperature required 7 days for ripening while it was 9 days in case of low temperature storage. In case of 28 days storage, banana kept in $KMnO_4$ package at

room temperature required 4 days while it took 5 to 7 days to ripen in low temperature storage. The results indicated that longer the days of storage, shorter the days required for ripening banana.

Bananas of 7 days storage did not show fungal infection in any treatment irrespective of temperature and packaging methods. On 14^{th} day of storage, fungal infection was observed only in non-perforated package at room temperature. On 21^{st} day, banana kept at room temperature showed fungal infection in both banavac and $KMnO_4$ packages. On the other hand, the fruits of banavac at low temperature storage condition were found fungus free. At low temperature storage for 28 days, bananas kept in banavac and banavac with $KMnO_4$ package were also found free from fungal infection.

In case of 7 days storage at room temperature, yellowish colored, soft textured edible bananas were found in both control and perforated polythene sheet. Perforated polythene sheet partially allowed O_2 and CO_2 movement during storage period. Banana in Banavac were found green and hard even on 21st day of storage at room temperature. It might be due to less oxygen for respiration and less ethylene production in Banavac. Similarly banana in Banavac with $KMnO_4$ package were found green and hard and not edible up to the end of experimental period i.e. 28 days of storage. In T_2 treatment $KMnO_4$ absorbed ethylene gas produced inside the bag resulting the lengthening of green life of banana. The bananas kept in non perforated bag were found yellowish, soft and edible on 14^{th} day of storage.

Organoleptic tastes were done on skin color, sweetness, pulp texture and skin peeling of banana. Both temperature and packaging methods did not have any effect on skin color of banana. The fruits of all the treatments were bright yellow at the time of ripening. The fruits of all the treatments were bright yellow at the time of ripening. The pulp texture was soft in all the treatments. In this study, sweetness of banana varied when kept at room temperature and low temperature storage. The fruits at room temperature storage were sweet to taste whereas it was very sweet at low temperature storage.

Total soluble solids (TSS) of fruits in banavac and $KMnO_4$ packages were recorded as 25.0% and 24.3%, respectively at room temperature. In case of low temperature storage, TSS of fruits of banavac, $KMnO_4$ and non-perforated packages were recorded to the 25.0%, 26.0% and 24.5%, respectively. No fruits remained for 21 days in other treatments in both room temperature and low temperature storage. The P^H of the fruits kept in of banavac and $KMnO_4$ packages at room temperature and banavac, $KMnO_4$ and non-perforated packages at low temperature storage for 21 days were 5.47, 5.62, 5.22, 5.08 and 5.45, respectively. Total acid of the fruits of banavac and $KMnO_4$ packages was 0.2048 and 0.2028% in case of room temperature storage while at low temperature storage, acid of the fruits of banavac, $KMnO_4$ and non-perforated packages were found to be 0.2102, 0.1995 and 0.2083%, respectively.

Ethylene had effect on ripening of both fresh and stored banana. Non-treated fruits required 7 days while the ethylene treated fruits of all the treatments took 2 to 3 days to ripen. Among the treatments higher dose (750 ppm) of ethylene took minimum time (2 days) to ripen. Banana fruits of both freshly harvested and 21 days stored in low temperature were found bright yellow at the ripening. Freshly harvested and stored fruits showed easy peeling in all the treatments except the treatment C750 ppm where peeling was difficult. The cold storage banana treated with ethylene was found soft in texture at the time of ripening. The freshly harvested fruits of all the treatments were found sweet to taste whereas the storage fruits tested very sweet. The pulp color of banana were yellowish in all the treatments. The fresh fruits were good at the ripening while the storage fruits were very good to taste.

Both fresh and stored bananas were found to have significant effect on reducing sugar, non-reducing sugar and total sugar content of the fruit pulp. Higher amount of total sugar (15.30%), reducing sugar (9.20%) and non-reducing sugar (6.10%)

was found in low temperature stored bananas where as lower in fresh banana (14.37% total sugar, 8.63% reducing sugar and 5.74% non-reducing sugar).

A significant effect on P^H and TSS content of the fruit pulp was observed in both fresh and stored banana. Stored banana contained the maximum P^H (5.31) and TSS (25.10%) while they were minimum (5.22 P^H and 24.11% TSS) in fresh banana. No significant effect of ethylene was recorded on total acid content in fresh banana (0.36%) and stored banana (0.31%).

Ethylene had effect on ripening of both fresh and stored banana. Non-treated fruits required 7 days while the ethylene treated fruits of all the treatments took 2 to 3 days to ripen. Among the treatments higher dose (750 ppm) of ethylene took minimum time (2 days) to ripen. Banana fruits of both freshly harvested and 21 days stored in low temperature were found bright yellow at the time of ripening. Freshly harvested and stored fruits showed easy peeling in all the treatments except the treatment C750 ppm where peeling was difficult. The cold storage banana treated with ethylene were found soft in texture at the time of ripening. The freshly harvested fruits of all the treatments were found sweet to taste whereas the storage fruits tested very sweet. The pulp color of banana was yellowish in all the treatments. The fresh fruits were good at the time of ripening while the storage fruits were very good to taste.

Chapter 6
CONCLUSION

CONCLUSION

A study on packaging methods, it is recommended that banavac and banavac with $KMnO_4$ are the best methods to increasing the shelf life of banana.

Between two temperatures, room temperature (28-30°C) and low temperature (16-17°C), low temperature (16-17°C) is the best for long time storage and it is sweeter than the room temperature (28-30°C) storage banana.

Interaction among control, banavac, banavac with $KMnO_4$, perforated polybag and non-perforated polybag, it is find out that banavac and banavac with $KMnO_4$ are higher shelf life of banana than other methods.

Ethylene treatment enhances ripening of banana. Banana ripe within 2-3 days when treated with ethylene while it will take 7 days in case normal ripening.

REFFERENCES

REFERENCES

Apelbaum, A., Y. Aharoni and N. Temkin-Gorodeiski. 1977. Effect of sub atmospheric pressure on the ripening process of banana fruits. Trop. Agric., Trin., 54: 39-46.

Badran, A.M. 1969. Controlled atmosphere storage of green bananas. U.S. Patent.

BBS. 2005. Statistical Year book of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning, Dhaka. 154p.

Burdan, O.J. 1969. Control of post harvest diseases of bananas. Quart. Agric. J., 95: 621-624.

Chiang, M.N. 1970. Studies on ethylene absorbents in sealed polythene box-liners for bananas. J. Hort. Sci., China, 16(5):9.

Chillet, M. and L.De. bellaire. 1997. Polybag packaging to control anthracnose of banana. Fruits, 51(3): 163-172

Cox, J.R. 1997. Postharvest treatment of bananas in the windward Islands. British crop protection council, UK., 1: 373-378.

Desai, B.B. and P.B. Deshpande. 1978. Chemical control of ripening of banana. Physiologia Plantarum, 44(3): 238-240.

Dominguez, M. and M. Vendrell. 1994. Effect of ethylene treatment on ethylene production, EFE activity and ACC levels in peel and pulp of banana fruit. Postharvest Biol. Technol., 4: 167-177.

El-Mahmoudi, L.T. and M.T. Eisawi. 1968. Studies on the storage of bananas. Agric. Res., Cairo, 46(3): 41-51

Elzayat, H.E. 1996. Influence of plastic wrapping on storage and quality of banana. Bulletin of Faculty of Agriculture, University of Cairo, 47(2): 295-303.

Elzayat, H. E. 1997. Influence of plastic wrapping on storage and quality of banana. Bulletin of Faculty of Agriculture, University of Cairo, 47(2): 295-303.

Gomez, K.A. and A.A., Gomez. 1984. Statistical Procedure for Agricultural Research. John Weley and Soa Inc., New York.

Ghosh, B.K., B. Patro and B.C. Barik. 1998. Effect of ripening agents and storage conditioa on the postharvest changes in banana fruits var. champa. Orissa J. of Hort. 25(1): 14-17.

Hardenburg, R.E.1971. Effect of in package environment on keeping quality of fruits and vegetables. Hort. Sci., 6: 198-201

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

Hossain, M.K. 1999. Effect of different post-harvest treatments on shelf life and physio-chemical characteristics of banana during storage. A MS thesis submitted to the Dept. of Horticulture, BAU, Mymeaingh, p.77

Hossain M.A. and M.A. Hoque. 2001. Disease Management and Production Technology of Banana. Horticulture research Centre, BARI, Gazipur.

Hoque, M.A. 2004. *Kolar Unnata Jat o er Chashabad Paddhati*. (Bengali). Publication No. fldr.09. HRC, BARI, Gazipur.

Kader, A.A. 1992. Postharvest Technology of Horticultural Crops. University of California, USA. 15p

Kader, A.A., D. Zagory and E.L. Kerbel. 1989. Modified atmosphere packaging of fruits and vegetables. CRC. Crit. Rev. Fd. Sci. Nutr., 28: 1-30

Kende, H. 1993. Ethylene Biosynthesis. Annual Review of Plant Physiology. Plant Mol. Biol., 44: 283-307.

Khader, S.E.A. 1991. Effect of postharvest application of GA_3 on postharvest behaviour of mango fruits. Scientia Hort., 47 (3-4): 317-321.

Khader, M.A.J., B.M.K. Chellappan, P.K. Chattopadhay and O.A.A. Pillai. 1996. Banana. *In*: Fruits: Tropical and subtropical. Eds. Bose, T.K. and S.K. Mitra. Naya Prokash, 206 Bidhan Sarani, Calcutta, India. pp.130-134.

Krishnamurthy, S. 1989. Storage life and quality of Robusta banana in relation to their stage of maturity and storage temperature. J. Fd. Sci. Technol., 92(2): 87-89

Liu, F.W. 1970. Storage of bananas in polythene bags with an ethylene absorbent. Hort. Sci., 5: 25-27.

Liu, F. W. 1978. Ripening bananas with ethapon in three polymeric film packages. Hort. Sci., 13: 688-90.

Maxie, E.C. 1968. Effect of gamma radiation on the ripening of banana fruits. Proc. Amer. Soc. Hort. Sci., 92: 235-54

Momen, M.N.; Y. Tastumi and K. Shimokawa. 1997a. Effects of coating treatment with sucrose fatty acid esters on the ripening of cavendish banana. Food Preserv. Sci., 23: 315-322

Momen, M.N.; Y. Tastumi and K. Shimokawa. 1997b. Effect of sucrose palmitic acid ester coating on the internal gas concentration of cavendish banana in relation to the ripening, respiration and ethylene production. Food Sci. Technol. Int. Tokyo, 3: 393-397

Momen, M.N., M. A. Rahim, A.M. Farooque and M.S.H. Chowdhury. 1993. Effect of some coating materials and physical measures on the prolongation of shelf life of banana. Progress. Agric., 4(1-2); 41-51.

Muthuswamy, S., R. Sadasivm, J.S. Sundararaj and V. Vasudevan. 1971. Storage studies on Dwarf Cavendish banana. Indian J. Agric. Sci., 41(5): 479-484.

Ndubizu, T.C.O. 1976. Delaying ripening in harvesting Nigerian green plantain. J. Agric. Sci., U.K., 87(3): 573-576.

Olorunda, A.O. 1976. Effect of ethylene absorbent on the storage life of plantain packed in polythene bags. Nigeria J. Sci., 1&2:

Palmer, J.K. 1971. The Banana. *In*: The biochemistry of fruits and their products. Ed. Hulme, A.C., Academic Press, London. pp. 65-105.

Patil, D.L. and N.G. Magar. 1975. Correlation between banana fruits ripening, its texture and pectin-methylsterase activity. Proc. Indian Aca. Sci., 81(1):127-130.

Patwary, M.M.A. 2001. Effects of different post-harvest treatments on physio-chemical changes in banana during storage. A MS thesis submitted to the Dept. of Horticulture, BAU, Mymeaingh.

PCCARD. 1988. The Philippines Recommends for Banana. 1988. Philippine Council for Agriculture, Forestry and Natural Resources Research and Development. Los Banos, Laguna, 71p

Raman, N.V., R. Sadasivam and T.M. Subramania. 1971. A note on the refrigerated storage of Robusta and Dwarf Cavendish banana. South Indian Hort., 19($^{1}/_{4}$): 78-79.

Rangana, S. 1979. Manual of Analysis of Fruit and Vegetable Products. Tata McGraw-Hill Publishing Company Limited, New Delhi, 112p.

Rao, M. and R. Rao. 1979. Postharvest changes in banana cv. Robusta. Indian J. Hort., 36(4): 387-393.

Rippon, L.E. and T. Prochoulias. 1976. Ripening respoaes of banana to temperature. Australian J. Expt. Anim. Husb., 16(78):140-144.

Sanchez, N.F.; I. Hernandez and C. Bueso de Vinas. 1970. Studies on the ripening of plantain under controlled condition. J. Agric. Puerto Rico, 55(4): 394-404

Saranda, K.H. and R.S.W. Wijeratnam. 1997. Control atmosphere storage of 'Embul' bananas. In Proceedings of the Sixth Annual Congress of the Post graduate Iatitute of Agriculture, University of Peradeniya, Sri Lanka, 17-22.

Scott, K.J. and E.A. Robert. 1966. Polythene bags to delay ripening of bananas during traaport and storage. Australian J. Expt. Agric. Anim. Husb., 6: 197-299

Scott, K.J. and S. Gandanegara. 1974. Effect of temperature on the storage life of bananas held in polythene bags with ethylene absorbent. Trop. Agric. 51(1): 23-26.

Scott, K.J., R.B.H. Wills and L.E. Ripon. 1971a. The use of sealed polythene bunch covers during growth as a retardant to the ripening of bananas. Trop. Agric. Trininad, 48: 163-165.

Scott, K.J., J.R. Blake, G. Strachan, B.L. Tugwell and W. B. Mcglasson. 1971b. Traaport of bananas at ambient temperatures using polythene bags. Trop. Agric., 48(3): 245-254.

Scott, K.J., W.B. McGlasson and E.A. Roberts. 1970. Potassium permanganate as an ethylene absorbent in polythene bags to delay ripening of bananas during storage. Australian J. Expt. Agric. Anim. Husb., 10: 237-240.

Sen, S.; P. Basuchaudhuri and M.P. Chowduri. 1978. Studies on some post harvest biochemical changes in banana under sealed polythene bagging storage. Indian Agric., 22(1): 29-33.

Shillingford, C.A. 1970. Banana fruit rot control in Jamaica. Pest Articles News Summ., 16: 69-75.

Shiraishi, S. 1980. Fundamental study for grape breeding in the environment controlled system I. Accumulation of organic acids in berries of main grape cultivars during their maturation. Bull. Fukuoka Hort. Exp. Sta. 18: 9-17.

Singh, A. 1990. Banana. *In*: Fruit Physiology and Production, Kalyani Publishers, New Delhi. pp. 285-300.

Smock, R.M. 1967. Methods of storing bananas. Philippines Agric., 51: 501-517.

Somogyi, M. 1952. Notes on sugar determination. J. Biol. Chem., 195: 19-23.

Subramanyam, H., N.V.N. Moorthy, S. Lakshiminarayana and V.B. Dalal. 1972. Control of fungal spoilage in Alphaao mangoes by pre-harvest application of fungicides. Acta Hort., 24: 224-226.

Thompson, A.K., B.O. Been and C. Pekia. 1974. Effect of humidity on ripening of plantain bananas. Experientiae, 30(1): 35-36.

Tomkia, R.G. 1962. The conditioa produced in film packages by fresh fruits and vegetables and the effect of these conditioa on storage life. J. Appl. Bacteriol., 25: 290-307.

Vendrell, M. 1970. Acceleration and delay of ripening in banana fruit tissue by giberellic acid. Australian J. Biol. Sci., 23: 553-559

Vendrell, M. and W.B.McGlasson. 1971. Inhibition of ethylene production in banana fruit tissue by ethylene treatment. Australian J. Biol. Sci., 24: 885-895.

Yahia, E. M. 1998. Modified and control atmospheres for tropical fruits. Hort. Rev., 22: 123-183.

Yahia, E.M. and A. Ait-Oubahou. 2001. Training Manual on: Post harvest Physiology, Technology and Handling of Horticultural crops. ARMP-TA, IDA Credit # 2815-BD, Dhaka. 68

Zica, L.F. and W. Brune. 1973. The effect of polythene wrapping on the coaervation and ripening of banana cultivar Prata. Esperimentiae, 16(3): 43-59.

APPENDICES

APPENDICES

I. Analysis of variance of data on % weight loss of fruits (21 days stored banana)

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	6.848	6.848	24.0993	0.0002
4	Factor B	3	1.467	0.489	1.7211	0.2029
6	AB	3	1.408	0.469	1.6512	0.2173
-7	Error	16	4.547	0.284		
	Total	23	14.269			

Coefficient of variation: 7.18%

II. Analysis of variance of data on % total sugar of fruits (21 days stored banana)

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	3.961	3.961	3200.7356	0.0000
4	Factor B	3	0.250	0.083	67.4237	0.0000
6	AB	3	0.123	0.041	33.0806	0.0000
-7	Error	16	0.020	0.001		
	Total	23	4.354			

Coefficient of variation: 0.24

III. Analysis of variance of data on % total soluble solids (TSS) of fruits (21 days stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	7.605	7.605	182.9591	0.0000
4	Factor B	3	0.245	0.082	1.9640	0.1601
6	AB	3	0.086	0.029	0.6930	
-7	Error	16	0.665	0.042		
	Total	23	8.601			

Coefficient of variation: 0.83%

IV. Analysis of variance of data on P^H of fruits (21 days stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	0.045	0.045	8.2628	0.0110
4	Factor B	3	0.237	0.079	14.5027	0.0001
6	AB	3	0.209	0.070	12.7914	0.0002
-7	Error	16	0.087	0.005		
	Total	23	0.579			

Coefficient of variation: 1.40%

V. Analysis of variance of data on % reducing sugar of fruits (fresh and stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	1.949	1.949	150.0980	0.0000
4	Factor B	3	0.142	0.047	3.6497	0.0354
6	AB	3	0.034	0.011	0.8778	
-7	Error	16	0.208	0.013		
	Total	23	2.334			

Coefficient of variation: 1.28%

VI. Analysis of variance of data on % non-reducing sugar of fruits (fresh and stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	0.799	0.799	25.7232	0.0001
4	Factor B	3	0.031	0.010	0.3363	
6	AB	3	0.082	0.027	0.8769	
-7	Error	16	0.497	0.031		
	Total	23	1.410			

Coefficient of variation: 2.98%

VII. Analysis of variance of data on % sugar of fruits (fresh and stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	5.245	5.245	299.0931	0.0000
4	Factor B	3	0.097	0.032	1.8389	0.1808
6	AB	3	0.102	0.034	1.9416	0.1636
-7	Error	16	0.281	0.018		
	Total	23	5.725			

Coefficient of variation: 0.89%

VIII. Analysis of variance of data on % total soluble solids of fruits (fresh and stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	5.802	5.802	954.3515	0.0000
4	Factor B	3	0.106	0.035	5.8067	0.0070
6	AB	3	0.011	0.004	0.5977	
-7	Error	16	0.097	0.006		
	Total	23	6.016			

Coefficient of variation: 0.32%

IX. Analysis of variance of data on % acid of fruits (fresh and stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	0.019	0.019	65.6065	0.0000
4	Factor B	3	0.025	0.008	28.7780	0.0000
6	AB	3	0.035	0.012	41.4532	0.0000
-7	Error	16	0.005	0.000		
	Total	23	0.083			

Coefficient of variation: 5.06%

X. Analysis of variance of data on P^H of fruits (fresh and stored banana).

K Value	Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	0.032	0.032	26.5578	0.0001
4	Factor B	3	0.252	0.084	70.8524	0.0000
6	AB	3	0.222	0.074	62.2631	0.0000
-7	Error	16	0.019	0.001		
	Total	23	0.525			

Coefficient of variation: 0.66%

XI. Format for organoleptic taste

Sample	**Color** (dull yellow/ yellow/ bright yellow)	**Peeling** (easy/ not easy)	**Texture** (firm/ soft/ very soft)	**Sweetness** (less sweet/ sweet/ very sweet)	**Flesh color** (yellowish/ whitish)	**Taste** (not good/ good/ very good)
C 0ppm						
C 250ppm						
C 500ppm						
C 750ppm						
F 0ppm						
F 250ppm						
F 500ppm						
F 750ppm						