PERMANGANATE BASED INDIGENOUS ETHYLENE SCRUBBER AND ITS EFFICACY ON SHELF LIFE OF BANANA cv. ROBUSTA

Thesis submitted in part fulfillment of the requirement for the degree of ***Master of Science (Horticulture)*** *to the Tamil Nadu Agricultural University, Coimbatore.*

By
M.MEENAMBIGAI
ID. No. 98-620-010

Department of Pomology
Horticultural College and Research Institute
Tamil Nadu Agricultural University
Coimbatore-641 003

2000


PERMANGANATE BASED INDIGENOUS
ETHYLENE SCRUBBER AND ITS EFFICACY ON
SHELF LIFE OF BANANA cv. ROBUSTA

CERTIFICATE

This is to certify that the thesis entitled **"PERMANGANATE BASED INDIGENOUS ETHYLENE SCRUBBER AND ITS EFFICACY ON SHELF LIFE OF BANANA cv. ROBUSTA"** submitted in part fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** to the Tamil Nadu Agricultural University, Coimbatore is a record of *bona fide* research work carried out by **Miss. M. MEENAMBIGAI (ID.No.98-620-010)** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place: Coimbatore
Date : 21. 7. 2000

(T.THANGARAJ)
Chairman

Approved by

Chairman : **T. THANGARAJ**

Members : **N. KUMAR**

P. JEYAKUMAR

External Examiner :
Date : 17.10.2000

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

Heartfelt thanks to my affectionate ***Mother Late Tmt. P. Mahalakshmi*** *for showering me with her grace and guiding me in every walk of fruition.*

I express my deep sense of gratitude and grateful thanks to my beloved Guide and Chairman of the Advisory Committee, ***Dr. T. Thangaraj****, Dean, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam for his sustained interest, perpetual motivation, constant encouragement and able guidance during the course of this investigation and the preparation of this thesis.*

I am highly obliged to the members of the Advisory Committee ***Dr. N. Kumar****, Professor and Head, Department of Pomology and* ***Dr. P. Jeyakumar****, Assistant Professor (Crop Physiology), Department of Pomology for their valuable suggestions and constant encouragement offered during the study.*

I wish to express my sincere thanks to ***Dr. R. S. Azhakiamanavalan****, Dean, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore for the facilities offered by him during the course of study.*

I am indebted to ***Dr. N. Chezhiyan****, Professor and Head, Dept. of Spices and Plantation Crops,* ***Dr. D. Veeraragavathatham****, Department of Olericulture,* ***Dr. M. Vijayakumar****, Professor and Head, Department of Floriculture,* ***Dr. M. Kannan****, Assistant Professor, Department of Olericulture,* ***Dr. K. Soorianathasundaram****, Assistant Professor, Department of Pomology,* ***Dr. T. Arumugam****, Assistant Professor, Department of Floriculture,* ***Dr. P. Jansirani****, Assistant Professor, Department of Olericulture and other staff members of the Department for their valuable suggestions during the study.*

I thank profusely ***Mr. R. Venkatachalam****, Assistant Professor, Department of Olericulture, for the superintendence of computers and printers in* *the Department and ever-ready help offered by him in bringing out the thesis to the full shape. I thank AHRDP for the computer facilities offered in the Department of Horticulture.*

I thank ***Dr. Z. John Kennedy****, Assistant Professor, Department of Microbiology,* ***Dr. Nagamani****, Assistant Professor, Department of Environmental Sciences,* ***Dr.Chandrasekaran****, Department of Entomology and* ***Dr. Santhanakrishnan****, Professor, Department of Microbiology for their valuable and well-timed help during the course of study.*

I wish to express my thanks to ***Mrs. I. Geethalakshmi, Mr. K. A. Shanmugasundaram , Mr. V. A. Sathiamoorthy, Mrs. P. Manonmani, Mrs. M. Mohanalakshmi*** *and* ***Mrs. Beena Jeeva*** *for their kindness and moral support offered during my study.*

With immense pleasure I thank my coadjutors ***Mrs. M. Visalakshi, Miss. B. Suma*** *and all* ***my dear comrades*** *for their constant and timely help during the course of investigation.*

I thank ***Mr.K . Chinnaswamy****, Lab assistant, for the kind helps offered by him during the course of research work.*

Last but not least I am thankful to my beloved father ***Dr. S. P. Manickam****, Ph.D.,* ***Miss.M. Ambi****, my sisters* ***Mrs. M. Parwathy, Mrs. M. Umayavalli****,, brothers-in-law* ***Mr.C. Subramanian*** *and* ***Mr. M. Ramakrishnan*** *whose solacing and wishes propelled me to work towards this cherished goal.*

I am also highly thankful to ***Tamil Nadu Agricultural University****, Coimbatore for the award of* ***TNAU Merit Scholarship*** *during the course of study.*

M. MEENAMBIGAI

ABSTRACT

ABSTRACT

PERMANGANATE BASED INDIGENOUS ETHYLENE SCRUBBER AND ITS EFFICACY ON SHELF LIFE OF BANANA cv. ROBUSTA

By

M. MEENAMBIGAI

Degree : **Master of Science (Horticulture)**

Chairman : **Dr. T. THANGARAJ**
Dean
Horticultural College and Research Institute
Tamil Nadu Agricultural University
Periyakulam - 625 604

2000

Investigations were carried out at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore - 641 003 to find out the efficacy of permanganate based indigenous ethylene scrubber on shelf life of banana cv. Robusta. The salient outcome of research findings is briefed here.

To find out the efficacy of permanganate based indigenous ethylene scrubber, the banana fruits were packed with saturated $KMnO_4$ and alkaline $KMnO_4$ scrubbers as treatments under ambient and cool conditions (13°C) for evaluation. Among the treatments and storage conditions evaluated, the fruits packed with clay and coirpith at 2.5:1 ratio with alkaline potassium permanganate as ethylene scrubber recorded a longer shelf life of 31.25 days under cool conditions (13°C) whereas the control recorded a shelf life of 17.50 days. Thus, there is 42.0 per cent increase in shelf life of fruits.

The same treatment recorded the least loss in weight (6.64 per cent), higher contents of TSS (23.89°Brix), acidity (0.37 per cent), ascorbic acid (10.62 mg/100g), total sugars (21.50 per cent), reducing sugars (16.47 per cent) and low ethylene concentration of 0.9217 μmol on 20th day of storage.

Fruits packed with clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber under cool conditions (13°C) recorded longer shelf life of 29.50 days, lower PLW of 8.90 per cent, higher contents of TSS (23.61°Brix), acidity (0.36 per cent), ascorbic acid (10.56 mg/100g), total sugars (21.32 per cent), reducing sugars (16.17 per cent) and low ethylene concentration of 0. 9387 μmol on 20th day of storage.

Under ambient conditions, the alkaline $KMnO_4$ as ethylene scrubber with clay and coirpith at 2.5:1 ratio recorded a longer shelf life of 19.75 days as against the control (14.00 days). Thus, there is 30 per cent increase in shelf life of fruits. The same treatment recorded lower PLW of 7.89 per cent, higher contents of TSS (22.81°Brix), acidity (0.37 per cent), ascorbic acid (10.46 mg/100g), total sugars (19.83 per cent), reducing sugars (16.72 per cent) and low ethylene concentration of 1.0026 μmol on 20th day of storage.

Under ambient conditions, the fruits packed with clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber recorded longer shelf life of 18.75 days, lower PLW of 17.13 per cent, higher contents of TSS (20.51°Brix), acidity (0.35 per cent), ascorbic acid (10.25 mg/100g), total sugars (20.86 per cent), reducing sugars (16.36 per cent) and low ethylene concentration of 1.2278 μ mol on 20th day of storage.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

APPENDICES

Sl. No.	TITLE
A.	Maturity (harvest) stages of banana
B.	Colour chart for ripening banana

INTRODUCTION

CHAPTER I

INTRODUCTION

Banana (*Musa sp.*) is the second largest fruit crop of the tropical and sub-tropical regions of the world. It is recognised as the fourth important food crop in terms of gross value after paddy, wheat and milk. At the national level, banana is one of the important fruit crops, which contributes for 31.5% of total fruit production (Anon., 1995). India is the largest producer of banana in the World with an annual production of 13.095 million tonnes from an area of 4.33 lakh hectares spread all over the country. The major banana producing states in India are Tamil Nadu, Maharashtra and Andhra Pradesh (Anon., 1999).

The annual domestic consumption of banana is estimated to be around 25 million tonnes for the next couple of decades. There is also ample export opportunities for Indian banana (Chadha, 1996).

Improvement in production of banana over last decade has been achieved through the manipulation of geometry, density, nutrient and water management besides plant protection measures. However, quality grade of fruits is much below the international standard. There is a considerable loss in the postharvest handling owing to insufficient knowledge on storage, packing, transportation etc. There is a need for research for producing high quality fruits for sustainable management of fruit quality without any deleterious effect on environment (Anon., 1995).

India being a tropical country, postharvest losses are much higher due to high temperature and also due to lack of technologies for handling and processing (Waskar and Roy, 1996). The Indian banana growers are losing around 20-80% of their production on account of the existing crude handling practices (Anon., 1999).

Bananas for export market should have a long shelf life so that it can fetch better market price. Increasing shelf life is crucial and it needs in-depth knowledge about the postharvest behaviour and the substances used for this purpose should meet international standards. Banana is a climacteric fruit and the ripening process starts on the synthesis of endogenous ethylene. Inhibiting the ripening process by reducing the ethylene level is the most important tool in achieving the keeping quality of banana. Thus, the management and control of fruit ripening is important for the successful global transport and marketing of banana fruits.

The present investigations were programmed with the following objectives to develop suitable ethylene scrubber, which is indigenous and cost effective for all sections of the banana growers.

i. to test the efficacy of different ratios of clay and coirpith with saturated potassium permanganate as ethylene scrubber under ambient conditions (30 - 32°C).

ii. to test the efficacy of different ratios of clay and coirpith with alkaline potassium permanganate as ethylene scrubber under ambient conditions (30 - 32°C).

iii. to test the efficacy of different ratios of clay and coirpith with saturated potassium permanganate as ethylene scrubber under cool conditions (13°C) and

iv. to test the efficacy of different ratios of clay and coirpith with alkaline potassium permanganate as ethylene scrubber under cool conditions (13°C).

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Banana is one of the most important fruit crops of India, occupying more than 3 percent of the area under fruits. The country is the largest producer of banana in the world with 13.095 million tonnes per annum. Though Indian bananas are equally tasty, lack in quality aspects like the presence of spots or black stripes owing to improper handling and storage, due to which Indian bananas are not much competitive in export market (Anon., 1999). The works carried out by various researchers on improving the shelf life of banana are available and the research works done on postharvest technology of banana and other related crops allied to the present study are reviewed here under the following headings.

1. Role of ethylene in fruit ripening
2. Use of ethylene absorbents
3. Packaging
4. Storage temperature
5. Heat treatment

2. 1. Role of Ethylene in Fruit ripening

Ethylene is the simplest unsaturated hydrocarbon compound and the structure is $H_2C = CH_2$. Ethylene is a plant hormone and it regulates ripening process of fruits. It regulates many aspects of plant growth including a rise in respiration, autocatalytic ethylene production and changes in colour, texture, aroma and flavour. Ethylene is biosynthesised from S-adenosylmethionine *via* 1-

aminocyclopropane-1-carboxylic acid (ACC) catalysed by ACC synthase and ACC oxidase.

Before the onset of ripening, preclimacteric fruit produce low levels of ethylene. This plays a major role in shortening the preclimacteric life of the fruit. But, at the onset of climacterium, there is a surge in ethylene production and its regulation becomes autocatalytic (Oetiker and Yang, 1995).

Based on these observations, two systems of ethylene production were introduced by McMurchie *et al.* (1972). *System 1* is the low rate of ethylene production in early preclimacteric fruit before the onset of ripening. *System 2* represents the autocatalytic burst of ethylene production accompanied by ripening process.

Fruits have been classified into climacteric and non-climacteric depending upon their respiratory behaviour during ripening. Climacteric fruit at the end of growth undergo a large increase in respiration accompanied by marked changes in composition and texture whereas non-climacteric fruit shows no change in respiration accompanied by distinct changes in composition. The other major difference is increase in ethylene production in climacteric fruit and vice-versa in non-climacteric fruit (McGlasson, 1985).

2. 2. Use of ethylene absorbents

Blanpeid (1990) reported that ethylene can be scrubbed from the storage atmosphere by using $KMnO_4$ and the chemical reaction is given below.

$$4\ KMnO_4 + C_2H_4 \longrightarrow 4MnO_2 + 4KOH + 2CO_2$$

Ethylene production is an early symptom of fruit ripening for both climacteric and non-climacteric fruits. If this reaches a critical level, changes in the metabolites are initiated associated with increased rate of respiration.

Undesirable levels of C_2H_4 in storage environment can be removed by simple ventilation with fresh air, provided the air is not polluted with high C_2H_4 levels. It is necessary to take care that C_2H_4 should not accidentally enter through the ventilation (Sherman, 1985).

A large number of reagents and techniques have been tested for many years, but only potassium permanganate is presently in commercial use (Denny, 1924). Self-indicating soda lime, that contains manganate, has been reported to remove ethylene from air (Nichols and Topping, 1966).

Ethylene and other volatile contaminants have been removed from air samples and from storage room atmosphere by either reacting them with chemicals or by absorbing them with inert material. It is suggested that the use of paraffin oil can remove volatiles from storage atmosphere (Dostal and Hoff, 1968). To reduce apple scald, brominated charcoal has been found to be effective but its effectiveness in removing ethylene was both positive and negative (Forsyth *et al.* 1969).

A number of commercial scrubbers are available in sachets, filters and blankets by companies such as Purafil, Ethylene Eaters, Ethylene Scrub Enterprises etc., The use of Purafil as an ethylene absorbent in closed packs extended the shelf life by seven days (Scott *et al.*, 1970).

Storing the banana fruits in sealed polyethylene bags showed promising result (Liu, 1970). It was also suggested that after a reasonable period of storage the bags must be opened to allow normal ripening.

The delayed ripening could be due to low concentrations of ethylene in Purafil packed fruits without any change in the CO_2 concentration as shown in kiwifruit (Scott, *et al.*, 1984) or it may be also attributed to the combined effect of reduced ethylene concentration due to the use of Purafil and modified atmospheric conditions of low O_2 and enhanced CO_2 in the sealed bags (Scott *et al.*, 1971).

Potassium permanganate has been reported to oxidise ethylene to ethylene glycol, thus partly delaying the ripening processes (Abeles, 1973). Potassium permanganate is the most effective ethylene absorbent and it can be used in such a way that it should be adsorbed on a suitable carrier with large surface area. Celite, vermiculite, silicagel, alumina pellets (Abeles, 1973), perlite (Saltveit, 1980) and expanded glass (Lidster and Lawrence, 1983) have all been successfully used as carriers.

The storage life of bananas cv. Williams over a range of temperature from 10 to 37°C was considerably increased by packing the fruit in sealed polyethylene bags. The addition of potassium permanganate on vermiculite (50g) as an ethylene absorbent further increased storage life (Scott and Gandanegara, 1974).

Patil and Magar (1975) studied the effect of Purafil, a silicate carrier impregnated with alkaline $KMnO_4$ kept in sealed polythene covers of bananas extended the storage life. Purafil reduced ethylene concentrations and extended the shelf life of pre-climacteric bananas by 16,8 and 4 days when stored at temperatures of 13, 24 and 31° C respectively. Similar observations were also made by Ndubizu (1976), Krishnamurthy and Kushalappa (1985) in banana.

Ndubizu (1976) reported that Nigerian green plantains stored with Purafil kept longer than those stored with potassium iodide or potassium dichromate. Of all the reactive chemicals, the non-corrosive chemical *viz.*, potassium permanganate ($KMnO_4$) is generally regarded as the most effective scrubber (Dostal and Hoff, 1968; Scott *et al.*, 1970; Abeles, 1973).

Scott (1975) used a vermiculite cement block soaked in $KMnO_4$ solution to remove ethylene from sealed bags containing banana. Perlite and $KMnO_4$ have also been used as an ethylene absorbent (Esguerra *et al.*, 1978).

Large number of commercial potassium permanganate scrubbers are available in sachets, filters, blankets and other specialized trapping devices. Ethylene is trapped most effectively when air is drawn through the scrubber. Potassium permanganate scrubbers are advantageous as the colour changes from purple to brown when the MnO_4^- is reduced to MnO_2. But, the major constraint for using this scrubber is its expensiveness (Saltveit, 1980).

Knee and Hatfield (1981) reported that $KMnO_4$ delayed ethylene accumulation in the storage atmosphere of apples.

Various materials like vermiculite, coke, pumice stone, sand and saw dust soaked with a strong solution of $KMnO_4$ were used as ethylene absorbents in banana packs (Parkin and Scott, 1979). Sherman (1985) indicated that ethylene could be destroyed by $KMnO_4$, a strong oxidising agent. To ensure an efficient destruction of ethylene, it is necessary that $KMnO_4$ be adsorbed on suitable carrier with large surface area.

Ethylene can also be scrubbed from the storage atmosphere either by trapping it or by converting it to other products, provided ventilation should not be there for removal (Sherman, 1985).

In Philippines, a low cost ethylene scrubber made of clay and silica rich ash from burnt rice hulls impregnated with $KMnO_4$ has been reported (Adlai, 1989). Blanpeid (1990) reported that $KMnO_4$ incorporated into beads of activated alumina were kept in a cabinet of apple and controlled atmosphere is pumped from controlled atmosphere room which resulted in change of colour of beads where fresh beads are purple and spent beads are brown in colour. By this method, ethylene can be scrubbed from the storage atmosphere. Abe and Watada (1991) used charcoal with palladium chloride as an absorbent to prevent accumulation of ethylene in banana packs.

Efforts were made to study the relative efficacy of Celite-permanganate and silica gel - permanganate mixture as ethylene absorbents in sealed polyethylene bags. The Celite - permanganate mixture as ethylene absorbent was more promising as compared to silica gel - permanganate mixture for storage of guava fruit. The storage of fruits in low-density polyethylene bag (200 gauge) with Celite - permanganate mixture showed minimum physiological loss in weight, slower ripening during storage and the fruit quality was comparable (Dutta *et al.*, 1991).

Jayaraman and Raju (1992) developed a self-stable and cost effective granulated ethylene scrubber based on $KMnO_4$ impregnated in an inert matrix formulated using alumina (Al_2O_3) and limestone against scrubber matrices like cement *vis-a-vis* an imported trade scrubber. The alumina, limestone and cement formulations showed satisfactory results in ethylene absorption and self-stability compared to the trade product. Ethylene scrubbing restricted the loss in PLW, firmness and brought about slower and steadier changes in TSS and acidity in fruits and thus retarded senescence.

The storage life of banana was doubled the duration in the absence of ethylene scrubber while the life was extended thrice when an ethylene absorbent on aluminium oxide was introduced (Satyan *et al.*, 1992). Potassium permanganate in saturated solution with clay ash chips as carrier significantly reduced the cumulative weight loss of 'Lakatan' banana during a period of 17 days in storage, without adversely affecting its edible quality at room temperatures in the Philippines (Claud and Calvo, 1993).

Storing 'Galia' melons in a controlled atmosphere with ethylene absorbent was proved to be effective. The quality of 'Galia' melons (*Cucumis melo*) stored in a controlled atmosphere (CA) of 10% CO_2 plus 10% O_2 with ethylene scrubber of 30g vermiculite soaked in saturated potassium permanganate for 14 days at 6°C and an additional 6 days at 20°C was significantly better than that of control fruit or fruit stored in controlled atmosphere only. Fruits stored in controlled atmosphere along with ethylene absorbent were firmer and exhibited less decay than fruit from the other treatments viz., control and controlled atmosphere alone (Aharoni *et al.*, 1993).

Purafil was found to be very effective ethylene absorbent and delayed climacteric peaks of ethylene and respiration upto 90 days of storage in case of apples (Mahajan and Chopra, 1994). The fruits packed with purafil had minimum weight and maximum firmness throughout the storage period.

The anti-ethylene effects of nitrous oxide have been demonstrated for the first time in the ripening and senescence sequences in tomato and avocado fruit. Continuous gas treatment by 80% nitrous oxide plus 20% oxygen had major inhibitory effects on ethylene production (Gouble *et al.*, 1995).

Potassium permanganate plays a very important role in the extension of storage life of strawberries as it is having a short postharvest life. The addition of $KMnO_4$ reduced ethylene accumulation and increased storage life by two days, which was about one day longer than for fruit without added $KMnO_4$ at 20°C. At 0°C, $KMnO_4$ extended the shelf life by eight days compared to six days for untreated fruit. The $KMnO_4$ treated fruit was found to be less susceptible to grey mould (*Botrytis cinerea*) which is the main cause of deterioration at 20°C (Wills and Kim, 1995).

Mango fruits cvs. Keitt and Palmer harvested at the preclimacteric stage were stored for 18 days at 10 or 15°C (85-90% RH) in bags containing vermiculite or silica gel impregnated with saturated aqueous $KMnO_4$ solution. Total soluble solids, alcohol, insoluble solids and starch contents after storage were significantly higher in Keitt fruits than on Palmer fruits (Briceno *et al.,* 1999).

2. 3. PACKAGING

Polythene bag storage (Modified Atmospheric Packaging)

Modified atmospheric packaging (MAP) is a dynamic system of storage where respiration of product and gas permeation of film continues to take place simultaneously. MAP consists of enclosing the fruits in a plastic bag such that there is limited exchange of air, leading to reduction in oxygen levels (Floros, 1990).

Packaging is an important factor responsible for improving the quality of saleable product (Pandey *et al.,* 1983). The package should be designed in such a way that the product should be delivered to the customer conveniently and in a good form. Moreover, the product kept inside the package should be free from mechanical injury during transit. Adequate packaging protects the produce from physiological, pathological and physical deterioration in the marketing channels and retains their freshness and attractiveness (Maini *et al.,* 1993). Thus, packaging plays an important role in postharvest management of fruits to assemble the produce in convenient units and to protect it from damages during handling and marketing.

Bananas are shipped in an unripe state in producing countries. With the development of a specialised reefer container, bananas are cooled to field temperature, say 30°C, down to the shipping temperature of 13 ± 1°C. After that, the bananas are subjected to controlled ripening when they reach the importing countries without removing them from box or package. These special features of the banana trade place special demands on banana packaging techniques (Charles and New, 1996).

Storing banana fruits in sealed polythene bags showed promise. After reasonable period of storage, the fruits were opened to allow normal ripening (Liu, 1970). Scott *et al.* (1971) has demonstrated the use of polythene bags for the storage and transfer of banana fruits.

Packaging guava fruits in polyethylene bags had remarkable effect on reducing physiological loss in weight and retention of firmness, greenness, acidity and organoleptic qualities compared to control fruits. Fruits packed in 300 gauge polythene bag with no ventilation recorded minimum weight loss, retained more firmness as well as greenness and extended the shelf life upto 10 days as against only 3 days in control fruits (Dutta *et al.*, 1991).

The storage life of banana fruits cv. Williams was considerably increased by packing the fruit in sealed polythene bags (Scott and Gandanegara, 1974).

Silvis *et al.* (1976) reported that the hands of three fourth matured bananas wrapped in polythene bags prolonged the storage life, reduced the weight loss and occurrence of storage rots.

Many workers, including Biale (1956) and Scott & Roberts (1966), have shown that pre-climacteric bananas stored in sealed polythene bags at ambient temperature remained hard and green for about one week longer than control. There is a disadvantage in storing post-climacteric fruit along with green pre-climacteric ones in polythene bag because storage life could not be lengthened due to ethylene produced by the post-climacteric fruits (Hales, 1963 and Smith, 1963).

Mature banana fruits of cv. Kalibabu, when sealed in polythene bags showed an extension in shelf life by upto seven days. The changes in skin chlorophyll, carotenoid content and pulp amylase activities of fruits were lower in polythene bags (Sen *et al.*, 1978).

MAP of bananas slowed down the respiration and thereby delayed the ripening (Carvalho, 1988). Marchal and Nolin (1990) and Satyan et al. (1992) made similar observations. Mature green 'Embul' banana fruits showed no peel colour development after 15 days of storage at 26 ± 3°C in sealed polythene bags whereas fruits in perforated and open bags showed full peel colour development by the ninth day (Sarananda, 1989).

In banana cv. Grand Naine, the use of sealed polythene bags reduced canker development compared with classical packing methods where open plastic film is currently used during export of Cavendish bananas (Chillet *et al.,* 1995).

Storing banana cv. Robusta in sealed polythene bags of 200 gauge thickness along with potassium permanganate based ethylene absorbent increased the storage life of fruits (Nayak, 1999).

2. 4. Storage temperature

High temperature also causes storage loss of fruits. Fruits stored at low temperature experiences reduced respiration, slowed physiological processes and reduced the growth of fungi. Plantains packed in plastic bags when held at 8°C in partial vacuum have prolonged storage life upto 65 days (Guillemot, 1976).

The pre-climacteric period of plantain fruits were extended when storage temperature was reduced and 14°C was the lowest temperature for free of chilling injury, which occurred at 6-10°C (George and Marriott, 1985). Shelf life was found to decrease exponentially with increasing temperature (Peacock, 1980).

Banana fruits when stored at high temperature led to physiological disorders and unsatisfactory ripening. Weight loss was less in banana fruits cv. Robusta held at 15°C and 20°C compared to room temperature. Quality of fruits after one to four weeks of storage at 20°C was found to be better than those stored at 15°C (Krishnamurthy, 1989).

High storage temperature accelerates softening of the pulp and inhibits chlorophyll breakdown in the peel thus leading to the 'green-ripe' condition in banana fruits (Zhang *et al.*, 1993). Storage of bananas at 13°C considerably suppressed respiration rate, ethylene production and ripening (Lebibet *et al.*, 1995).

Mature 'Kalibabu' bananas packed under modified atmospheric conditions using Low Density Polyethylene bags along with saturated potassium permanganate based ethylene scavenger at 14°C increased storage life upto 30 days (Chamara *et al.*, 2000).

2. 5. Heat treatment

Hot water treatment has been used to control fungal diseases and insect infestation of fruit for many years besides insecticides, fungicides and fumigants. The U. S. Environmental Protection Agency, 1984 has banned the use of chemicals for control of pests and diseases. These regulatory restrictions compelled the use of physical method of disinfestation of fruits and one such method is heat treatment of fruits (Couey, 1989).

Hot water treatment is inherently more effective than humid air as a heat transfer medium and when properly circulated through the load of fruit, quickly establishes a uniform profile of temperature. Hot water treatment is effectively used for controlling microbial diseases than for insect control.

Papaya fruits when exposed to hot water at 44 to 49°C for 20 minutes were effective against *Colletotrichum gloeosporioides* Penz. and *Phytophthora palmivora* Butler, except during periods of heavy infection (Akamine and Arisumi,1953).

Mango fruits were dipped in hot water at 50 to 55°C for 15 minutes and they were stored for 30 to 45 days at 9 to 10°C without affecting the flavour or general appearance (Smoot and Segall, 1963).

For disinfestation of banana fruits without detriment to either quality or shelf life, Armstrong (1982) developed a 15 minute hot water (50°C) immersion treatment as an alternative quarantine treatment to Ethylene-di-bromide fumigation for the control of *Ceratitis capitata, Dacus cucurbita* and *Dacus dorsalis* in Brazilian variety that are shipped from Hawaii to the U.S.A.

Mature green banana fruits after harvest were dipped in hot water at 50°C for 15 minutes remained green for 14 days after exposure to ethylene at 15-20°C temperature without quality loss whereas the control fruits overripe but, the 54°C for 20 minutes treatment caused some blackening on the fruit surface (Friths and Chalker, 1983).

Though fruits like banana are heat tolerant (Paull, 1990), one should be very cautious in taking up the hot water treatment, despite the pronounced effects of hot water dips. To reduce the population of microorganisms, higher temperatures necessitated by the short treatment time (upto 60 minutes) can easily damage fruit tissues, if the recommended exposure time is exceeded (Mayberry and Hartz, 1992).

Banana cv. Robusta fruits were dipped in hot water at 55°C for 10 minutes and they were found to be most effective against storage rot incidence (Nayak, 1999).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Investigations were carried out at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore – 641 003 during 1999 - 2000 to develop an indigenous ethylene scrubber for banana cv. Robusta to extend the shelf life and to improve the postharvest qualities.

3. 1. Experiment I:

Studies on the efficacy of different ratios of clay and coirpith with saturated potassium permanganate as ethylene scrubber under ambient conditions

3. 1. 1. Materials:

3. 1. 1. 1. Fruits

The fruits of cv. Robusta maintained at the University orchard formed the basic experimental material. The plants were maintained under uniform cultivation practices (Anon., 1994). The bunches were harvested at 80% maturity based on the maturity indices reported by Rameshwar (1993) (Appendix A). Five fruits were used per replication.

3. 1. 1. 2. Polythene bags

Polythene bags of size 100 X 100 cm and 200 gauge thickness were used (Nayak, 1999).

3. 1. 1. 3. Ethylene scrubber

Potassium permanganate of AR Grade was employed in the study.

3. 1. 1. 4. Carriers

The locally available indigenous materials viz., clay and coirpith were used as carrier for potassium permanganate. The clay and coirpith were tried in different ratios ranging from 1:1 to 2.5:1 (Plate 1).

3. 1. 1. 5. Gas Chromatograph Instrument

The Nucon gas chromatograph instrument fitted with Poropak Q column was used for measuring ethylene gas (Plate 3).

3. 1. 1. 6. Standard ethylene

Standard ethylene of (Bhoruka Can Calibration Gas) was used for measurement of ethylene.

3. 1. 1. 7. Sealing machine

The sealing machine (AERMEC) was used uniformly for sealing the bags after filling with fruits along with ethylene scrubber.

3. 1. 2. Methods

3. 1. 2. 1. Preparation of ethylene scrubber

For the preparation of ethylene scrubber, a known quantity of dry clay particles and powdered coirpith were taken and mixed well before soaking in saturated potassium permanganate solution. The quantity of clay and coirpith varied according to the ratios as indicated in the technical program. The preparation of saturated $KMnO_4$ solution was made by dissolving AR grade $KMnO_4$, constantly stirring all the time adding more quantities of $KMnO_4$ everytime when some quantity of $KMnO_4$ still remains insoluble, further addition of $KMnO_4$ stopped. After stirring thoroughly, the supernatant solution was used for the preparation of ethylene scrubber. The quantity of solution added varied according to the ratio. After fully soaking in the solution, the saturated carrier material was made into a square block of 100 g weight and it was covered with a muslin cloth by suitable stitching. This block was finally used as ethylene scrubber (Plate 2).

3. 1. 2. 2. Ethylene measurement

Airtight plastic containers of roughly 2 litre capacity procured from local shop were used for ethylene trapping (Plate 7). Airtight valve was fitted on the top of the container along with high quality septum. The fruits five in number as per the treatment were kept inside the container with or without ethylene scrubbers of varying ratios. These containers were kept inside the laboratory under ambient conditions. For collecting and injecting gas, airtight Hamilton syringe of 1 ml capacity was used.

The Gas Chromatograph Instrument was fitted with Poropak Q column for ethylene measurement. Flame Ionisation Detector (FID) was used. The oven temperature was set at 150°C, injector temperature at 170°C and detector temperature at 190°C. 1 ml of standard ethylene gas was injected through the injector port and detected peak values were stored in the computer. Similarly, 1 ml of sample was injected and the ethylene gas was detected based on area occupied and peaks detected. A standard curve was drawn from the data generated using WINACDS package.

3. 1. 2. 3. Procedure

The fruits were harvested at 80% maturity from the field during morning hours. It was immediately separated into hands using a sharp knife and was transported to the laboratory. Banana leaf bits were used as cushioning materials while transporting. Hands of five fruits were separated for each treatment and all the fruits were subjected to a standard hot water treatment (Nayak, 1999). The hot water treatment consisted of dipping the fruits in hot water at 54 ± 1°C for a period of 10 minutes. Water was taken in a bucket, which was heated using an immersion coil, and the temperature was measured using a digital thermometer kept inside the water. The temperature was constantly maintained during the treatment for all the fruits by suitably heating or by adding cold water. The fruits were totally immersed inside hot water for specified period. The fruits after hot water treatment were immediately dipped in cold water and shade dried till the outer surface of the fruit is moisture free. The fruits were weighed accurately using an electronic balance and the weight of individual polythene bag was also recorded. The fruits were kept inside the polythene bag with or without scrubber and sealed airtight in unventilated polythene bags.

3. 1. 3. Treatment details:

Number of treatments : 5

T1 Clay + Coirpith (1.0: 1.0)

T2 Clay + Coirpith (1.5: 1.0)

T3 Clay + Coirpith (2.0: 1.0)

T4 Clay + Coirpith (2.5: 1.0)

T0 Control (Fruits sealed in polythene bag without scrubber)

Number of replications : 4

Design : CRD

3. 2. Experiment II

Studies on the efficacy of different ratios of clay and coirpith with alkaline potassium permanganate as ethylene scrubber under ambient conditions

The experiments were carried out as in the case of materials and methods followed under Experiment I with the following deviations.

3. 2. 1. Materials:

3. 2. 1. 1. Ethylene scrubber

Potassium permanganate along with 2-3 pellets of sodium hydroxide was employed in the study.

3. 2. 2. Methods

Potassium permanganate of AR Grade was taken and dissolved in known volume of water till it gets saturated and 2-3 pellets of laboratory grade sodium hydroxide pellets/litre were added to make it alkaline and used for making the ethylene scrubber.

3. 2. 3. Treatment details

Number of treatments : 5

T1 Clay + Coirpith (1.0: 1.0)

T2 Clay + Coirpith (1.5: 1.0)

T3 Clay + Coirpith (2.0: 1.0)

T4 Clay + Coirpith (2.5: 1.0)

T0 Control (Fruits sealed in polythene bag without scrubber)

Number of replications : 4

Design : CRD

3. 3. Experiment III

Studies on the efficacy of different ratios of clay and coirpith with saturated potassium permanganate as ethylene scrubber under cool conditions (13°C)

The experiments were carried out as in the case of materials and methods followed under Experiment I with the following deviations.

3. 3. 1. Methods

3. 3. 1. 1. Ultra low temperature cabinet

Ultra low temperature cabinet was used for maintaining cool condition and the temperature was set at 13°C till the termination of storage.

3. 3. 2. Methods

The fruits with ethylene scrubber after necessary treatment were kept in ultra low temperature cabinet at 13°C.

3. 3. 3. Treatment details

Number of treatments : 5

T1 Clay + Coirpith (1.0: 1.0)

T2 Clay + Coirpith (1.5: 1.0)

T3 Clay + Coirpith (2.0: 1.0)

T4 Clay + Coirpith (2.5: 1.0)

T0 Control (Fruits sealed in polythene bag without scrubber)

Number of replications : 4

Design : CRD

3. 4. Experiment IV

Studies on the efficacy of different ratios of clay and coirpith with alkaline potassium permanganate as ethylene scrubber under cool conditions (13°C)

The experiments were carried out as in the case of materials and methods as in the case of Experiment I with the following deviations.

3. 4. 1. Materials

3. 4. 1. 1. Ethylene scrubber

Potassium permanganate along with 2-3 pellets of sodium hydroxide was employed in the study.

3. 4. 1. 2. Ultra low temperature cabinet

Ultra low temperature cabinet was used for maintaining cool condition and the temperature was set at 13°C till the termination of storage (Plate 4-6).

3. 4. 2. Methods

3. 4. 2. 1. Preparation of ethylene scrubber

Potassium permanganate of AR grade was taken and dissolved in known volume of water till it gets saturated and 2-3 pellets of laboratory grade sodium hydroxide/litre were added to make it alkaline and used for making ethylene scrubber.

3. 4. 2. 2. Procedure

The fruits with ethylene scrubber after necessary treatment were kept in ultra low temperature cabinet at 13°C.

3. 4. 3. Treatment details

Number of treatments : 5

T1	Clay + Coirpith (1.0: 1.0)
T2	Clay + Coirpith (1.5: 1.0)
T3	Clay + Coirpith (2.0: 1.0)
T4	Clay + Coirpith (2.5: 1.0)
T0	Control (Fruits sealed in polythene bag without scrubber)

Number of replications : 4

Design : CRD

3. 5. Observations recorded:

3. 5. 1. Physical characters

3. 5. 1. 1. Physiological Loss in Weight (PLW)

An initial weight of fruit was taken and subsequent weights were taken once in two days. The weight of polythene bag and scrubber were recorded initially and adjusted during calculations of differential weight. The PLW was arrived at, following the formula below and expressed in percentage.

$$PLW = \frac{\text{Initial weight- Final weight}}{\text{Initial weight}} \times 100$$

3. 5. 1. 2. Peel colour change

The days taken for the peel to turn into light yellow colour was recorded in each of the treatment and expressed in numbers.

3. 5. 1. 3. Fruit softening

The soft nature of the fruit pulp was approximately judged using fingers. The number of days taken for softening as judged by finger feeling and expressed in number for each treatment.

3. 5. 1. 4. Shelf life (Days)

The days taken for the fruits to loose its edibility by over softening and decay is taken and expressed in number of days for each treatment.

3. 5. 1. 5. Peel colour (mean index)

The colour of the fruit was recorded once in two days using the standard colour chart developed by United Fruit Sales Corporation (Appendix B) as quoted by Armstrong (1982).

3. 5. 2. Biochemical characters

The following biochemical characters were analysed when the fruit reached edible maturity stage in each treatment.

3. 5. 2. 1. Total Soluble Solids (TSS)

Total soluble solids of ripe fruits in each of the treatment was taken using Carl Zeiss Hand Refractrometer and the result was expressed in ' °Brix'.

3. 5. 2. 2. Acidity

The acidity of the fruits in each of the treatment was estimated as per the procedures of A. O. A. C. (1960) using 0.1N potassium hydroxide (KOH) and expressed as percent citric acid.

3. 5. 2. 3. Ascorbic acid

The ascorbic acid content of the fruits in each of the treatment was determined by using 2,6-dichlorophenol indophenol dye titration as per the methods adopted by Freed (1966) and expressed as mg/ 100g of fresh sample.

3. 5. 2. 4. Estimation of sugars

Total sugars and reducing sugars were estimated by Lane and Eyon (1923) titrimetric method using Fehling's solution and expressed as percentage.

3. 5. 2. 5. Sugar-acid ratio

Sugar-acid ratio was calculated by dividing total sugars with acidity and expressed in numbers.

3. 5. 2. 6. Ethylene estimation

The ethylene released by fruits in each of the experiment was measured once in five days in a Nucon Gas Chromatograph instrument using standard ethylene gas and the data on retention time, height of the peak, area covered were recorded and the ethylene concentration was computed using the formula adopted by Sadasivam and Manickam (1996) and expressed in µmol.

$$\text{Standard amount of ethylene (E) } \mu\text{mol} = \frac{0.0446 \times Z\mu\,l.}{\text{Peak height in mm.} \times \text{attenuation}}$$

Amount of ethylene evolved = E X Peak height of the sample in mm. X attenuation

where 0.0446 = Constant

Z = Amount of sample injected (μ l.)

Based on the evolution of ethylene, the efficiency of ethylene scrubber was observed.

Statistical methods

The data gathered were subjected to statistical scrutiny adopting the standard procedures as laid down by Panse and Sukhatme (1967) and the results interpreted.

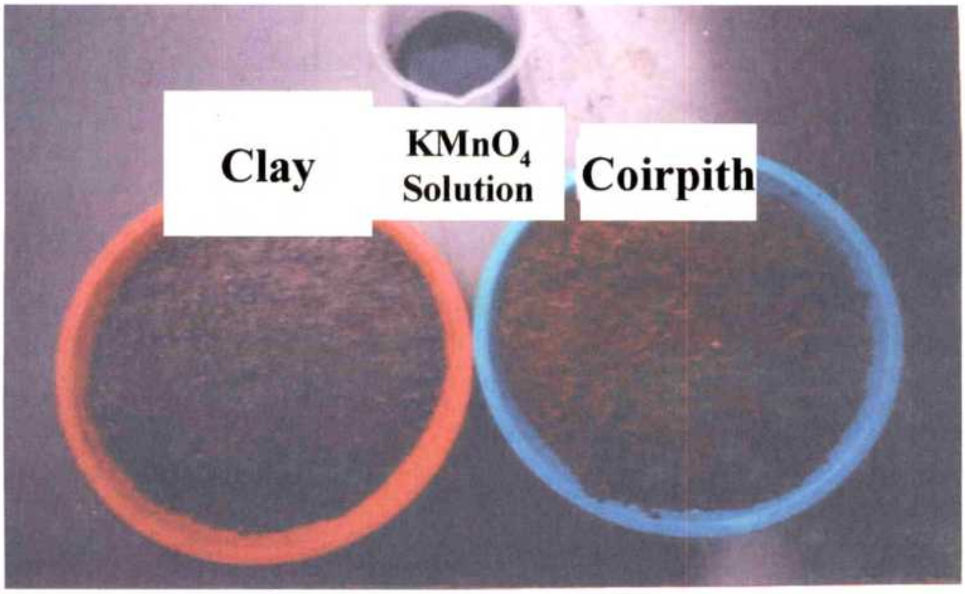


Plate 1. Materials used for making indigenous scrubber

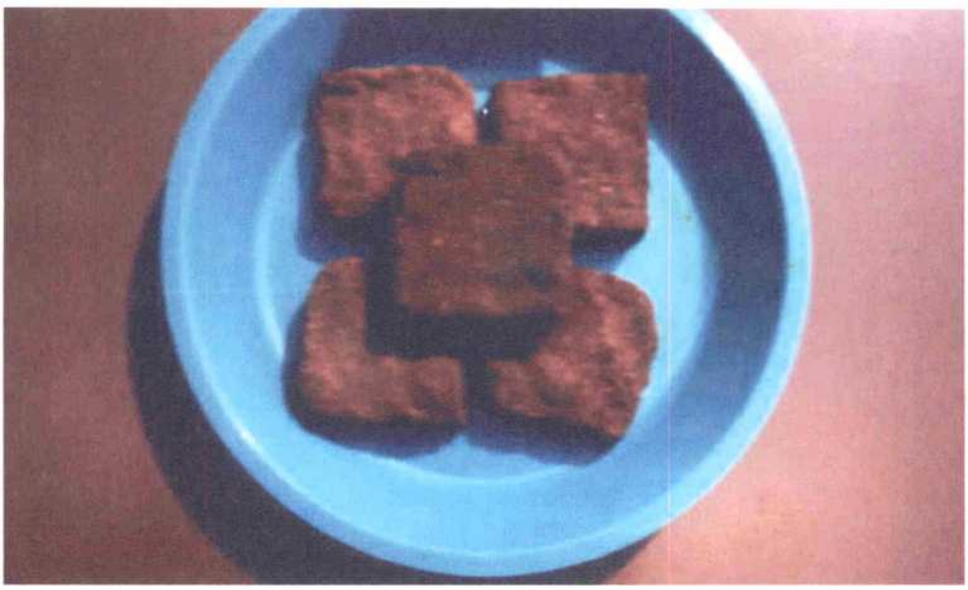


Plate 2 . Indigenous ethylene scrubber

Plate 3. Nucon - Gas chromatography unit

Plate 4. Ultra low temperature cabinet

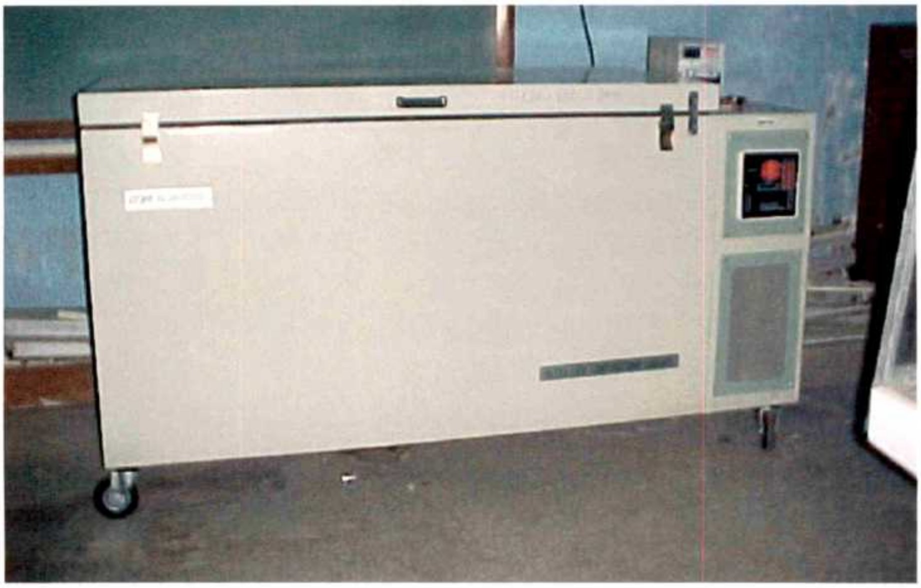


Plate 5. Ultra low temperature cabinet - An inside view

Plate 6. Robusta fruits in racks for keeping in ultra low temperature cabinet

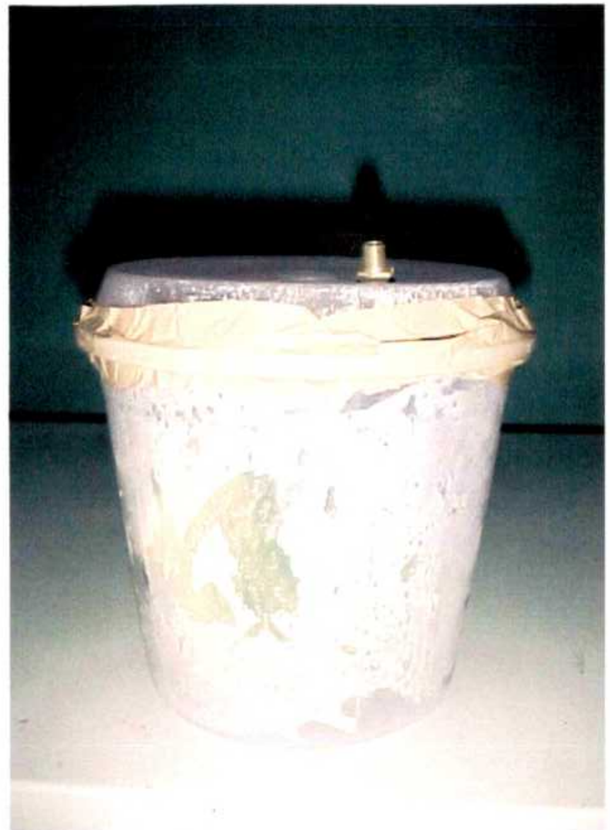


Plate 7. Air-tight container for containment of ethylene

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The experiment was carried out to find out the effect of different ratios of clay and coirpith with saturated or alkaline potassium permanganate as ethylene scrubber under ambient or cool conditions (13°C) on shelf life of banana cv. Robusta. The results generated in the present study are presented below.

4. 1 Experiment I

Studies on the efficacy of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber under ambient conditions

4. 1. 1. Physical characters

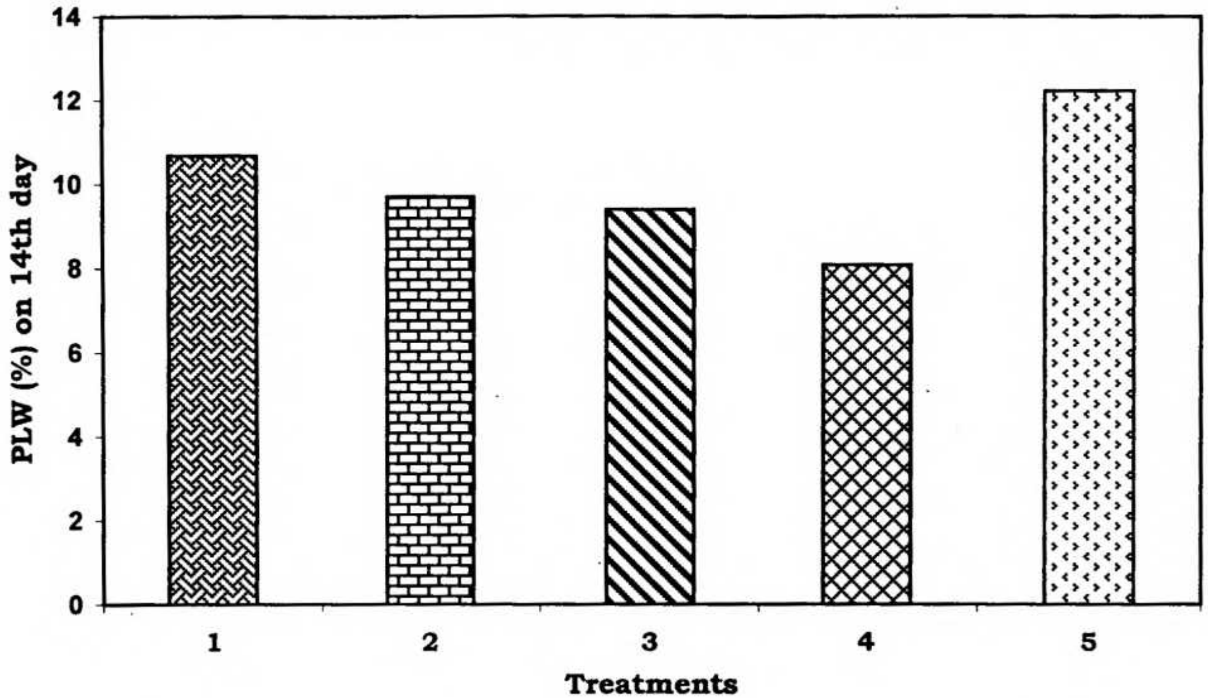
4. 1. 1. 1. Physiological Loss in Weight (PLW)

The effect of ethylene scrubber at different levels of clay and coirpith with saturated $KMnO_4$ on PLW of banana cv. Robusta was significant and presented in Table 1 and Fig. 1. The PLW ranged widely from 2.72 to 19.96 per cent in clay and coirpith at 1:1 ratio. The PLW advanced with increase in storage life from 3.45 to 18.78 per cent. Among the treatments, the PLW was higher in clay and coirpith at 1:1 ratio (19.96 per cent) followed by clay and coirpith at 1.5:1 ratio (19.32 per cent) and clay and coirpith at 2:1 ratio (18.69 per cent) on eighteenth day of storage. The control recorded higher PLW (12.23 per cent) on fourteenth day of storage compared to all other treatments. Among the treatments, clay and

Table 1. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on PLW (%) under ambient conditions

Treatments	Duration of storage (Days)								
	2	4	6	8	10	12	14	16	18
Clay + Coirpith (1 : 1)	2.72	5.18	7.40	8.50	9.37	10.11	10.69	10.86	19.96
Clay + Coirpith (1.5 : 1)	3.43	6.16	6.51	7.24	7.33	8.62	9.71	10.63	19.32
Clay + Coirpith (2 : 1)	3.28	4.42	6.02	6.74	7.44	8.88	9.40	9.93	18.69
Clay + Coirpith (2.5:1)	3.52	4.48	4.36	5.31	6.70	7.46	8.09	8.47	17.13
Control	4.29	6.48	8.35	9.27	10.03	11.28	12.23	-	-
Mean	**3.45**	**5.34**	**6.53**	**7.41**	**8.17**	**9.27**	**10.03**	**9.97**	**18.78**
CD (0.05)	0.35	1.36	1.02	0.84	0.97	0.65	0.55	0.88	0.82

Fig. 1. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on PLW (%) under ambient conditions



1 - Clay+Coirpith (1:1)
2 - Clay+Coirpith (1.5:1)
3 - Clay+Coirpith (2:1)
4 - Clay+Coirpith (2.5:1)
5. Control

coirpith at 2.5:1 ratio showed slower rate of loss in weight till eighteenth day of storage.

4. 1. 1. 2. Days taken for peel colour change

The data on days taken for peel colour change and fruit softening as influenced by different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber under ambient conditions is presented in Table 2.

The peel colour change ranged widely from 12.50 to 14.75 days. Among the treatments, clay and coirpith at 2.5:1 ratio took maximum of 14.75 days for peel colour change followed by clay and coirpith at 2:1 ratio (14.50 days). The control recorded a minimum of 12.50 days for peel colour change.

4. 1. 1. 3. Days taken for fruit softening

The days taken for fruit softening ranged widely from 13.50 to 17.25 days. Among the treatments, clay and coirpith at 2.5:1 ratio recorded maximum of 17.25 days for fruit softening which was closely followed by clay and coirpith at 2:1 ratio (17.00 days). On the contrary, the control exhibited a minimum of 13.50 days for fruit softening.

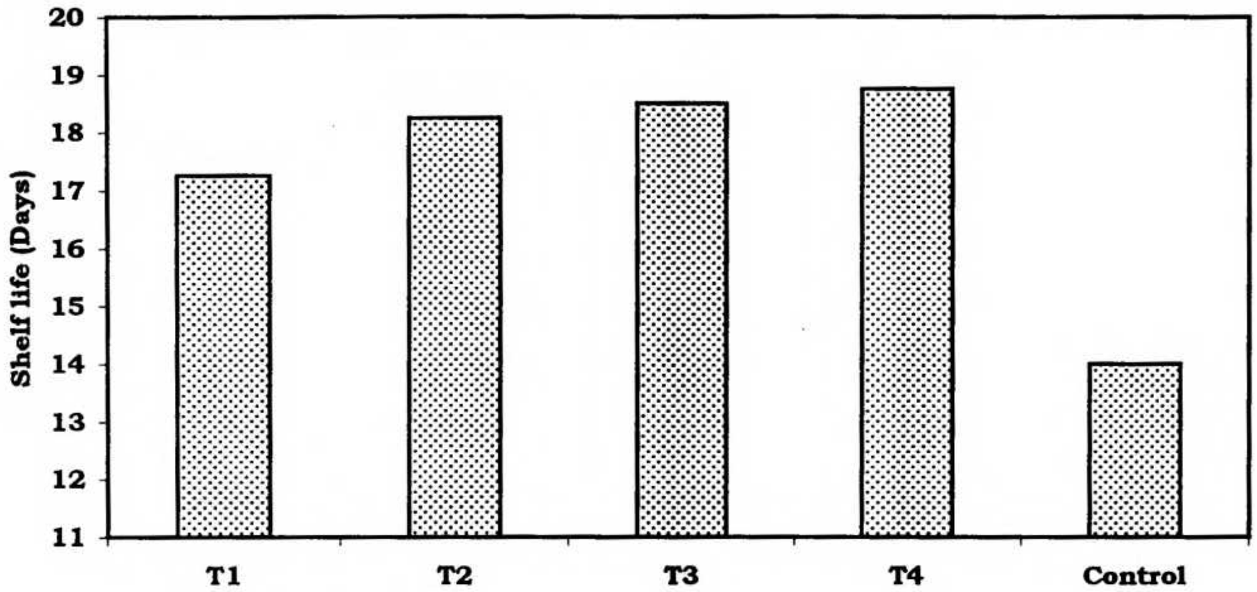
4. 1. 1. 4. Shelf life

The data on shelf life as influenced by different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber under ambient conditions are presented in Table 3 and Fig 2. The shelf life in general ranges from 14.00 to 18.75 days in different treatments. Among the treatments, the shelf life was more in clay and coirpith at 2.5:1 ratio (18.75 days). Clay and coirpith at 2:1 ratio was

Table 2. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on days taken for peel colour change, fruit softening and shelf life under ambient conditions

Treatments	Days taken for peel colour change	Days taken for fruit softening	Shelf life (Days)
Clay + Coirpith (1 : 1)	13.00	16.25	17.25
Clay + Coirpith (1.5 : 1)	13.50	16.75	18.25
Clay + Coirpith (2 : 1)	14.50	17.00	18.50
Clay + Coirpith (2.5:1)	14.75	17.25	18.75
Control	12.50	13.50	14.00
Mean	**13.65**	**16.20**	**17.70**
CD (0.05)	0.75	0.78	0.67

Fig. 2. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on shelf life under ambient conditions



T1-Clay+Coirpith (1:1)
T2-Clay+Coirpith (1.5:1)
T3-Clay+Coirpith (2:1)
T4-Clay+Coirpith (2.5:1)

the next best treatment, which recorded shelf life of 18.50 days (Plate 9). The shelf life was significantly low (14.00 days) in control. (Plate 8).

4. 1. 1. 5. Peel colour (mean index)

The peel colour of the fruit recorded in alternate days indicated that clay and coirpith at 2.5:1 ratio retained peel colour in the edible colour range (1.0 - 4.0 index) upto 20 days which is shown in Table 3. But, there were no significant differences among the other treatments and the control fruits retained peel colour range (1 - 5.5 index) within 14 days.

4. 1. 2. Biochemical characters

The biochemical characters *viz.,* Total Soluble Solids (TSS), acidity, ascorbic acid, total sugars, reducing sugars and sugar-acid ratio were analysed at edible maturity stage and the results are presented in Table 4. Significant effects due to different treatments on edible maturity were observed. The days taken for edible maturity ranged from 13 to 18 days. The clay and coirpith at 2.5:1 ratio registered a maximum of 18 days for edible maturity, followed by clay and coirpith at 1.5:1 ratio (17.75 days), as against the minimum of 13.00 days in control.

4. 1. 2. 1. Total Soluble Solids (TSS)

Total soluble solids in the fruits of different treatments exhibited deviations from 19.38 to 20.51°Brix. TSS was found to be higher in clay and coirpith at 2.5:1 ratio (20.51°Brix) which was significantly superior to all the other treatments. The fruits packed with clay and coirpith at 2:1 and 1:1 ratio

Table 3. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on peel colour (mean index) under ambient conditions

Treatments	Peel colour (mean index) on days after treatment										
	0	2	4	6	8	10	12	14	16	18	20
Clay + Coirpith (1 : 1)	1	1	1.5	2	2.25	2.75	2.75	3	4.5	5.0	-
Clay + Coirpith (1.5 : 1)	1	1	1.25	1.5	2.25	2.5	3	3.75	4	4	-
Clay + Coirpith (2 : 1)	1	1	1.25	2	2.5	3	3.25	3.75	4	4	-
Clay + Coirpith (2.5:1)	1	1	1.25	2	2.5	3	3	3.25	3.75	4	4
Control	1	1	1.5	1.75	2.75	3.5	4	5.5	-	-	-

recorded lower TSS of 19.67 and 19.83°Brix respectively as compared to control (19.38°Brix).

4. 1. 2. 2. Acidity

Acidity levels analysed in fruits of different treatments ranged between 0.29 and 0.35 per cent. Clay and coirpith at 2.5:1 ratio recorded maximum acidity of 0.35 per cent as compared to control (0.29 per cent). The other treatments recorded significantly higher acidity level than the control.

4. 1. 2. 3. Ascorbic acid

The ascorbic acid content analysed in fruits of various treatments ranged from 8.92 to 10.25 mg/100g of fresh sample. However, the ascorbic acid level was high in clay and coirpith at 2.5:1 ratio (10.25 mg/ 100g) followed by clay and coirpith at 2:1 ratio (9.98 mg/100g). The fruits packed with clay and coirpith at 1:1 and 1.5:1 ratios exhibited low levels of ascorbic acid (9.21 and 9.73 mg/100g) respectively and control recorded a very low ascorbic acid content of 8.92mg/100g.

4. 1. 2. 4. Total Sugars

The total sugars estimated in the fruits of different treatments varied significantly. The total sugars in different treatment ranges from 17.35 to 20.86 per cent. The fruits of the treatment clay and coirpith at 2.5:1 ratio registered higher sugar content (20.86 per cent) as compared to control (17.93 per cent). The clay and coirpith at 1:1 and 1.5:1 ratios recorded significantly lower values of total sugars *viz.*, 17.35 and 17.93 per cent respectively.

Table 4. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on biochemical changes under ambient conditions

Treatments	Edible maturity (days)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100 g)	Total sugars (%)	Reducing sugars (%)	Sugar-acid ratio
Clay + Coirpith (1 : 1)	17.00	19.83	0.30	9.21	17.35	14.18	57.83
Clay + Coirpith (1.5 : 1)	17.75	19.92	0.32	9.73	17.92	13.19	56.00
Clay + Coirpith (2 : 1)	17.00	19.67	0.33	9.98	19.50	15.18	59.09
Clay + Coirpith (2.5:1)	18.00	20.51	0.35	10.25	20.86	16.36	59.60
Control	13.00	19.38	0.29	8.92	17.93	12.98	61.83

4. 1. 2. 5. Reducing Sugars

The reducing sugar content ranged from 12.98 to 16.36 per cent in different treatments. The higher percentage of reducing sugar content was recorded in clay and coirpith at 2.5:1 ratio (16.36 per cent) while the fruits of clay and coirpith at 1.5:1 ratio possessed significantly low levels of reducing sugars (13.19 per cent). The control exhibited a very low level of reducing sugar content (12.98 per cent).

4. 1. 2. 6. Sugar-acid ratio

The sugar-acid ratio worked out in the ripe fruits of different treatments exhibited significant differences. The higher sugar-acid ratio (61.83) was observed in fruits of control which was significantly superior over all other treatments including fruits packed with clay and coirpith at 2.5:1 ratio (59.60).

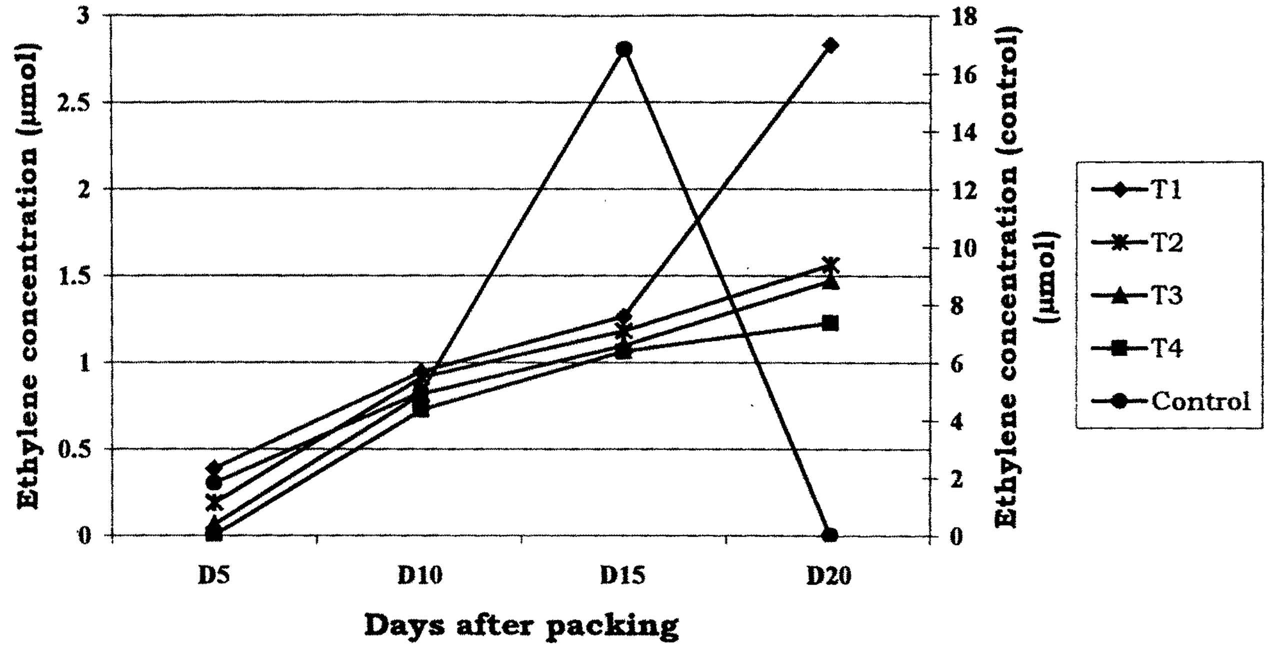
4. 1. 2. 7. Ethylene measurement

The ethylene concentration within the treatment showed an increasing trend with an increase in the storage duration upto 20 days which is tabulated in Table 5 and Fig. 3. Compared to all the treatments, the fruits packed with clay and coirpith at 2.5:1 ratio exhibited low ethylene evolution of 1.2278 μmol on twentieth day of storage. However, the control exhibited a very high concentration of ethylene (16.8271 μmol) on fifteenth day of storage itself, which is significantly higher than all treatments. It is also evident from the data that due to high ethylene concentration in control, the shelf life was very less (14.00 days) compared to others.

Table 5. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on ethylene scrubbing under ambient conditions

Treatments	Days after packing	Ethylene concentration (µmol)	Shelf life (Days)
Clay + Coirpith (1 : 1)	5	0.3862	
	10	0.9432	17.25
	15	1.2631	
	20	2.8315	
Clay + Coirpith (1.5:1)	5	0.1873	
	10	0.9126	18.25
	15	1.1813	
	20	1.5632	
Clay + Coirpith (2:1)	5	0.0631	
	10	0.8176	18.50
	15	1.0963	
	20	1.4721	
Clay + Coirpith (2.5:1)	5	Nil	
	10	0.7236	18.75
	15	1.0623	
	20	1.2278	
Control	5	1.8136	14.00
	10	4.9632	
	15	16.8271	
	20	-	

Fig. 3. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on ethylene scrubbing under ambient conditions



T1 - Clay+Coirpith (1:1)
T2 - Clay+Coirpith (1.5:1)
T3 - Clay+Coirpith (2:1)
T4 - Clay+Coirpith (2.5:1)

4. 2. Experiment II

Studies on the efficacy of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber under ambient conditions

4. 2.1. Physical characters

4. 2. 1. 1. Physiological Loss in Weight (PLW)

The effect of ethylene scrubber at different levels of clay and coirpith with alkaline $KMnO_4$ on PLW of banana cv. Robusta under ambient conditions is significant and presented in Table 6 and Fig. 4. The PLW ranged widely from 3.46 to 10.93 per cent in clay and coirpith at 2.5:1 and 1:1 ratio. Among the treatments, PLW was higher in clay and coirpith at 1:1 ratio (10.93 per cent) followed by clay and coirpith at 1.5:1 ratio (10.36 per cent) and 2:1 ratio (10.13 per cent) and the lower PLW was recorded in clay and coirpith at 2.5:1 ratio (7.89 per cent) on eighteenth day of storage. The control recorded higher PLW (9.83 per cent) on fourteenth day of storage compared to all treatments. Among all the treatments, clay and coirpith at 2.5:1 ratio recorded slower rate of loss in weight till eighteenth day of storage.

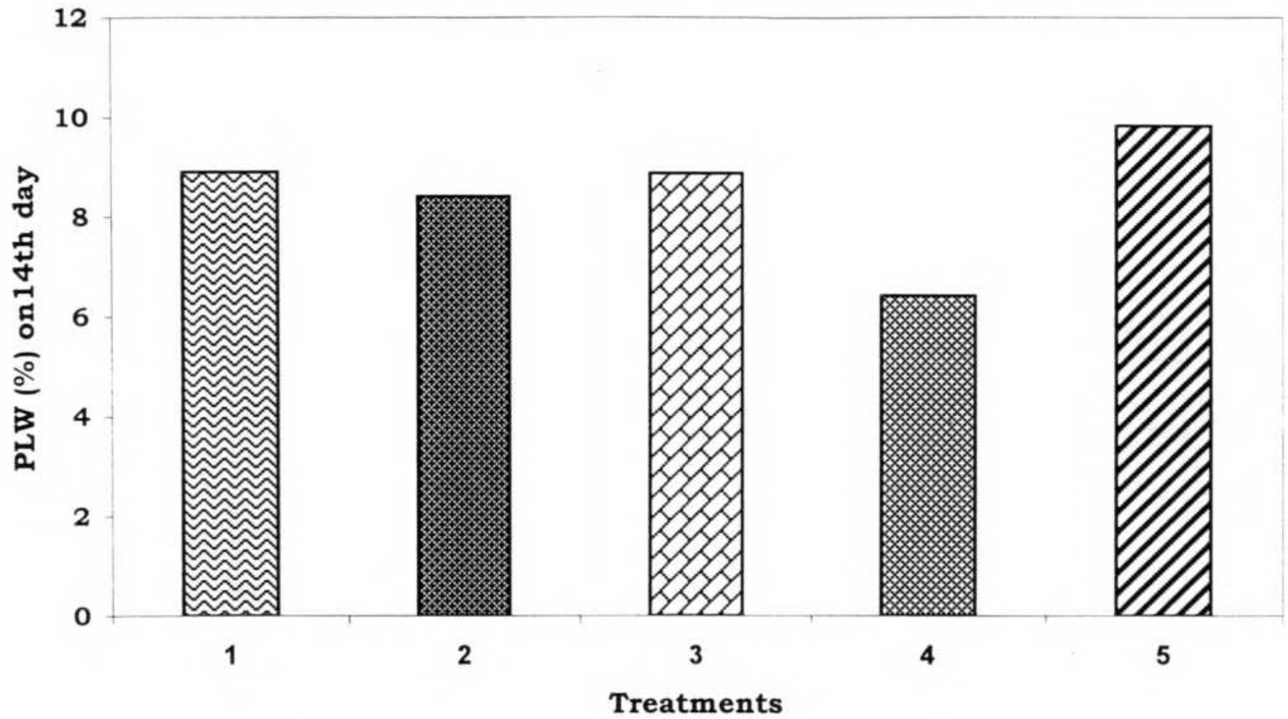
4. 2. 1. 2. Days taken for peel colour change

The data on days taken for peel colour change and for fruit softening influenced by different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber is presented in Table 7. The different treatments exhibited a significant variation and it ranged from 14.50 to 18.75 days for peel colour change. Maximum of 18.75 days was recorded in clay and coirpith at 2.5:1 ratio

Table 6. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on PLW (%) under ambient conditions

Treatments	Duration of storage (Days)								
	2	4	6	8	10	12	14	16	18
Clay + Coirpith (1 : 1)	3.50	4.26	5.03	6.79	6.67	7.25	8.91	9.79	10.93
Clay + Coirpith (1.5 : 1)	4.31	4.40	4.68	5.66	6.58	7.62	8.41	9.52	10.36
Clay + Coirpith (2 : 1)	3.90	5.07	5.82	6.16	8.11	8.67	8.88	9.47	10.13
Clay + Coirpith (2.5:1)	3.46	4.92	3.69	4.09	4.97	5.36	6.43	7.11	7.89
Control	4.81	5.07	6.10	6.65	7.91	8.95	9.83	-	-
Mean	**4.00**	**4.74**	**5.06**	**5.87**	**6.85**	**7.57**	**8.49**	**8.97**	**9.83**
CD (0.05)	NS	NS	NS	NS	1.47	1.43	1.33	1.35	1.44

Fig. 4. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on PLW (%) under ambient conditions



1-Clay+Coirpith (1:1)   3-Clay+Coirpith (2:1)   5. Control
2-Clay+Coirpith (1.5:1)   4-Clay+Coirpith (2.5:1)

followed by clay and coirpith at 2:1 ratio (17.75 days). The control recorded a minimum of 14.50 days for peel colour change.

4. 2. 1. 3. Days taken for fruit softening

In respect of days taken for fruit softening, significant differences were noticed between the treatments. Clay and coirpith at 2.5:1 ratio registered a maximum of 19.50 days closely followed by clay and coirpith at 2:1 ratio (18.50 days) while it was minimum in control (14.75 days).

4. 2. 1. 4. Shelf life

The data on shelf life as influenced by different ratios of clay and coirpith with alkaline $KMnO_4$ is presented in Table 7 and Fig. 5. The shelf life of different treatments ranged from 14.00 days to 19.00 days. The shelf life was found to be longer in clay and coirpith at 2.5:1 ratio (19.75 days) as against the control (14.00 days) (Plate 10).

4. 2. 1. 5. Peel colour (mean index)

The peel colour of the fruits recorded on alternate days indicated that fruits packed with clay and coirpith at 2.5:1 ratio retained peel colour range (1.0 - 4.0 index) closely followed by clay and coirpith at 2:1 ratio upto 20 days. On the contrary, the control fruits retained peel colour ranges (1.0 - 6.0 index) within 14 days of storage (Table 8).

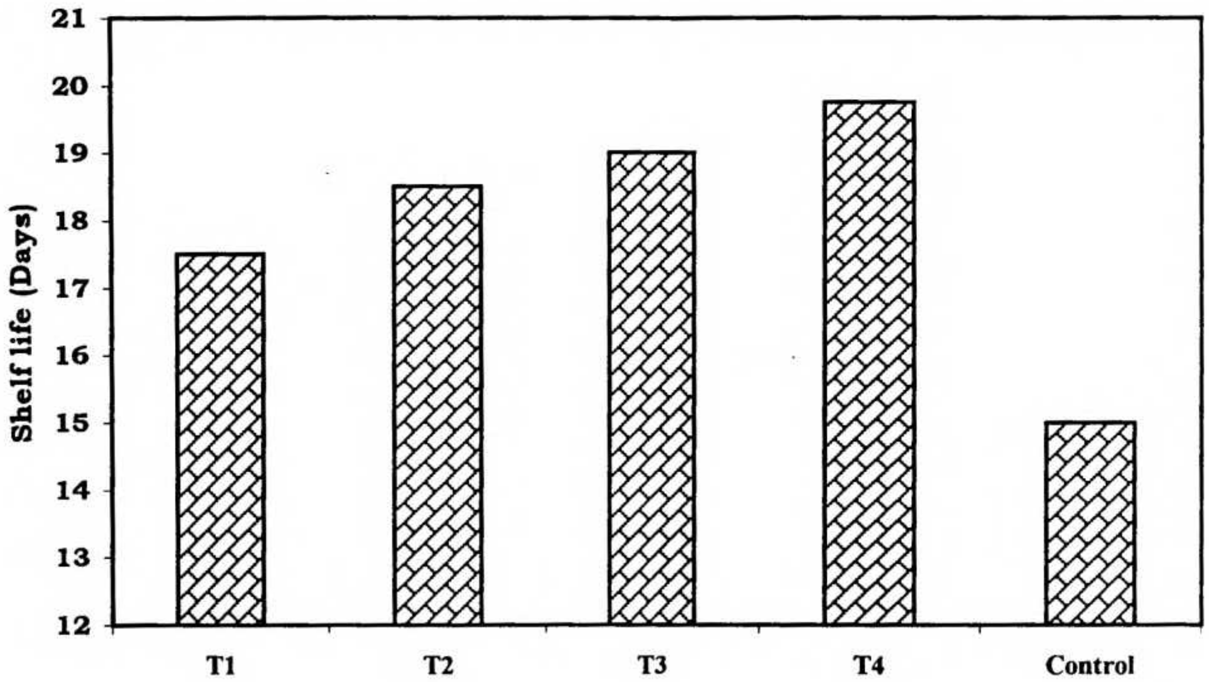
4. 2. 2. Biochemical characters

The biochemical characters viz., Total Soluble Solids, acidity, ascorbic acid, total sugars, reducing sugars and sugar-acid ratio were analysed at edible

Table 7. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on days taken for peel colour change, fruit softening and shelf life under ambient conditions

Treatments	Days taken for peel colour change	Days taken for fruit softening	Shelf life (Days)
Clay+ Coirpith (1 : 1)	14.75	16.25	17.50
Clay + Coirpith (1.5 : 1)	17.50	18.00	18.50
Clay + Coirpith (2 : 1)	17.75	18.50	19.00
Clay + Coirpith (2.5:1)	18.75	19.50	19.75
Control	14.50	14.75	14.00
Mean	**16.65**	**17.40**	**17.95**
CD (0.05)	1.92	1.20	1.31

Fig. 5. Effect of differernt ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on shelf life under ambient conditions



T1 - Clay+Coirpith (1:1) T3 - Clay+Coirpith (2:1)
T2 - Clay+Coirpith (1.5:1) T4 - Clay+Coirpith (2.5:1)

maturity stage and the results are presented in Table 9. The days taken for edible maturity in general ranged from 13.25 to 19.75 days. The fruits packed with clay and coirpith at 2.5:1 ratio registered a maximum of 19.75 days for reaching edible maturity followed by clay and coirpith at 2:1 ratio (19.00 days) whereas the control reached the edible maturity stage earlier (13.25 days).

4. 2. 2. 1. Total Soluble Solids

Total Soluble Solids in the fruits of different treatments exhibited deviations from 19.80 to 22.81°Brix. It was higher in fruits with clay and coirpith at 2.5:1 ratio (22.81°Brix) which was significantly superior to all other treatments. The fruits of the treatments, clay and coirpith at 1:1 and 1.5:1 ratio recorded lower TSS of 19.80 and 19.91°Brix respectively as compared to control (19.93°Brix).

4. 2. 2. 2. Acidity

Acidity levels analysed in fruits ranged narrowly from 0.37 per cent in fruits packed with clay and coirpith at 2.5:1 ratio to 0.33 per cent in clay and coirpith at 1:1 ratio. Higher acidity levels was recorded in T4 treatment (0.37 per cent) and control recorded lower acidity level (0.30 per cent).

4. 2. 2. 3. Ascorbic acid

Ascorbic acid content was higher in fruits packed with clay and coirpith at 2.5:1 ratio (10.46 mg/100 g) followed by the control (10.21 mg/100g). The fruits of the treatments, clay and coirpith at 1.5:1 and 1:1 ratios recorded low level of ascorbic acid content (8.76 and 9.18 mg/100g) respectively.

Table 8. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on peel colour (mean index) under ambient conditions

Treatments	Peel colour (mean index) on days after treatment										
	0	2	4	6	8	10	12	14	16	18	20
Clay + Coirpith (1 : 1)	1	1	1	1.5	1.75	2	2.75	3	3.5	4.5	-
Clay + Coirpith (1.5 : 1)	1	1	1.25	1.5	2	2.5	2.75	3.75	4	4	-
Clay + Coirpith (2 : 1)	1	1	1.5	2	2.25	2.5	2.5	2.75	3	3.5	4
Clay + Coirpith (2.5:1)	1	1	1.5	1.75	2	2.75	3	3.5	3.75	4	4
Control	1	1	1.5	1.75	2	3.5	3.75	6	-	-	-

4. 2. 2. 4. Total Sugars

The total sugars estimated in different treatments varied significantly. The fruits of the treatment clay and coirpith at 2.5:1 ratio registered higher sugar content (19.83 per cent) as compared to control 16.93 per cent. The treatments, clay and coirpith at 1:1 and 2:1 ratios recorded significantly lower values of total sugars *viz.*, 17.31 and 17.38 per cent respectively.

4. 2. 2. 5. Reducing Sugars

The reducing sugar content estimated in the ripe fruits varied significantly. The higher reducing sugar content was recorded in fruits packed with clay and coirpith at 2.5:1 ratio (16.72 per cent), while the fruits of the treatment clay and coirpith at 1.5:1 ratio possessed significantly low level of reducing sugars (14.63 per cent) compared to control (15.43 per cent).

4. 2. 2. 6. Sugar-acid ratio

The higher sugar acid ratio (56.43) was recorded in fruits of control which was significantly superior over other treatments and fruits packed with clay and coirpith at 2.5:1 ratio recorded maximum of 53.59.

4. 2. 2. 7. Ethylene measurement

The ethylene concentration within the treatments showed an increasing trend with an increase in the storage duration upto 20 days (Table 10 and Fig. 6). Clay and coirpith at 2.5:1 ratio showed no ethylene evolution till fifth days after packing. Compared to all the treatments, the clay and coirpith at 2.5:1 ratio

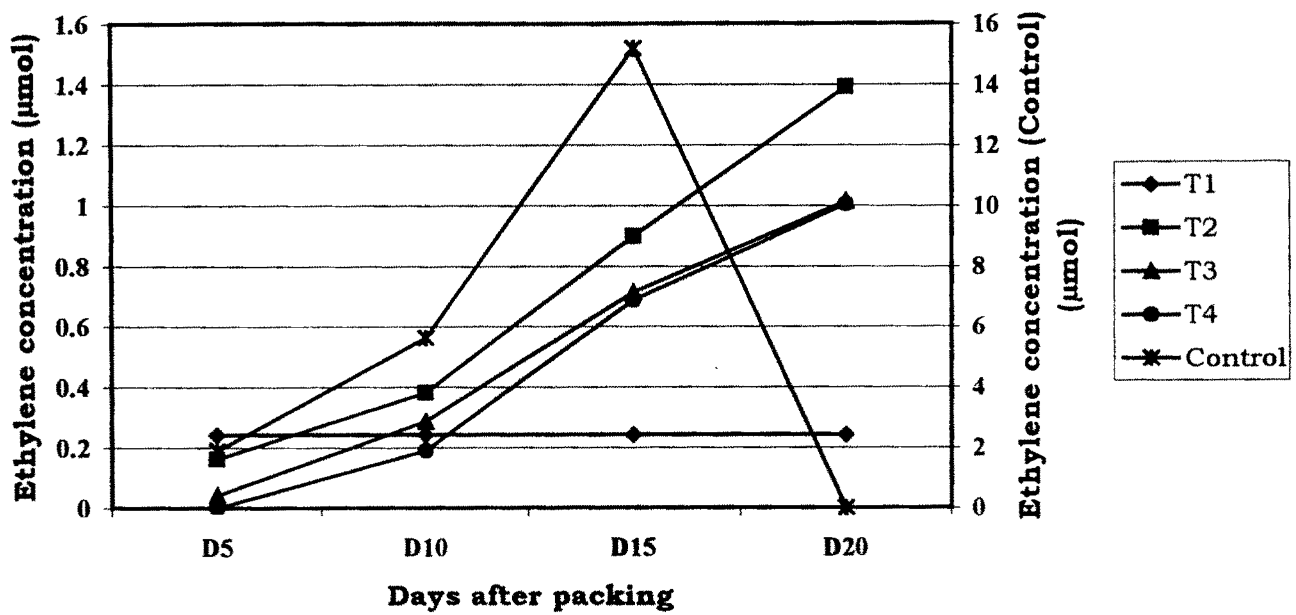
Table 9. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on biochemical changes under ambient conditions

Treatments	Edible maturity (days)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100 g)	Total sugars (%)	Reducing sugars (%)	Sugar-acid ratio
Clay + coirpith (1 : 1)	17.00	19.80	0.33	9.18	17.31	15.16	52.45
Clay + Coirpith (1.5 : 1)	18.00	19.91	0.34	8.76	18.15	14.63	53.38
Clay + Coirpith (2 : 1)	19.00	20.18	0.35	9.46	17.38	16.13	49.66
Clay + Coirpith (2.5:1)	19.75	22.81	0.37	10.46	19.83	16.72	53.59
Control	13.25	19.93	0.30	10.21	16.93	15.43	56.43

Table 10. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on ethylene scrubbing under ambient conditions

Treatments	Days after packing	Ethylene concentration (μmol)	Shelf life (Days)
Clay + Coirpith (1: 1)	5	0.2432	
	10	0.5612	17.50
	15	0.9813	
	20	1.8673	
Clay + Coirpith (1.5:1)	5	0.1632	
	10	0.3816	18.50
	15	0.8973	
	20	1.3918	
Clay + Coirpith (2:1)	5	0.0412	
	10	0.2863	19.00
	15	0.7132	
	20	1.0132	
Clay + Coirpith (2.5:1)	5	Nil	
	10	0.1893	19.75
	15	0.6872	
	20	1.0026	
Control	5	1.8976	14.00
	10	5.6321	
	15	15.1876	
	20	-	

Fig. 6. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on ethylene scrubbing under ambient conditions



T1 - Clay+Coirpith (1:1) T3 - Clay+Coirpith (2:1)
T2 - Clay+Coirpith (1.5:1) T4 - Clay+Coirpith (2.5:1)

exhibited low ethylene evolution of 1.0026 μmol on twentieth day of storage. However, the control exhibited a very high ethylene evolution of 15.1876 μmol on fifteenth day of storage itself, which is significantly higher than all treatments. It is also observed that due to high ethylene concentration in control, the shelf life was very less (14.00 days) compared to others.

4. 3. Experiment III

Studies on the efficacy of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber under cool conditions (13°C)

4. 3. 1. Physical characters

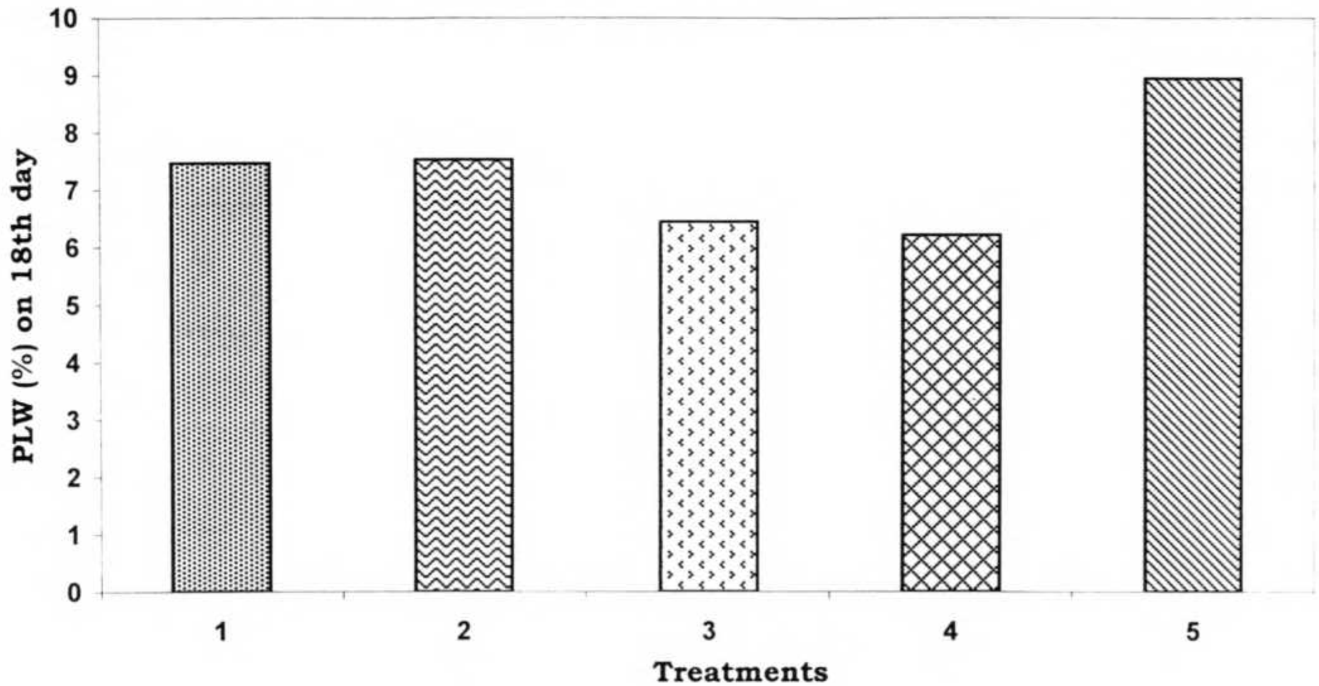
4. 3. 1. 1. Physiological loss in weight (PLW)

The effect of ethylene scrubber at different levels of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on PLW under cool conditions (13°C) is significant and presented in Table 11 and Fig. 7. The PLW ranged widely from 2.75 to 11.96 per cent in clay and coirpith at ratios of 2.5:1 and 1:1. The mean PLW advanced with increase in storage life from 4.05 to 10.60 per cent. Among the treatments, PLW was higher in 11.96 per cent in clay and coirpith at 1:1 ratio followed by 1.5:1 ratio (11.37 per cent) and 2:1 ratio (10.16 per cent) and PLW was found to be lower in clay and coirpith at 2.5:1 ratio (8.90 per cent) on twentieth day of storage. The control recorded higher PLW (10.71 per cent) on eighteenth day of storage compared to all treatments. Among all treatments, the clay and coirpith at 2.5:1 ratio showed slower rate of loss in weight till twentieth day of storage.

Table 11. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on PLW (%) under cool conditions (13°C)

Treatments	Duration of storage (Days)									
	2	4	6	8	10	12	14	16	18	20
Clay + Coirpith (1:1)	4.19	4.67	5.16	6.11	6.75	7.13	8.78	10.32	11.38	11.96
Clay + Coirpith (1.5:1)	4.50	4.83	5.76	6.38	7.40	9.21	9.59	10.43	11.08	11.37
Clay + Coirpith (2:1)	4.10	4.66	5.16	6.24	7.00	7.81	8.52	9.42	9.90	10.16
Clay + Coirpith (2.5:1)	2.75	3.59	3.79	4.67	5.14	6.04	6.74	7.19	8.21	8.90
Control	4.73	5.84	6.14	6.75	7.44	8.07	8.73	9.55	10.71	-
Mean	**4.05**	**4.72**	**5.20**	**6.03**	**6.75**	**7.65**	**8.47**	**9.38**	**10.26**	**10.60**
CD (0.05)	0.62	0.92	0.96	1.05	1.40	1.14	1.30	1.06	1.36	1.07

Fig. 7. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on PLW (%) under cool conditions (13° C)



1 - Clay+Coirpith (1:1) 3 - Clay+Coirpith (2:1) 5. Control
2 - Clay+Coirpith (1.5:1) 4 - Clay+Coirpith (2.5:1)

4. 3. 1. 2. Days taken for peel colour change

The data on days taken for peel colour change and fruit softening as influenced by different ratios of clay and coirpith with saturated $KMnO_4$ under cool conditions (13°C) is presented in Table 12. The number of days taken for peel colour change ranged significantly from 17.25 to 22.25 in different treatments. Earliest change in peel colour was observed in control (17.25 days) followed by clay and coirpith at 1:12 ratio (18.00 days). Delayed change in peel colour was observed in clay and coirpith at 2.5:1 ratio (22.25 days).

4. 3. 1. 3. Days taken for fruit softening

The number of days taken for fruit softening ranged significantly from 18.00 days in control to 26.00 days in clay and coirpith at 2.5:1 ratio followed by clay and coirpith at 2:1 ratio (22.00 days).

4. 3. 1. 4. Shelf life

The data on shelf life as influenced by different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber under cool conditions is presented in Table 12 and Fig. 8. The shelf life in general ranged from 18.00 days to 29.50 days. The shelf life was more in clay and coirpith at 2.5:1 ratio (29.50 days) closely followed by clay and coirpith at 2:1 ratio treatment (26.50 days) while it was low in control (18.00 days) (Plate 11).

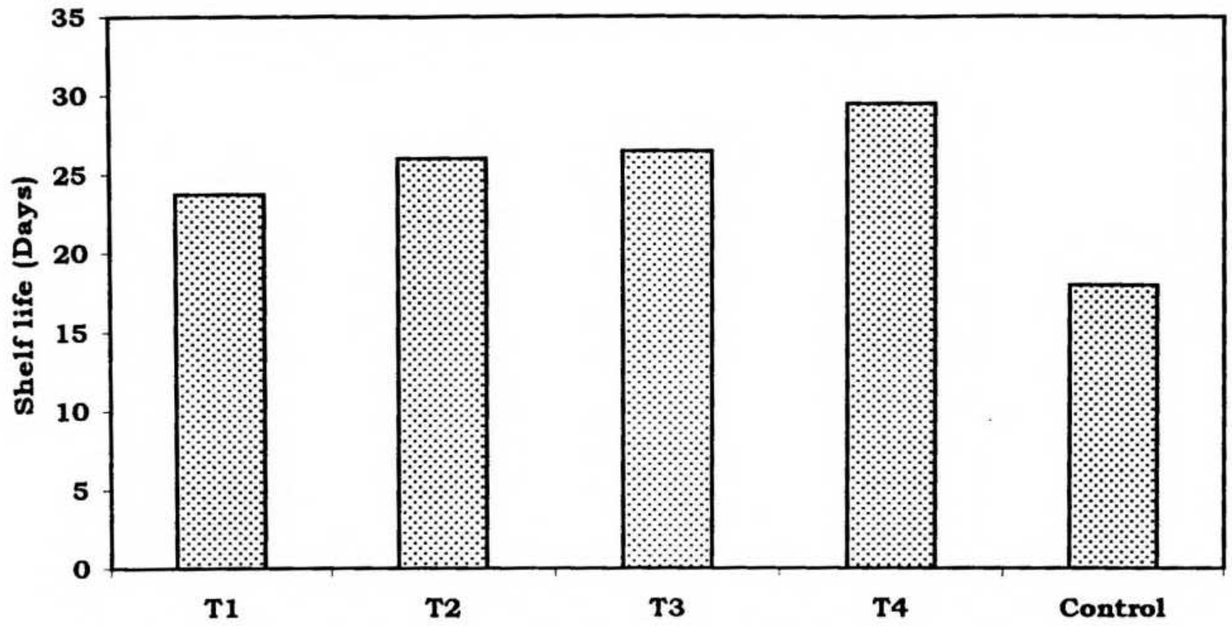
4. 3. 1. 5. Peel colour (mean index)

The peel colour of the fruits was recorded on alternate days and it indicated that fruits packed with clay and coirpith at 2.5:1 ratio retained peel

Table 12. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on days taken for peel colour change, fruit softening and shelf life under cool conditions (13°C)

Treatments	Days taken for peel colour change	Days taken for fruit softening	Shelf life (Days)
Clay + Coirpith (1 : 1)	18.25	19.00	23.75
Clay + Coirpith (1.5 : 1)	18.00	19.75	26.00
Clay + Coirpith (2 : 1)	19.75	22.00	26.50
Clay + Coirpith (2.5:1)	22.25	26.00	29.50
Control	17.25	18.00	18.00
Mean	**18.80**	**20.95**	**24.75**
CD (0.05)	1.83	0.34	1.28

Fig. 8. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on shelf life under cool conditions (13°C)



T1 - Clay+Coirpith (1:1)   T3 - Clay+Coirpith (2:1)
T2 - Clay+Coirpith (1.5:1)   T4 - Clay+Coirpith (2.5:1)

colour range (1.00 - 4.00 index) upto 20 days closely followed by clay and coirpith at 1:1 ratio. The control fruits retained peel colour (1.00 - 6.00 index) upto 20 days (Table 13).

4. 3. 2. Biochemical characters

The biochemical characters *viz.*, Total Soluble Solids, acidity, ascorbic acid, total sugars, reducing sugars and sugar-acid ratio were analysed at edible maturity and the results are presented in Table 14. Significant differences were observed for days to edible maturity among the different treatments. The days taken for edible maturity varied from 23.00 days in clay and coirpith at 1:1 ratio treatment to 27.63 days in clay and coirpith at 2.5:1 ratio. Thus, the control fruits came to edible maturity earlier (22.38 days) when compared to all the other treatments.

4. 3. 2. 1. Total Soluble Solids

Total soluble solids in the fruits of different treatments exhibited deviation from 19.99 to 23.61°Brix. It was higher (23.61°Brix) in fruits of clay and coirpith at 2.5:1 ratio treatment which was significantly superior to all the other treatments. The fruits of the treatments, clay and coirpith at 1.5:1 and 1:1 ratio recorded lower TSS of 19.99 and 20.13°Brix respectively as compared to control (21.32°Brix).

4. 3. 2. 2. Acidity

Acidity levels analysed in the fruits ranged very narrowly from 0.28 per cent in control to 0.36 per cent in clay and coirpith at 2.5:1 ratio.

Table 13. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on peel colour (mean index) under cool conditions (13°C)

Treatments	Peel colour (mean index) on days after treatment										
	0	2	4	6	8	10	12	14	16	18	20
Clay + Coirpith (1:1)	1	1	1	1	1	1	1.5	1.75	3	3.5	4.0
Clay + Coirpith (1.5:1)	1	1	1	1	1	1	1	1.75	3.5	4	5.0
Clay + Coirpith (2:1)	1	1	1	1	1	1	1	1.5	3	4	5.5
Clay + Coirpith (2.5:1)	1	1	1	1	1	1	1	1.75	2	2.75	3.0
Control	1	1	1	1	1	1	1.5	1.75	3	3.75	6.0

Table 14. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on biochemical changes under cool conditions (13°C)

Treatments	Edible maturity (days)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100 g)	Total sugars (%)	Reducing sugars (%)	Sugar-acid ratio
Clay + Coirpith (1:1)	23.00	20.13	0.32	10.16	19.73	15.23	61.65
Clay + Coirpith (1.5:1)	24.50	19.99	0.33	9.08	20.16	15.82	61.09
Clay + Coirpith (2:1)	23.41	22.38	0.35	8.37	20.83	14.38	59.51
Clay + Coirpith (2.5:1)	27.63	23.61	0.36	10.56	21.32	16.17	59.22
Control	22.38	21.32	0.28	9.62	19.76	15.62	70.57

4. 3. 2. 3. Ascorbic acid

The ascorbic acid level of the treated fruits ranged between 8.37 mg/100 g to 10.56 mg/100g. The ascorbic acid level was high in clay and coirpith at 2.5:1 ratio treatment (10.56 mg/100g) followed by clay and coirpith at 1:1 ratio treatment (10.16 mg/100g). The fruits of treatments, clay and coirpith at 2:1 and 1.5:1 ratios exhibited low levels of ascorbic acid *viz.*, 8.37 and 9.08 mg/100g respectively than the control (9.62 mg/100g).

4. 3. 2. 4. Total Sugars

The total sugars estimated in the fruits of different treatments varied significantly. The fruits of treatment, clay and coirpith at 2.5:1 ratio registered higher sugar content (21.32 per cent) as compared to control (19.76 per cent). The treatments, clay and coirpith at 1:1 and 1.5:1 ratios recorded significantly lower level of sugar content *viz.*, 19.73 and 20.16 per cent respectively.

4. 3. 2. 5. Reducing Sugars

The higher percentage of reducing sugar content was recorded in clay and coirpith at 2.5:1 ratio (16.17 per cent) while the fruits of clay and coirpith at 2:1 ratio recorded significantly lower levels of reducing sugars (14.38 per cent) than the control (15.62 per cent).

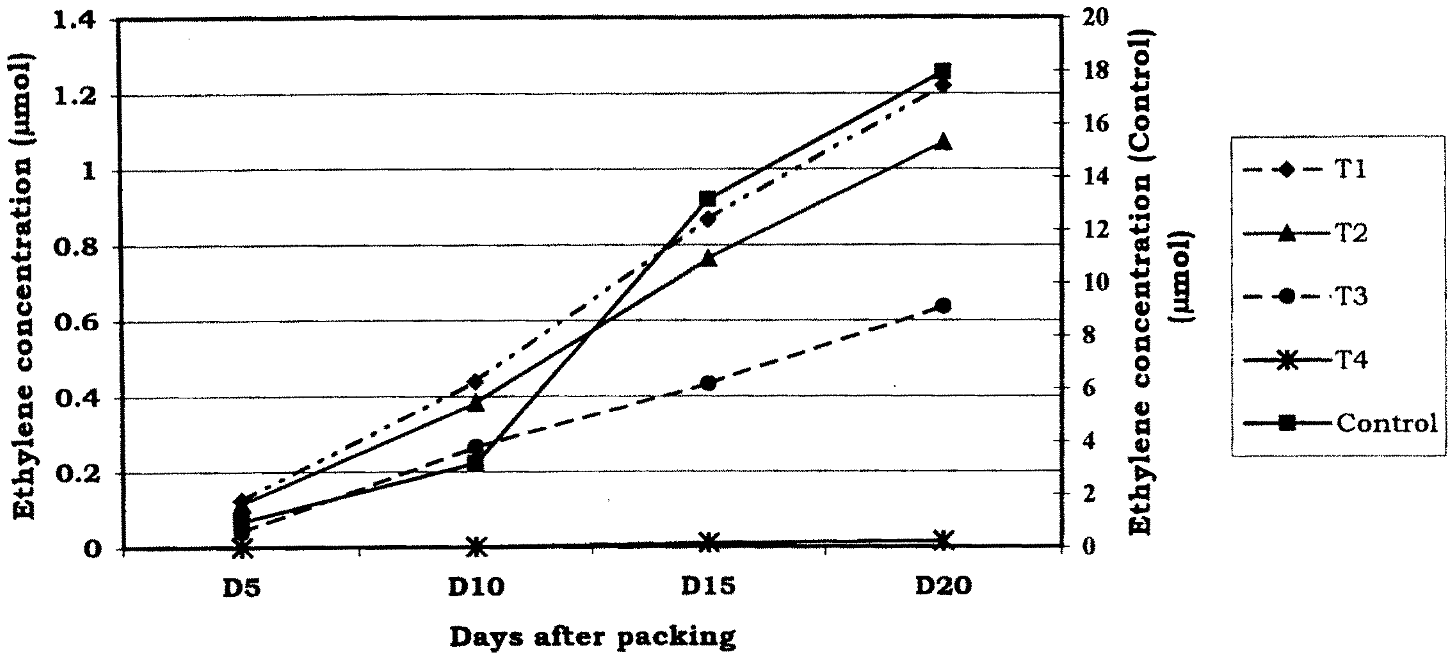
4. 3. 2. 6. Sugar-acid ratio

Among the treatments, the higher sugar-acid ratio was observed in control (70.57) and lower sugar-acid ratio was observed in fruits packed with clay and coirpith at 2.5:1 ratio (59.22).

Table 15. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on ethylene scrubbing under cool conditions (13°C)

Treatments	Days after packing	Ethylene concentration (µmol)	Shelf life (Days)
Clay + Coirpith (1:1)	5	0.1256	23.75
	10	0.4387	
	15	0.8672	
	20	1.6632	
Clay + Coirpith (1.5:1)	5	0.1133	26.00
	10	0.3806	
	15	0.7632	
	20	1.2314	
Clay + Coirpith (2:1)	5	0.0410	26.50
	10	0.2653	
	15	0.4316	
	20	1.0012	
Clay + Coirpith (2.5:1)	5	Nil	29.50
	10	Nil	
	15	0.1566	
	20	0.9387	
Control	5	0.9631	18.00
	10	3.1926	
	15	13.1218	
	20	18.1899	

Fig. 9. Effect of different ratios of clay and coirpith with saturated $KMnO_4$ as ethylene scrubber on ethylene scrubbing under cool conditions (13°C)



T1 - Clay+Coirpith (1:1)   T3 - Clay+Coirpith (2:1)
T2 - Clay+Coirpith (1.5:1)   T4 - Clay+Coirpith (2.5:1)

4. 3. 2. 7. Ethylene measurement

The ethylene concentration within the treatments showed an increasing trend with an increase in the storage duration upto 20 days which is presented in Table 15 and Fig. 9. Clay and coirpith at 2.5:1 ratio showed no ethylene evolution till tenth day of storage. Among the treatments, clay and coirpith at 2.5:1 ratio exhibited low ethylene concentration of 0.9387 μmol on twentieth day of storage. The control recorded very high ethylene concentration of 18.1899 μmol, which is significantly higher than all treatments. It is also observed that due to high ethylene concentration in control, the shelf life was comparatively less (18.00 days).

4.4. Experiment IV

Studies on the efficacy of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber under cool conditions (13°C)

4.4.1. Physical characters

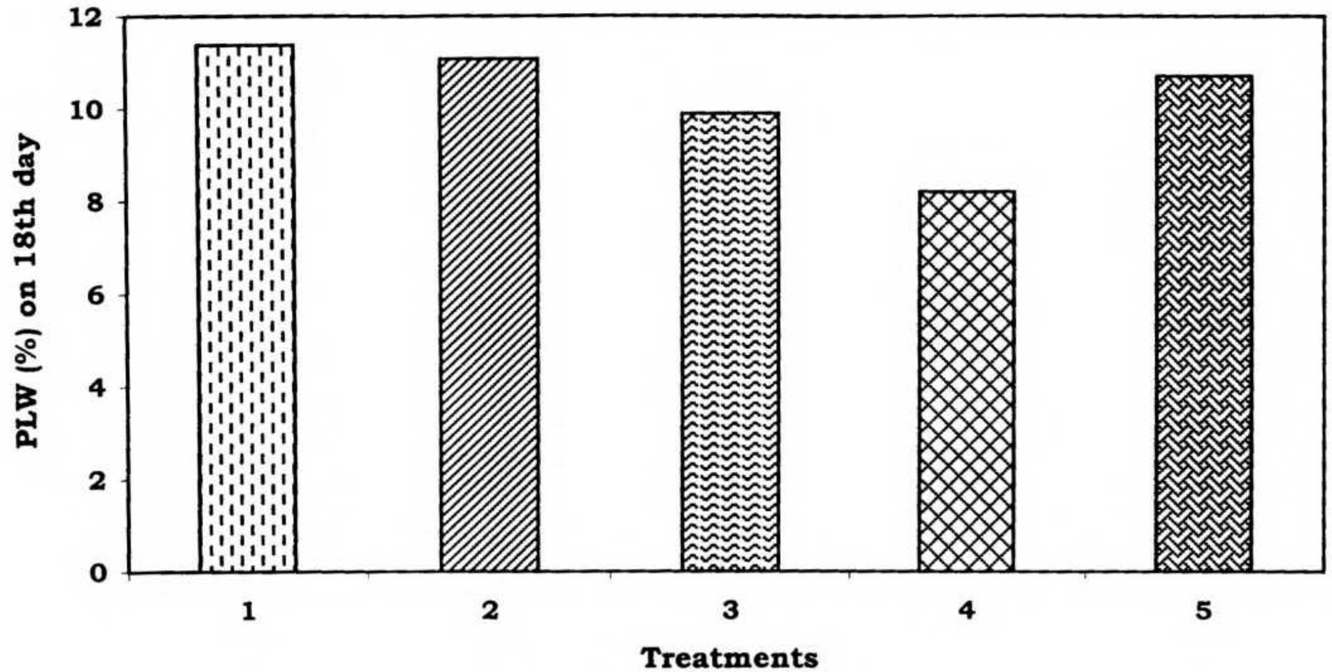
4. 4.1.1. Physiological loss in weight (PLW)

The effect of ethylene scrubber at different levels of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on PLW under cool conditions is found to be significant and presented in Table 16 and Fig. 10. The PLW ranged widely from 2.24 per cent in clay and coirpith at 1.5:1 ratio to 8.95 per cent in control. The mean PLW advanced with increase in storage life from 2.78 to 7.25 per cent. Among the treatments, the PLW was higher in clay and coirpith at 1:1 ratio (7.876 per cent) followed by clay and coirpith at 1.5:1 ratio (7.68 per cent) and

Table 16. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber PLW (%) under cool conditions (13°C)

Treatments	Duration of storage (Days)									
	2	4	6	8	10	12	14	16	18	20
Clay + Coirpith (1 : 1)	2.48	3.41	3.62	4.24	4.66	5.44	5.96	6.38	7.47	7.86
Clay + Coirpith (1.5 : 1)	2.24	3.53	4.63	5.19	5.59	6.43	7.15	7.49	7.53	7.68
Clay + Coirpith (2 : 1)	2.64	3.50	3.69	4.24	4.68	5.12	5.59	6.14	6.45	6.82
Clay + Coirpith (2.5:1)	2.33	3.48	3.60	4.05	4.42	4.53	5.00	5.68	6.22	6.64
Control	4.22	4.58	5.30	5.82	6.34	6.93	7.43	8.01	8.95	-
Mean	**2.78**	**3.70**	**4.17**	**4.71**	**5.14**	**5.69**	**6.23**	**6.74**	**7.32**	**7.25**
CD (0.05)	0.50	0.64	0.57	0.82	0.73	0.61	0.62	1.14	0.81	0.91

Fig. 10. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on PLW (%) under cool conditions (13°C)



1-Clay+Coirpith (1:1)
2-Clay+Coirpith (1.5:1)
3-Clay+Coirpith (2:1)
4-Clay+Coirpith (2.5:1)
5. Control

clay and coirpith at 2:1 ratio (6.82 per cent). The PLW was found to be lower in fruits packed with clay and coirpith at 2.5:1 ratio (6.64 per cent) on twentieth day of storage. The control recorded significantly higher PLW (8.95 per cent) on eighteenth day of storage compared to other treatments. Among the treatments, clay and coirpith at 2.5:1 ratio showed slower rate of loss in weight till twentieth day of storage.

4. 4. 1. 2. Days taken for peel colour change

The data on days taken for peel colour change and fruit softening as influenced by different ratios of clay and coirpith with alkaline $KMnO_4$ under cool conditions are presented in Table 17. Among the treatments, a maximum of 25.00 days was recorded for the peel colour change in clay and coirpith at 2.5:1 ratio treatment followed by clay and coirpith at 2:1 ratio treatment (20.75 days). The control took a minimum of 15.75 days for the peel colour change.

4. 4. 1. 3. Days taken for fruit softening

In respect of days taken for fruit softening, significant differences were noticed among the treatments. Fruits packed with clay and coirpith at 2.5:1 ratio registered a maximum of 25.75 days closely followed by clay and coirpith at 2:1 ratio treatment (22.75 days) while it was minimum (17.25 days) in the control.

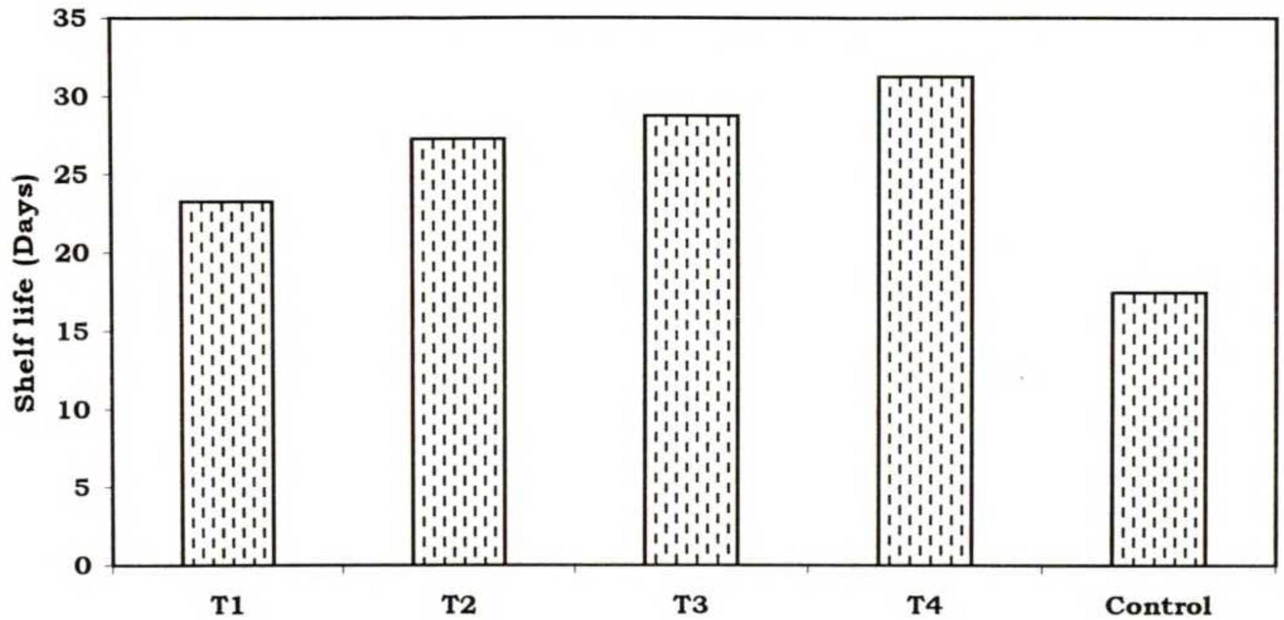
4. 4. 1. 4. Shelf life

The data on shelf life as influenced by different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber under cool conditions (13°C) is presented in Table 17 and Fig. 11. The shelf life in general ranged from 17.50

Table 17. Effect of different ratios of clay and coirpith with alkaline KMnO4 as ethylene scrubber on days taken for peel colour change, fruit softening and shelf life under cool conditions (13°C)

Treatments	Days taken for peel colour change	Days taken for fruit softening	Shelf life (Days)
Clay + Coirpith (1:1)	17.75	18.75	23.25
Clay + Coirpith (1.5:1)	19.00	19.75	27.25
Clay + Coirpith (2:1)	20.75	22.75	28.75
Clay + Coirpith (2.5:1)	25.00	25.75	31.25
Control	15.75	17.25	17.50
Mean	**19.65**	**20.85**	**25.60**
CD (0.05)	0.58	0.93	1.46

Fig. 11. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on shelf life under cool conditions (13°C)



T1 - Clay+Coirpith (1:1)
T2 - Clay+Coirpith (1.5:1)
T3 - Clay+Coirpith (2:1)
T4 - Clay+Coirpith (2.5:1)

days to 31.25 days. The treatments differ significantly and shelf life was more in clay and coirpith at 2.5:1 ratio treatment (31.25 days) followed by clay and coirpith at 2:1 ratio treatment (28.75 days). The shelf life was low in control (17.50 days) (Plate 12).

4. 4. 1. 5. Peel colour (mean index)

The peel colour of the fruits recorded on alternate days indicated that the treatment clay and coirpith at 2.5:1 ratio retained peel colour range (1.00 - 3.00 index) upto 20 days which was closely followed by clay and coirpith at 2:1 ratio (1.00 – 3.00 index). On the contrary, the control fruits retained peel colour range (1.00 – 6.00 index) upto 20 days (Table 18).

4. 4. 2. Biochemical characters

The biochemical characters *viz.*, Total Soluble Solids, acidity, ascorbic acid, total sugars, reducing sugars and sugar-acid ratio were analysed at edible maturity stage and results are presented in Table 19. Significant effects due to different treatments on edible maturity were observed. The days taken for edible maturity in general ranged from 22.25 to 29.38 days. Clay and coirpith at 2.5:1 ratio treatment registered a maximum number of 29.38 days for reaching edible maturity stage followed by clay and coirpith at 2:1 ratio (26.16 days) as against a minimum of 22.63 days in control.

4. 4. 2. 1. Total Soluble Solids

Total soluble solids in the fruits of different treatments exhibited deviations from 19.32 to 23.89°Brix. It was higher in fruits of clay and coirpith at

Table 18. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on peel colour (mean index) under cool conditions (13°C)

Treatments	Peel colour (mean index) on days after treatment										
	0	2	4	6	8	10	12	14	16	18	20
Clay + Coirpith (1:1)	1	1	1	1	1.5	1.5	1.75	2	2	3	4.2
Clay + Coirpith (1.5:1)	1	1	1	1	1	1	1.5	2	2	2	4.5
Clay + Coirpith (2:1)	1	1	1	1	1	1.5	1.75	2	2.5	2.75	3.0
Clay + Coirpith (2.5:1)	1	1	1	1	1	1.5	1.5	1.75	2	2.5	3.0
Control	1	1	1	1	1.5	1.5	1.5	2	3	3.5	6.0

2.5:1 ratio treatment (23.89°Brix) which was significantly superior to all other treatments. The fruits of the treatment clay and coirpith at 1.5:1 and 1:1 ratios recorded lower TSS of 19.32 and 21.38°Brix respectively as compared to control (21.86 °Brix).

4. 4. 2. 2. Acidity

Acidity levels analysed in the fruits ranged very narrowly from 0.28 per cent in control to 0.37 per cent in clay and coirpith at 2.5:1 ratio.

4. 4. 2. 3. Ascorbic acid

The ascorbic acid level of the treated fruits ranged between 9.61 mg/100g and 10.62 mg/100g. However, the ascorbic acid level was high in clay and coirpith at 2.5:1 ratio treatment (10.62 mg/100g) followed by clay and coirpith at 1:1 ratio treatment (10.13 mg/100g). The fruits of treatments clay and coirpith at 2:1 and 1.5:1 ratios exhibited low levels of ascorbic acid *viz.*, 9.86 and 10.11 mg/100g respectively.

4. 4. 2. 4. Total Sugars

The total sugars estimated in the fruits of different treatments varied significantly. The fruits of treatment, clay and coirpith at 2.5:1 ratio registered higher sugar content (21.50 per cent) as compared to control (19.63 per cent). The treatments, clay and coirpith at 1:1 and 1.5:1 ratios recorded significantly lower values of sugar content *viz.*, 19.71 and 20.63 per cent respectively.

Table 19. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on biochemical changes under cool conditions (13°C)

Treatments	Edible maturity (days)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100 g)	Total sugars (%)	Reducing sugars (%)	Sugar-acid ratio
Clay + Coirpith (1:1)	22.25	21.38	0.33	10.13	19.71	13.63	54.73
Clay + Coirpith (1.5:1)	24.63	19.32	0.35	10.11	20.63	15.71	58.94
Clay + Coirpith (2:1)	26.16	22.16	0.36	9.86	21.32	16.32	59.22
Clay + Coirpith (2.5:1)	29.38	23.89	0.37	10.62	21.50	16.47	58.11
Control	22.63	21.86	0.28	9.61	19.63	13.16	70.11

4. 4. 2. 5. Reducing Sugars

The higher reducing sugar content was recorded in fruits of clay and coirpith at 2.5:1 ratio treatment (16.47 per cent), while the fruits of treatment clay and coirpith at 1:1 ratio possessed significantly low levels of reducing sugars (13.63 per cent) compared to the control (13.16 per cent).

4. 4. 2. 6. Sugar-acid ratio

Among the treatments, the higher sugar-acid ratio was observed in control (70.11) and lower sugar-acid ratio was observed in fruits packed with clay and coirpith at 1: 1 ratio (54.73).

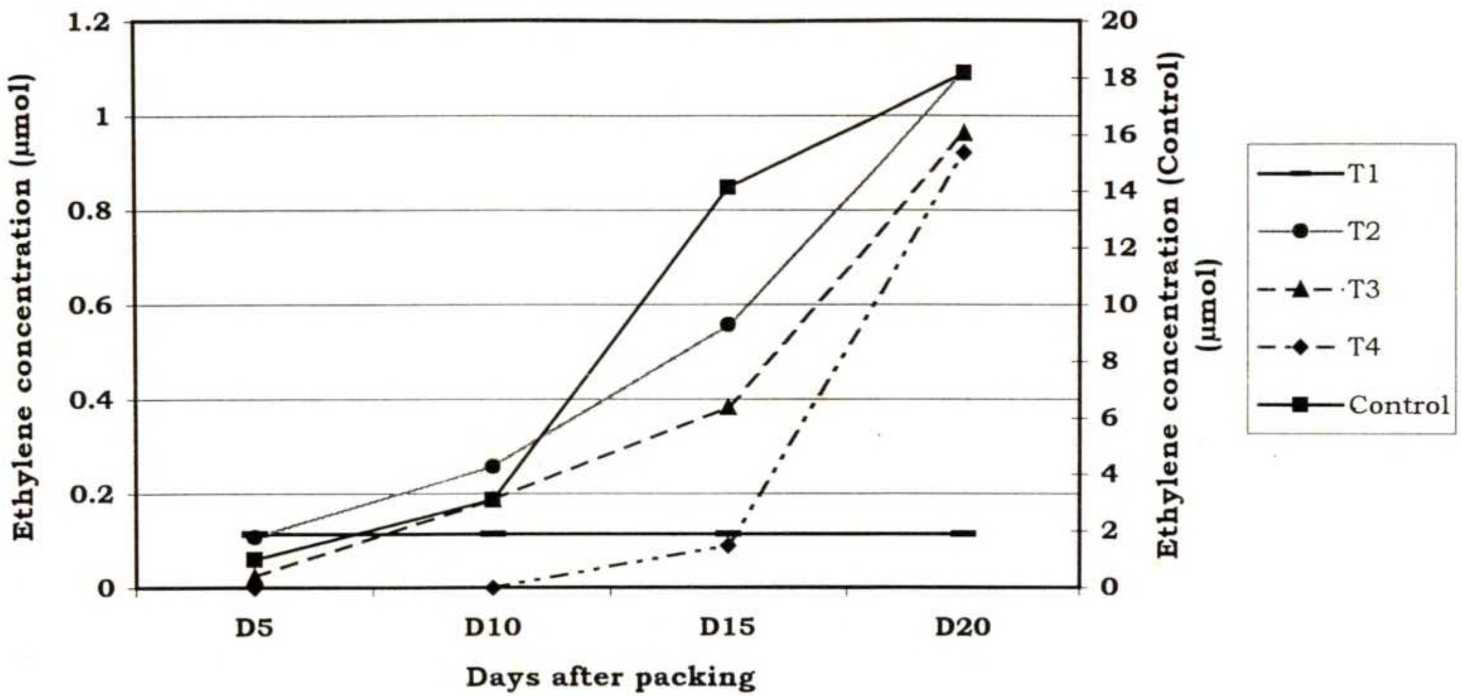
4. 4. 2. 7. Ethylene measurement

The ethylene concentration within the treatments showed an increasing trend with an increase in the storage duration upto 20 days.(Table 20 and Fig. 12). Clay and coirpith at 2.5:1 ratio showed no ethylene evolution till tenth day of storage. On twentieth day of storage, clay and coirpith at 2.5:1 ratio showed low ethylene evolution of 0.9217 μmol compared to other treatments. The control recorded very high ethylene concentration of 18.1632 μmol, which is significantly higher than all treatments. It is also observed that due to high ethylene concentration in control, the shelf life was comparatively low (18 days).

Table 20. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on ethylene scrubbing under cool conditions (13°C)

Treatments	Days after packing	Ethylene concentration (μmol)	Shelf life (Days)
Clay + Coirpith (1:1)	5	0.1132	23.25
	10	0.3631	
	15	0.7183	
	20	1.3263	
Clay + Coirpith (1.5:1)	5	0.1061	27.25
	10	0.2561	
	15	0.5563	
	20	1.0892	
Clay + Coirpith (2:1)	5	0.0231	28.75
	10	0.1863	
	15	0.3826	
	20	0.9623	
Clay + Coirpith (2.5:1)	5	Nil	31.25
	10	Nil	
	15	0.0896	
	20	0.9217	
Control	5	0.9821	18.00
	10	3.1186	
	15	14.1163	
	20	18.1632	

Fig. 12. Effect of different ratios of clay and coirpith with alkaline $KMnO_4$ as ethylene scrubber on ethylene scrubbing under cool conditions (13°C)



T1- Clay+Coirpith (1:1)   T3 - Clay+Coirpith (2:1)
T2- Clay+Coirpith (1.5:1)   T4 - Clay +Coirpith (2.5:1)

Plate 8. Control fruits in ambient conditions 14 days after storage

Plate 9. Effect of saturated $KMno_4$ based scrubber (after 18 days) under ambient conditions

9a. T1 - CLAY + COIRPITH (1.0 : 1.0) **T2 - CLAY + COIRPITH (1.5 : 1.0)**

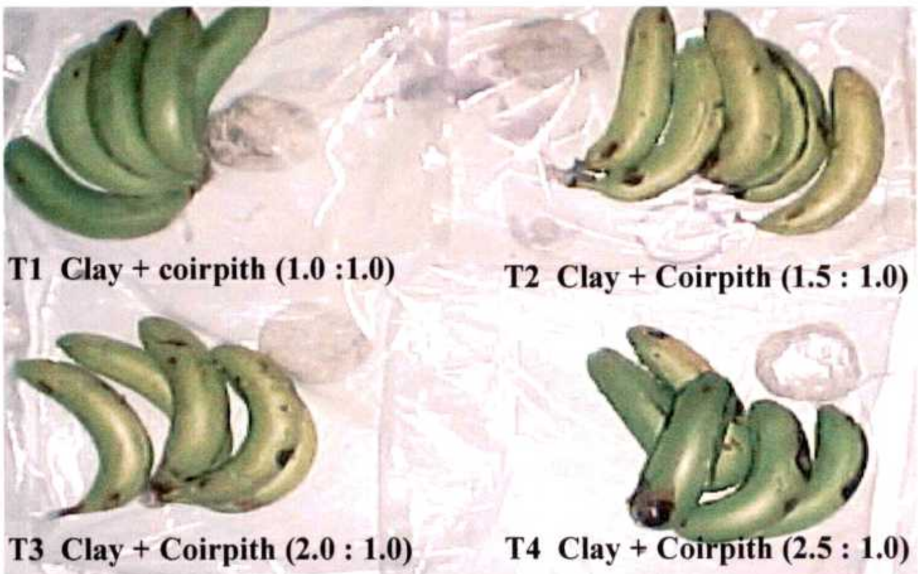
9b. T3 - CLAY + COIRPITH (2.0 : 1.0) **T4 - CLAY + COIRPITH (2.5 : 1.0)**

Plate 10. Effect of alkaline $KMno_4$ based scrubber (after 20 days) under ambient conditions

10 a. T2 CLAY + COIRPITH (1.5:1.0) T3 CLAY + COIRPITH (2.0:1.0)

10 b. T4 CLAY + COIRPITH (2.5 : 1.0)

Plate 11. Storage rot in control fruits - after 20 days of storage at 13°c



11a. Effect of saturated $KMno_4$ based scrubber on storage life at 13°c

Plate 12. Effect of alkaline based KMno$_4$ scrubber on storage life at 13°c

12 a. T2 CLAY + COIRPITH (1.5 : 1.0)

12 b. T3 CLAY+ COIRPITH (2.0 : 1.0)

12 c. T4 CLAY + COIRPITH (2.5 : 1.0)

DISCUSSION

CHAPTER V

DISCUSSION

India is the largest producer of banana and is bestowed with the best climatic conditions. There is scope for export of bananas to Gulf countries besides Japan. Amidst stiff competition from South Africa and other countries, India has to take up the export as a challenge. The production cost is a factor in limiting our export prospects besides, the lack of technologies for handling, packing, transporting and storage of bananas which ultimately attempts to deliver disease-free and quality fruits in the export market.

The varietal wealth India has is unique and besides the common varieties in the export market, India has to attempt to put into export market the new varieties of its own choice.

The main constraint India faces in the production of banana are the incidence of diseases and postharvest losses, which accounts for 20 – 80 per cent. This is mainly due to insufficient knowledge on storage, packing and transportation. Banana being a climacteric fruit becomes highly perishable after harvest due to high metabolic rate and ethylene production (Anon., 1999).

The metabolic rates of harvested produce are manageable within limits. In particular, the respiration and transpiration rates in the fruits are of concern to a postharvest scientist in packing the fruits for market. Factors affecting the respiration are many like the nature of commodity, the variety, the stage of maturity on harvest, the method of harvest, the time of harvest, the location in which it is grown, the weather conditions prevail during the growing season, the nature of manures and fertilisers applied, the chemicals and growth regulators used and also other cultural practices besides the storage temperature, gas composition, light intensity, wind velocity, the volume of the container, the size of storage room, the methods of stacking etc. Low temperature storage has always been considered a proven technology for extending the shelf life. However, the technology suffers from heavy initial investments, high technical investments and maintenance cost. Refrigerated transport is still hard to adapt because of the above mentioned reasons.

Storage gas composition is of considerable importance and is frequently employed commercially in foreign countries. This has been more used in temperate fruits. The ratio of CO_2, O_2 besides ethylene assumes importance in the management of storage atmosphere. Higher the levels of CO_2, lower are the respiration rate and metabolic activity while the trend is reverse in respect of O_2. The next important gas in this is the management of ethylene, the wonder compound.

A fruit can have a long storage life only if the metabolic rate is low, with consequent minimal loss of reserved food (Burton, 1982). Efforts to increase the shelf life of banana should necessarily focus on decreasing the metabolic rate and reducing the synthesis of ethylene in harvested tissues. The beneficial and harmful effects of ethylene on the harvested horticultural products have been well documented (Sherman, 1985). It is known that ethylene is produced naturally by the climacteric fruits during ripening and which plays a key role in the subsequent ripening process (Couey, 1989).

Ethylene a natural plant hormone, plays a central role in the initiation of ripening, has shown to damage several fruits and vegetables by accelerating senescence (ripening and aging). Its removal from storage atmosphere is known to extend the shelf life, especially in mixed storage situation (Musa, 1983). A method that has been in commercial practice is the oxidation of ethylene by potassium permanganate impregnated in a matrix of a few proprietary formulations is in use in the west which have to be imported at high cost making their application commercially non-viable (Jayaraman and Raju, 1992).

Ethylene management is very crucial in handling and storage. The responses of climacteric and non-climacteric fruits to ethylene are different. The sensitivity of fruits to ethylene again is governed by multivarious factors. Ethylene concentration is an important criterion, which needs to be considered. More the concentration of ethylene in the storage atmosphere, more is the response especially by non-climacteric fruits. While, an one-time application is adequate for climacteric fruits, a continuous supply of ethylene is needed for non- climacteric fruits. Climacteric fruits like banana respond very heavily to ethylene even at low concentrations. So, elimination of ethylene from the storage atmosphere indirectly helps in the extension of shelf life.

On account of the facts described hitherto, the management of ethylene in the storage atmosphere becomes very crucial. Commercial grade ethylene scrubbers have been developed and are in use elsewhere in the world. However, in India, no such advancements have been reported so for.

However recently, development of ethylene scrubber using locally available materials *viz.*, thermocol, filterpaper, blotting paper, chalk, coirpith, clay, ash, rice hull, sawdust and lantana flower powder either individually or in combination was tested by Nayak (1999). Out of which, clay and coirpith combination was found to increase the shelf life of banana cv. Robusta.

The present investigations are a sequel to the series of experiments conducted by Nayak (1999). In the present study, indigenous ethylene scrubber was made using clay and coirpith as carrier materials and saturated or alkaline potassium permanganate as oxidant under ambient or cool conditions (13°C). The evaluation criteria were primarily the physiological loss in weight, days taken for peel colour change, fruit softening, shelf life besides changes in total soluble solids, acidity, ascorbic acid, total sugars, reducing sugars, sugar-acid ratio and ethylene measurement.

Studies carried out presently have revealed many positive indications, which is in line with the reports mentioned below.

Influence of ethylene scrubber on physical characters of banana cv. Robusta

Water loss represents an important loss of saleable weight and eventually the materials becomes unsaleable as a result of wilting. Weight loss was continuous during storage due to moisture loss. Salunke (1984) opined that during ripening process, total carbohydrates was converted to soluble sugar and some of them are metabolised through respiration and therefore, carbon was lost as carbondioxide and pointed it to be one of the reasons for loss in weight during ripening. Metabolism of carbohydrates also produces water, which on evaporation causes reduction in weight.

The fruits packed with the carrier materials *viz.*, clay and coirpith at a ratio of 2.5:1 impregnated with saturated $KMnO_4$ under ambient conditions recorded least weight loss during storage compared to other treatments. Similarly, fruits packed with the carrier materials *viz.*, clay and coirpith at a ratio of 2.5:1 impregnated with alkaline $KMnO_4$ under ambient conditions also recorded least weight loss during storage compared to other treatments. Compared to saturated $KMnO_4$ based scrubber, the alkaline $KMnO_4$ based scrubber showed lower loss in weight irrespective of the treatments under ambient conditions. This might be due to the alkaline nature of the later causing least reduction in weight. The results obtained and reported earlier by Mahajan and Chopra (1994) in apple fruits packed with commercial ethylene absorbent 'Purafil' amply endorse the same. Modified gaseous levels might presumably slowed down loss in weight in fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ as ethylene scrubber. This finding is in line with the finding reported by Marchal and Nolin (1990), where the packaging along with ethylene absorbent maintained optimal humidity and ethylene levels, which in turn slowed down the process of evapotranspiration.

The fruits packed with carrier materials *viz.*, clay and coirpith at a ratio of 2.5:1 impregnated with saturated $KMnO_4$ under cool conditions (13°C) recorded least weight loss compared to all other treatments during storage. Also, the fruits packed with carrier materials *viz.*, clay and coirpith at a ratio of 2.5:1 ratio impregnated with alkaline $KMnO_4$ under cool conditions recorded least weight loss than other treatments during storage. Compared to saturated $KMnO_4$ based ethylene scrubber, the alkaline $KMnO_4$ based scrubber showed lower PLW irrespective of the treatments. This might be due to the alkaline nature of the later causing least reduction in weight. The results obtained and reported earlier by Scott and Gandanegara (1974) in banana fruit cv. ' Williams' packed with ethylene absorbent amply endorse the same. Compared to ambient conditions, the loss in weight is said to be less under cool conditions due to reduction in the process of evapotranspiration and respiration activities. This is also in confirmation with the findings reported by Lebibet *et al.* (1995) in banana fruits who observed that storing fruits at 13°C reduced respiration and delayed ripening leading to reduction in weight loss.

Regarding the peel colour change, it was observed as the number of days taken for the peel to turn into light yellow colour. The efficacy of ethylene scrubber was judged based on the change of peel colour. The different ratios of clay and coirpith behaved strikingly, independent from one another. The fruits packed with clay and coirpith at a ratio of 2.5:1 impregnated with saturated $KMnO_4$ under ambient conditions was most effective in extending the days taken for peel colour change than all other treatments. The delayed peel colour change might be due to the higher content of clay (2.5 parts) resulting in more absorption of $KMnO_4$ (250 ml) than other treatments. This could have oxidised ethylene more effectively and suppressed respiration. The fruits packed with clay and coirpith at a ratio of 2.5:1 impregnated with alkaline $KMnO_4$ under ambient conditions was effective in extending the days taken for peel colour change than other treatments and the control took only minimum number of days taken for peel colour change. The delayed peel colour change in fruits packed with clay and coirpith at 2.5:1 ratio might be due to more absorption capacity of alkaline $KMnO_4$ (250 ml) by 2.5 parts of clay than other treatments. Compared to saturated $KMnO_4$, alkaline $KMnO_4$ based ethylene scrubber was found to be effective in delaying the peel colour change. The reason might be due to the effect of alkalinity in the later causing reduced rate of respiration. The results are in confirmation with the findings reported by Esguerra *et al.* (1978) who used perlite as carrier material for $KMnO_4$ for delaying the ripening process and similar observations were made by Claud and Calvo (1993).

Under cool conditions (13°C), the fruits packed with clay and coirpith at a ratio of 2.5:1 impregnated with saturated $KMnO_4$ showed delayed peel colour change than all treatments. This might be due to increased clay content causing more absorption of $KMnO_4$ (250 ml) by the carrier materials leading to more absorption of ethylene. The fruits packed with clay and coirpith at a ratio of 2.5:1 impregnated with alkaline $KMnO_4$ showed still delayed peel colour change than the saturated $KMnO_4$ based scrubber. This might be presumably due to the alkalinity of the later and also due to higher amount of clay (2.5 parts) resulting in more absorption of ethylene. Compared to ambient condition storage, the cold storage at 13°C led to delayed peel colour change. This might be due to the low temperature causing reduced rate of respiration and ripening. This finding is in consonance with the findings reported by Esguerra *et al.* (1978), Claud and Calvo (1993) and Lebibet *et al.* (1995).

Regarding the number of days taken for fruit softening, the fruits packed with clay and coipith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber took longer time for fruit softening. Similarly, the fruits packed with clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as ethylene scrubber took comparatively longer time for fruit softening than the saturated $KMnO_4$ based scrubber. This might be due to the alkalinity of the later, which absorbed ethylene more effectively. The softening of fruits during the course of ripening may be the result of cell wall degradation and hydrolysis of cell contents. The results are in accordance with the findings of Leopold and Kridemann (1975). The high clay content in clay and coirpith at 2.5:1 ratio might be have absorbed more $KMnO_4$ resulting in delayed fruit softening.

Under cool conditions, clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as ethylene scrubber took comparatively longer time for fruit softening than clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber. This might be due to the alkaline nature of the former, which is in confirmation with the findings reported by Leopold and Kridemann (1975). Due to high clay content in clay and coirpith at 2.5:1 ratio, absorption of $KMnO_4$ was high resulting in delayed fruit softening. Compared to ambient conditions, the fruits stored in cool conditions showed delayed fruit softening. This might be presumably due to very low temperature prevailing in the storage temperature causing suppressed respiration, reduced ethylene evolution and delayed ripening. This finding corroborates the findings of Lebibet *et al.* (1995) and Chamara *et al.* (2000).

With regard to shelf life, the fruits packed with clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber extended the shelf life than other ratios of clay and coirpith. This might be due to high clay content, which absorbed $KMnO_4$, more efficiently thereby reducing ethylene concentration in the storage atmosphere. Compared to saturated $KMnO_4$ based scrubber, fruits packed with alkaline $KMnO_4$ as scrubber extended the shelf life by atleast one day. This might be due to reduced respiration, reduction in the concentration of ethylene in the storage atmosphere and delayed ripening due to alkalinity. This is in confirmation with the findings reported by Fuchs and Godreiski (1971), Nelson (1939) and Mahajan and Chopra (1994) who reported that ethylene could be oxidised to ethylene glycol by $KMnO_4$. Patil and Magar (1975), Esguerra et al. (1978), Satyan *et al.* (1992), Claud and Calvo (1993) and Nayak (1999) also reported similar effects. Extension of shelf life in banana through sealed polythene bags was also reported by Scott and Gandanegara (1974), Sen *et al.* (1978), Sarananda (1989) and Marchal and Nolin (1990).

Under cool conditions (13°C), the fruits packed with clay coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber extended the shelf life compared to other ratios of clay and coirpith. This might be due to higher clay content causing more absorption of $KMnO_4$ leading to efficient removal of ethylene in the storage atmosphere. Compared to saturated $KMnO_4$ based scrubber, fruits packed with clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as scrubber extended the shelf life by atleast 1.75 days. This is really a significant achievement for commercial market. This might be due to alkalinity of the later leading to efficient removal of ethylene. This is in confirmation with the findings reported by Mahajan and Chopra (1994) in apple fruits packed with commercial ethylene scrubber 'Purafil'. Compared to ambient condition storage, fruits packed and kept in cool condition had longer shelf life by 10.50 days. It is really a major breakthrough for commercial export market. This might be due to reduction in respiration rate and less ethylene evolution. This is in confirmation with the findings reported by Scott and Gandanegara (1974), Lebibet *et al.* (1995) and Chamara *et al.* (2000).

Influence of ethylene scrubber on biochemical characters of banana cv. Robusta

Postharvest biochemical changes, which reduce the quality and quantity of constituents, are of great nutritional significance. In the present investigation, it was evident that different ratios of clay and coirpith impregnated with saturated or alkaline $KMnO_4$ under ambient or cool conditions significantly influenced the contents of total soluble solids, acidity, ascorbic acid, total sugars, reducing sugars and sugar-acid ratio of ripe bananas after storage.

Under ambient conditions, the total soluble solids, total sugars and reducing sugars were found to be on the higher side in fruits packed with clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber. Similarly, fruits packed with alkaline $KMnO_4$ as ethylene scrubber resulted in high TSS, total sugars and reducing sugars. These results are in confirmation with the findings reported by Dutta *et al.* (1991) in guava var. Lucknow 49 where the contents of total soluble solids, total sugars and reducing sugars were lower in fruits stored without any absorbents compared to the fruits stored in Celite - $KMnO_4$ as ethylene absorbent. Similar findings were also reported by Sharma *et al.* (1989) in grapes.

Under cool conditions also, the fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ as ethylene scrubber showed higher levels of total soluble solids, total sugars and reducing sugars. This corroborates with the findings of Dutta *et al.* (1991) and Lebibet *et al.* (1995) and Chamara *et al.* (2000).

Under ambient condition of storage, the fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ showed higher acidity and ascorbic acid levels at edible maturity stage. This might be due to slower rate of respiration and ripening of fruits by the use of ethylene scrubber. This observation is in consonance with the findings of Dutta *et al.* (1991) and Tandon *et al.* (1984) in guava fruits cv. Lucknow 49. Under cool conditions, the fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ showed higher acidity and ascorbic acid content. This might be due to very low level of respiration, low rate of ethylene evolution and ripening process in very low temperature. This finding is in confirmation with the findings reported by Lebibet *et al.* (1995), Chamara *et al.* (2000), Dutta *et al.* (1991) and Tandon *et al.* (1984).

With regard to sugar-acid ratio, fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ as ethylene scrubber under ambient or cool conditions showed less sugar-acid ratio. This might be probably due to higher levels of acidity in the said treatment.

The effects of an effective ethylene absorption has been vividly reflected on the ripening behaviour of fruits sealed in polythene bags with ethylene scrubber. Among all the ratios of clay and coirpith, fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ showed very less concentration of ethylene and this might be due to higher absorption capacity of clay leading to effective removal of ethylene. Under cool conditions (13°C), the fruits packed with clay and coirpith at 2.5:1 ratio with saturated or alkaline $KMnO_4$ showed still lower concentration of ethylene due to effective removal of ethylene by the scrubber and also prevailing low temperature storage leading to reduced rate of respiration and ripening process. This is in confirmation with the findings reported by Chamara *et al.* (2000) who reported that the storage life of 'Kolikuttu' bananas extended upto 31 days by using alkaline $KMnO_4$ as ethylene scavengers at 14°C. Similar observations were also reported by Lebibet *et al.* (1995).

The highlight of the present investigation is the delay in ripening of banana fruits cv. Robusta by 31.25 days due to the presence of clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as ethylene scrubber under cool conditions (13°C) as against the package without scrubber where the fruits ripened within 18 days of storage. Thus, there is 42 per cent increase in the shelf life of fruits. It is really a significant achievement for commercial banana trade in global level where refrigeration is found to be necessary. Another important achievement is the delay in ripening of banana cv. Robusta by 20 days under ambient conditions due to the presence of clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as ethylene scrubber against the package without scrubber where the fruits ripened within 14 days of storage. Thus, there is 30 per cent increase in shelf life of fruits. This technique is also an important achievement for banana growers and traders and it is easily adaptable, highly economic and environmentally safe. Thus, the extension in shelf life achieved was phenomenal to the tune of 31.25 and 20 days under cool and ambient conditions respectively, which is many fold beyond our requirement.

Thus, the study has fulfilled its mandate and brought out viable technique, which can open up newer awareness in export promotion of this valuable and easily available fruit commodity in the country.

SUMMARY

CHAPTER VI

SUMMARY

The outcome of the series of experiments conducted on banana cv. Robusta to develop permanganate based indigenous ethylene scrubber on shelf life for export market are summarised.

Under ambient conditions, clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber recorded a significantly longer shelf life (18.75 days) followed by clay and coirpith at 2:1 ratio (18.50 days) as against the shelf life of 14.00 days in control.

The fruits packed with clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber recorded minimum PLW (8.09 per cent) as against the control (12.23 per cent) on the fourteenth day of storage.

Regarding biochemical characters, the total soluble solids (20.51°Brix), acidity (0.35 per cent), ascorbic acid (10.25 mg/100g), total sugars (20.86 per cent) and reducing sugars (16.36 per cent) were found to be on the higher side in clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber. The same treatment was found to be effective in ethylene scrubbing in storage atmosphere (1.0623 µmol) as against the control (16.8271µmol) on fifteenth day of storage.

Under ambient conditions, fruits packed with clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as ethylene scrubber recorded significantly a longer shelf life (19.75 days) followed by clay and coirpith at 2:1 ratio (19.00 days) as against the control (14.00 days). Thus, there is 30 per cent increase in shelf life of fruits. The same treatment recorded a minimum PLW of 6.43 per cent as against the control (9.83 per cent) on fourteenth day of storage.

With regard to biochemical characters, the total soluble solids (22.81°Brix), acidity (0.37 per cent), ascorbic acid (10.46 mg/100g), total sugars (19.83 per cent) and reducing sugars (16.72 per cent) were found to be on the higher side in fruits packed with clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as ethylene scrubber.

The same treatment was found to be effective in ethylene scrubbing (0.6872 μmol) as against the control (15.1876 μmol) on fifteenth day of storage.

Under cool conditions (13°C), the shelf life was significantly more (29.50 days) in fruits packed with clay and coirpith at 2.5:1 ratio with saturated $KMnO_4$ as ethylene scrubber, followed by 26.50 days in fruits packed with clay and coirpith at 2:1 ratio as against the control (18.00 days).

The PLW was found to be low (8.21 per cent) in fruits packed with clay and coirpith at 2.5:1ratio with saturated $KMnO_4$ as ethylene scrubber whereas the control recorded 10.71 per cent on eighteenth day of storage under cool conditions (13°C).

The biochemical characters *viz.*, the total soluble solids (23.61°Brix), acidity (0.36 per cent), ascorbic acid (10.56 mg/100g), total sugars (21.32 per cent) and reducing sugars (16.17 per cent) were found to be on the higher side in fruits packed with clay and coirpith at 2.5:1 ratio under cool conditions. The same treatment was found to be effective in ethylene removal (0.9387 μmol) as against the control (18.1899 μmol) on twentieth day of storage.

The shelf life was found to be significantly more (31.25 days) in fruits packed with clay and coirpith at 2.5:1ratio with alkaline $KMnO_4$ as ethylene scrubber followed by 28.75 days in fruits packed with clay and coirpith at 2:1 ratio as against the control (17.50 days). Thus, there is 42 per cent increase in shelf life of fruits.

The PLW was found to be low (6.22 per cent) in fruits packed with clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ as against the control (8.95 per cent) on eighteenth day of storage.

The biochemical characters *viz.*, the total soluble solids (23.89 °Brix), acidity (0.37 per cent), ascorbic acid (10.62 mg/100g), total sugars (21.50 per cent) and reducing sugars (16.47 per cent) were found to be on the higher side in fruits packed with clay and coirpith at 2.5:1 ratio with alkaline $KMnO_4$ under cool conditions. The same treatment was found to be effective in ethylene removal (0.9217 μmol) as against the control (18.1632 μmol) on twentieth day of storage.

REFERENCES

REFERENCES

Abe, E. and A. E. Watada. 1991. Ethylene absorbent to maintain quality of lightly processed fruits and vegetables. **J. Food. Sci., 56**: 1589-1952.

*Abeles, F. B. 1973. **Ethylene in plant biology**. Academic press, New York. pp. 16, 24, 25, 153-196.

*Adlai Amor. 1989. New technology to aid banana trade. **Partners in Research for Development, 2**: 16-19.

Aharoni, Y., Azicacopel and Elazar Fallik. 1993. Storing 'Galia' melons in a controlled atmosphere with ethylene absorbent. **Hort. Sci., 28** (7): 725-726.

Akamine, E.K. and T. Arisumi. 1953. Control of postharvest decay of fruits of papaya (*Carica papaya* L.) with special reference to the effects of hot water. **Proc. Amer. Soc. Hort. Sci.,** 270-274.

Anonymous, 1994. **Manual on crop production techniques of horticultural crops.** Department of Horticulture and Plantation Crops, Madras 2. pp. 137-139.

Anonymous, 1995. **Annual Report**. NRCB. Trichy, Tamil Nadu. pp : 35-53.

Anonymous, 1999. **Plant Horti Tech. 1**: 42-43.

A. O. A. C. 1960. Official methods of analysis. **Association of Agricultural Chemists,** 9th Ed, Washington, D. C. pp. 2004.

Armstrong, J. W. 1982. Development of a hot water immersion quarantine treatments for Hawaiian grown Brazilian bananas. **J. Econ. Entomol., 75**: 787-790.

Biale, J. B. 1956. Postharvest physiology and biochemistry of fruits. **Ann. Re. Plant Physiol., 1** : 183-206.

Blanpeid, G. D. 1990. Low ethylene CA storage of apples. **Post Harvest News Info., 1**: 29-34.

Briceno, S., J. Zambrano and E. Castellanos. 1999. Delaying fruit ripening in the mango cultivars Keitt and Palmer using the mixtures vermiculite - $KMnO_4$ and silicagel - $KMnO_4$. **Agronomia Tropical (Maracay), 49** (1): 41 – 49.

Burton, W. G. 1982. **Postharvest physiology of food crops**. Longman Group Ltd., New York.

*Carvalho, H. A. 1988. Quality of banana cv. Prata previously stored in polyethylene bags and ripened in ambient conditions at high relative humidity. **Hort. Abst., 60** (12) : 10370.

Chadha, K. L. 1996. Call to improve postharvest management of banana. Inaugural address of International Conference of challenges for banana production and utilization in 21st century, 24th September 1996, Trichy, India.

*Chamara, D., K. Illeperuma, P. T. Galappatty and K. H. Sarananda. 2000. Modified atmosphere packaging of 'Kolikuttu' bananas at low temerature. **J. Hort. Sci. and Biotech., 75** (1): 92-96.

Charles, D. and J. H. New. 1996. Packaging for export from developing countries – developments in packaging of Windward islands bananas. **Postharvest News and Info.,** 25N – 30N.

*Chillet, M., L. D. Lapeyre de Bellaire and J. Joa. 1995. An experimental model to assess the effect of packaging on canker in export bananas. **Fruits, 50**(3): 173-181.

Claud, E. J. and B. S. Calvo. 1993. Chemical control of ripening of Lakatan banana. **USM**. CA, **4**: 139-144.

Couey, H. M. 1989. Heat treatment for control of postharvest disease and insect pests of fruit. **Hort. Sci., 24**: 198-202.

*Denny, F. E. 1924. Hastening the coloration of lemons. **J. Agr. Res., 27**: 757-769.

Dostal, H. C. and J. E. Hoff. 1968. Feasibility of using parafin oil for purification of storage atmosphere. **Hort. Sci., 3**: 46-48.

Dutta, P., A. K. Banik, R. Ray Chaudhury and R. S. Dhua. 1991. Influence of ethylene absorbents on shelf life of guava fruits. **Indian J. Hort., 48** (3): 213-216.

*Esguerra, E. B., D. B. Mendoza and E. B. Pantastico. 1978. Regulation of fruit ripening. Use of perlite $KMnO_4$ insert as an ethylene absorbent. **Philippin. J. Sci., 107**: 23-31.

*Floros, J. D. 1990. Controlled and modified atmospheres in food packaging and storage. **Chem. Engg. Progress, 26** (6): 25-32.

*Forsyth, F. R., C. A. Eaves and H. J. Lightfoot. 1969. Storage quality of McIntosh apple as affected by removal of ethylene from the storage atmosphere. **Canadian J. Plant Sci., 49**: 567.

Freed, M. 1966. **Methods of vitamin assay**. Inter Science Pub. Inc, New York.

Friths, D. J. and F. C. Chalker. 1983. Hotwater treatment of banana fruit. **Aust. Hort. Res. Newsl., 55** : 140-141.

Fuchs, Y. and N. Temkin-Gorodeiski. 1971. The course of ripening banana fruits stored in sealed polyethylene bags. **J. Am. Soc. Hort. Sci., 96**: 401-403.

George, J. B. and J. Marriott. 1985. The effect of some storage conditions on the storage life of plantains. **Acta Hort., 158**: 439-447.

Gouble, B., D. Fath and P. Soudain. 1995. Nitrous oxide inhibition of ethylene production in ripening and senescing climacteric fruits. **Postharvest Biol. Technol., 5**: 311-321.

Guillemot, J. 1976. Storage trials with plantains. **Fruits, 31** (11): 698-700.

Hales, K. C. 1963. Refrigerated transport on shipboard. **Adv. in Fd Res., 21**: 147-201.

Jayaraman, K. S. and P. S. Raju. 1992. Development and evaluation of a permanganate - based ethylene scrubber for extending the shelf life of fresh fruits and vegetables. **J. Fd. Sci. Technol., 29** : 77-83.

Knee, M. and S. G. S. Hatfield. 1981. Benefits of ethylene removal during apple storage. **Ann. Appl. Biol., 98**: 157-165.

Krishnamurthy, S. 1989. Storage life and quality of Robusta banana in relation to their stage of maturity and storage temperature. **J. Fd. Sci. Technol., 26** (2): 87-89.

Krishnamurthy, S. and C. G. Kushalappa. 1985. Studies on the shelf life and quality of Robusta bananas as affected by post harvest treatments. J. **Hort. Sci., 60** (4): 549-556.

Lane, J. H. and L. Eyon. 1923. Determination of reducing sugars by Fehling's solution with methylene blue as indicator. **J. Soc. Chem. India, 42**: 327.

Lebibet, D., I. Metzidakis and D. Gerasopoulos. 1995. Effects of storage temperatures on the ripening response of banana fruit grown in the mild winter climate of Crete. **Acta Hort., 379**: 521-526.

Leopold, A. C. and P. E. Kridemann. 1975. **Fruiting in plant growth and development.** TMB edition, pp. 327.

Lidster, P. D. and R. A. Lawrence. 1983. Factors affecting the removal of ethylene by potassium permanganate. **Hort. Sci., 18** (4): 615.

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

Mahajan, B. V. C. and S. K. Chopra.1994. Studies on the storage behaviour of apple packed with ethylene absorbents. **Indian Fd. Packer, 3**: 11-18.

Maini, S. B., B.B. Lal and J. C. Anand. 1993. Fruit Packaging. In : **Advances in Horticulture,** vol 4 - **Fruit crops**. Part 4. (Eds. Chadha, K. L. and O. P. Pareek), Malhotra Publishing House, New Delhi.

Marchal, J. and J. Nolin. 1990. Fruit quality, pre and post harvest physiology. **Fruits** (Paris), Special Issue. pp. 119-122.

Mayberry, K. S. and T. K. Hartz. 1992. Extension of muskmelon storage life through the use of hot water treatment and polyethylene crops. **Hort. Sci., 27**: 324-326.

McGlasson, W. B. 1985. Ethylene and fruit ripening. **Hort. Sci., 20** (1): 51-54.

McMurchie, E. J., W. B. McGlasson, and I. L. Eaks. 1972. Treatment of fruit with propylene gives information about the biogenesis of ethylene. **Nature (London), 237**: 235-236.

*Musa, S. K. 1983. Reduction of postharvest losses in vegetable and fruits in a developing country. **Proc. Int. Cong. Fd. Sci. and Tech. Oublin, 5**: 165.

Nayak, V. G. 1999. Development of pre and postharvest handling package for residue-free export bananas cv. Robusta. **Ph. D., (Hort.) Thesis**, Tamil Nadu Agricultural University, Coimbatore.

Ndubizu, T. O. C. 1976. Delaying ripening in harvested Nigerian green plantains. **J. Agric. Sci. Camb., 87** : 573 –576.

Nelson, R. C. 1939. Studies on production of ethylene in ripening process in apples and bananas. **Food Res., 4**: 173-178.

Nichols, R. and A. Topping. 1966. Absorption of ethylene by self-indicating soda lime. **Nature, 211**: 217.

Oetiker, J. H. and S. F. Yang. 1995. The role of ethylene in fruit ripening. **Acta Hort., 398**: 167-178.

Pandey, U. B., Lallan Singh, J. R. Bhonde, V. K. Singh and R. P. Gupta. 1983. Studies on sorting, grading and packaging of onion. Proc. Nat. Workshop on Onion, 17-18 Dec. 1983. Nasik, NAFED and Ministry of Agriculture, GOI.

Panse, U. G. and P. V. Sukhatme. 1967. In: **Statistical method of Agricultural workers.** ICAR, New Delhi.

*Parkin, R. and K. J. Scott, 1979. Banana bunches stored without refrigeration. Agric. Gaz. N. S. W., 90: 52. In : **Hort. Abstr., 50** : 7444.

Patil, D. L. and N. G. Magar. 1975. Extension of storage life of preclimacteric bananas. **Res. J. Mahatma Phule Agric. Univ., 6** : 116-125.

Paull, R. E. 1990. Postharvest heat treatments and fruit ripening. **Postharvest News Info., 1** : 355-363.

*Peacock, B. C. 1980. Banana ripening- Effect of temperature on fruit quality. **Qid. J. Agric. Anim. Sci., 37** (1): 39-45.

Rameshwar, A. 1993. Fruit maturity. In : **Advances in Horticulture,** Vol. 4. **Fruit crops** (Eds., K. L. Chadha and O. P. Pareek) Malhotra Publishing House, New Delhi. pp.1161-1702.

Sadasivam, S. and A. Manickam. 1996. **Biochemical methods - New Age International Publishers,** New Delhi, India. pp. 256.

Saltveit, M. E. Jr. 1980. An inexpensive chemical scrubber for oxidizing volatile organic contaminants in gases and storage room atmospheres. **Hort. Sci., 15** (6): 759-760.

Satyan, S., K. Y. Scott and D. Graham. 1992. Storage of banana bunches in sealed polythene tubes. **J. Hort. Sci., 67**: 283-287.

Salunke, D. K. 1984. **Chemical control of losses in postharvest biotechnology of fruits. Vol. I**, Boca Raton, FL: CRC, pp. 168.

Sarananda, K. H. 1989. Response of Embul banana to modified atmosphere storage. **Trop. Agric., 145**: 113-119.

Scott, K. J. 1975. The use of polythene bags to extend shelf life of bananas after harvest. **Food Technol. Aust., 27**: 481-482.

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

Scott, K. J., J. Giugni and W.M. Bailey. 1984. The use of polyethylene bags and ethylene absorbent to extend the life of kiwifruit (*Actinidia chinensis* Planch.) during cool storage. **J. of Hort. Sci., 59** : 563-566.

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. **Aust. J. Exptl. Agric. Animal. Hus., 10** : 237-240.

Scott, K. J., J. R. Blake, G. Strachan, B. L. Tubewell, and G. B. McGlasson. 1971. Transport of bananas at ambient temperatures using polyethylene bags. **Trop. Agric. (Trinidad), 48:** 243-254.

Scott, K. J. and E. A. Roberts. 1966. Polyethylene bags to delay ripening of bananas during transport and storage. **Aust. J. Expt. Agric. Animal Hus., 6** : 197-199.

Sen, S. P., P. Basu Chowdhuri and M. P. Chowdhuri. 1978. Studies on some postharvest biochemical changes in banana under sealed polythene bagging storage. **Indian. Agric., 22** (1): 20-33.

Sharma, R. K., J. K. Ransingh and S. S. Sharma. 1989. A note on the effect of diphenyl fumigant to enhance the life of grapes. **Haryana J. Hort. Sci., 18**: 61-64.

Sherman, M. 1985. Control of ethylene in postharvest environment. **Hort. Sci., 20**: 57-60.

*Silvis, S. H., S. K. Musa, A. K.Thompsom, Omer Mohamed Sulafakhalid, Saliah and Y. M. Abdulla. 1976. Reduction of wastage during postharvest handling of bananas in Sudan. **Trop. Agric., 53**: 89-94.

Smith, W. H. 1963. The use of carbon dioxide in the transport and storage of fruits and vegetables. **Adv. in Fd. Res., 12**: 95-146.

Smoot, J.J. and R. H. Segall. 1963. Hot water as a postharvest control of mango anthracnose. **Plant Dis. Rptr., 47**: 739-742.

Tandon, D. K., P. G. Adsule and S. K. Kalra. 1984. Effect of certain postharvest treatments on the shelf life of guava fruits. **Indian J. Hort., 41** (1/2): 88-92.

*Waskar, D. P. and S. K. Roy. 1996. Methods adopted for extending the shelf life of banana fruit – A review. **Agric. Rev., 17**: 132-138.

Wills, R. B. H. and G. H. Kim. 1995. Effect of ethylene on postharvest life of strawberries. **Postharvest Biol. Technol., 6**: 249-255.

Zhang, D., B. Y. Huang and K. J. Scott. 1993. Some physiological and biochemical changes of green-ripe bananas at relative high storage temperatures. **Acta Hort., 343**: 81-85.

* Originals not seen.

APPENDICES

APPENDIX A

Maturity (harvest) stages of banana

Maturity (%)	Description
70	Fingers angular, skin dark green
80	Fingers slightly less angular, skin dark green
90	Fingers turning to be round, skin dull green
100	Round fingers, earliest top fruits turning greenish yellow

Rameshwar (1993)

APPENDIX B

Colour chart for ripening Banana – Developed by United Fruit Sales Corporation

Colour Details	Index No.
Mature green	1
Green with traces of yellow	2
More green than yellow	3
More yellow than green	4
Green tip only	5
All yellow	6
Yellow flecked with brown	7

Armstrong (1982)