Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso

By

Mr. MAYURESH ARAVIND PUROHIT
B.Sc. (Hort.)

DEPARTMENT OF POST HARVEST MANAGEMENT OF FRUIT, VEGETABLE AND FLOWER CROPS

POST GRADUATE INSTITUTE OF POST HAREVST MANAGEMENT, KILLA-ROHA

FACULTY OF AGRICULTURE

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI – 415 712, DIST: - RATNAGIRI (M.S.)

July – 2015

Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso

A thesis submitted to the

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI

(Agricultural University)

Dist. Ratnagiri

(Maharashtra State)

in partial fulfillment of the requirements for the degree of

Master of Science
(POST HARVEST MANAGEMENT)

in

FRUIT, VEGETABLE AND FLOWER CROPS

by

Mr. MAYURESH ARAVIND PUROHIT
B.Sc. (Hort.)

DEPARTMENT OF FRUIT, VEGETABLE AND FLOWER CROPS

POST GRADUATE INSTITUTE OF POST HAREVST MANAGEMENT, KILLA-ROHA

FACULTY OF AGRICULTURE,

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH,

DAPOLI –415 712, DIST: - RATNAGIRI (M.S.)

JULY, 2015

: Chairman and Research Guide:

(P. D. Veerkar)
Assistant Professor,
Department of Agricultural Econo
College of Agriculture, Dapoli- 415

: Members:

(S. S. Wadkar)
Associate Professor,
Department of Agricultural Economics,
College of Agriculture, Dapoli

(A. C. Sawant)
Professor,
Department of Agronomy,
College of Agriculture, Dapoli

(V. G. Naik)
Assistant Professor,
Department of Agricultural Economics,
College of Agriculture, Dapoli

LIST OF TABLES.

CERTIFICATE

Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv.Alphonso

A thesis submitted to the

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI
(Agricultural University)
Dist. Ratnagiri (Maharashtra State)

in partial fulfilment of the requirements for the degree of

Master of Science

(POST HARVEST MANAGEMENT)

in

FRUITS, VEGETABLES AND FLOWERS CROPS

by

Mr. Mayuresh Aravind Purohit.
B. Sc. (Hort.)

Approved by the Advisory Committee

: Chairman and Research Guide:

(K.H. Pujari)
Associate Dean
P.G.I. P.H.M. Killa- Roha
Dist. Raigad.

: Members :

(P.P. Relekar)
Associate Professor,
P.G.I.P.H.M. Killa- Roha.
Dist. Raigad.

(V.S.Pande)
Head of the Department,
Department of Plant Pathalogy
College of Agriculture,Dapoli
Dr. B.S.K.K.V, Dapoli.

Candidate's Declaration

I thereby declare that the thesis or any part thereof has not been previously submitted by me for the degree of any other University.

Date : July, 2015 *Mayuresh Aravind Purohit*

Acknowledgement

Honestly today, I cannot found any words to express my feelings on this happiest moment of completion of my Research work and this manuscript. "Time is money" is the rule of this competitive word and I feel that I am able to complete this work in time is only and only because of blessings of God Ganesh, my mother, my father and a kind and loveable gentleman.

He not only guide me in my research but made me able to be a real master in every aspect of life i.e. my honourable chairman of advisory committee and my research guide ***Dr.K.H.Pujari,*** *Professor and Associate Dean, Post Graduate Institute of Post Harvest Management, Killa, Roha. Dr. Pujari is the person who initiated and allowed me into this competitive world of creative research through his constant encouragement, constructive criticism, scholarly advice and un-questioned mastery of the subject.*

It is proud privilege to place on record my sincere thanks to ***Dr.P.P.Relekar****, Associate Professor, Post Graduate Institute of Post Harvest Management, Killa, Roha,* ***Dr.V.S. Pande****, Professor and Head, Department of Plant Pathalogy, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, the honourable members of my advisory committee for their keen interest, inspiring guidance and unconditional help during my research.*

I extend my sincere thanks to ***Dr.P.G.Borkar****, Associate Professor, Department of Plant Pathalogy and* ***Mr.M.M.Kulkarni*** *Assistant Professor, Department of Horticulture for his moral boosting support and constant encouragement throughout my research and educational life in Dapoli.*

I express my since
re thanks to ***Mr.Pethe, Dr.Khandekar, Dr.Mali****,* ***Mr.J.J.Kadam, Mr.C.B.Gondhalekar*** *who always gave me inspiration and help during my research and educational life in Dapoli.*

I would also like to thank all the non-teaching staff especially Mr. Shedge sir, Mr. Khapare Sir, Mr.Debaje sir, Mrs. Potphode Madam, P. G. Institute of Post Harvest Management, Killa, Roha for their generous help and co-operation during the course of my work and study period.

I would also like to thank all JSW Project staff, Mr. D.K.Jadhav, Mr.V.V.Zagde, Mr.N.T. Dhobe, Mr. Ashfaque Khan, Miss. Desai madam, Mrs. Kadam Madam, Mr. Mane, Nilesh Baikar, Rakesh Bhuvad, Sumit Mahadik who helped wholeheartedly.

I also extend my deep sense of honour to ***Dr. B. Venkateswarlu****, Honourable Vice Chancellor, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dr.R.G.Burate, Dean, Faculty of Agriculture Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dr.U.V Mahadkar, Director of Research, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, and Dr.S.A.Chavan, Associate Dean, College of Agriculture, Dapoli for providing me the necessary facilities during the course of study.*

I will always like to be in debt of the eight persons who always showed keen interest in my research and always help me without asking for any help, my wonderful friends Sanket, Roshan, Hemant (walya), Abhichek, Akash, Govind, Pranav and Suhas.

I wish to convey my thanks to my classmates and innumerable friends like Yugandhara, Rupali, Harshala, Priyanka More, Priyanka Raut, Shweta and Mita for their joyful company throughout my M.Sc.degree curriculum

.

I thank my father Aravind M. Purohit my beloved mother Mrs. Veena A. Purohit in each every aspect of my life and my grandmother Vijaya aaji, my grandfather Mr.Suresh (Aappa), my sister Miss. Mugdha, my uncle Vinda, my aunty Nila other family members for their love, sacrifice, encouragement and blessings who took mammoth part in building up my career.

Last but not the least I thank Roshan Mohire for page setting of this thesis.

Killa-Roha

Date: July 2015 ***(Mayuresh Aravind Purohit)***

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

DEPARTMENT OF POST HARVEST MANAGEMENT OF FRUIT, VEGETABLE AND FLOWER CROPS
POST GRADUATE INSTITUTE OF POST HARVEST MANAGEMENT
DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI

Thesis Title	**:**	Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso.
Name of the student	**:**	Mr. Purohit Mayuresh Aravind
Regd. No.	**:**	PHMRM-1380
Degree	**:**	M.Sc.(Post Harvest Management)
Name and designation of the Guide	**:**	Dr. K. H. Pujari Associate Professor, P. G. Institute of Post Harvest Management.

ABSTRACT

An investigation entitled "Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso." was undertaken at the Department of Post Harvest Management of Fruit, Vegetable and Flower Crops, Post Graduate Institute of Post Harvest Management, during the year 2014 – 2015.

The mango Cv. Alphonso fruits were treated with 0.5 per cent chitosan and kept at different temperature conditions *viz.*, 20^{0}C, 25^{0}C, 30^{0}C and ambient temperature (24-33^{0}C) and were analysed for changes in chemical parameters, PLW, ripening behaviour and sensory qualities.

It was observed that the fruits ripened at 25^{0}C or 30^{0}C temperature exhibited uniformity in ripening, good quality and better shelf life than those ripened at 20 ^{0}C and ambient condition. It was observed that the PLW, spoilage and shriveling were markedly reduced in 25^{0}C temperature storage condition as compared to other storage conditions. The chemical parameters such as TSS, reducing and total sugars exhibited an increasing trend while

decreasing trend in titratable acidity and moisture content was observed irrespective of treatments during storage.

As regards to the sensory evaluation, the mango fruits treated with 0.5 per cent chitosan and stored at 25^0C temperature obtained highest sensory score.

फळे, भाजीपाला आणि फूल पिकांचे काढणी पश्चात व्यवस्थापन विभाग
काढणी पश्चात व्यवस्थापन पदव्युत्तर संस्था
डॉ. बाळासाहेब सावंत कोकण कृषि विद्यापीठ, दापोली

प्रबंध शीर्षक	:	"चिटोसन आणि तापमान याचा हापूस आंबा पिकवणीवर होणारा परिणाम अभ्यासणे."
विद्यार्थीचे नाव	:	श्री. मयुरेश अरविंद पुरोहित.
नोंदणी क्रमांक	:	पी एच एम आर एम – १३८०
अभ्यासक्रम	:	एम् एस् सी (पी. एच. एम.)
संशोधन मार्गदर्शकाचे नाव आणि हुद्दा	:	डॉ. के. एच. पुजारी सहयोगी अधिष्ठाता काढणी पश्च्यात व्यवस्थापन पदव्युत्तर संस्था, किल्ला – रोहा, जि. रायगड.

<u>प्रबंध गोषवारा</u>

काढणी पश्चात व्यवस्थापन पदव्युत्तर संस्थेमध्ये फळे, भाजीपाला आणि फूल पिकांचे काढणी पश्चात व्यवस्थापन विभागात चिटोसन आणि तापमान याचा हापूस आंबा पिकवणीवर होणारा परिणाम अभ्यासणे हा प्रगोग सन २०१४-२०१५ या वर्षामध्ये डॉ. बाळासाहेब सावंत कोकण कृषि विद्यापीठ, दापोली येथे करण्यात आला. अभ्यास करताना हापूस आंबा फळे काढणीनंतर ०.५ टक्के चिटोसनच्या द्रावणात बुडवून २०° सेल्सिअस, २५° सेल्सिअस, ३०° सेल्सिअस तापमान आणि सर्व सामान्य तापमान (२४-३३° सेल्सिअस) ला ठेवण्यात आली. आंबा फळे पिकतांना होणारे रासायनिक बदल, वजनातील घट, तापमानाचा फळे पिकताना आंब्यांच्या प्रतिवर होणारा परिणाम अभ्यासला.

प्रयोगाअंती असे निष्कर्श आले की हापूस आंबा जर २५° सेल्सिअस किंवा ३०° सेल्सिअस नियंत्रित तापमानाला ठेवला तर आंबा पूर्णपणे व्यवस्थित पिकवला जातो आणि इतर २०° सेल्सिअस नियंत्रित तापमान आणि सर्व सामान्य तापमानात पिकवलेल्या आंब्यापेक्षा उत्तम प्रतिचा व चवीचा आंबा मिळतो. २५° सेल्सिअस तापमानाला साठवलेल्या आंबा फळात वजनतील घट, रोग आणि सुरकुतण्याचे प्रमाण हे इतर तापमानाला

साठवलेल्या फळांच्या तुलनेत कमी आढळून आले. रासायनिक घटक जसे की एकुण विद्राव्य घटक , शर्करा, सापेक्ष शर्करा यांचे प्रमाण वाढताना आढळून आले तर आम्लता आणि पाण्याचे प्रमाण कमी होताना आढळून आले.

अभिंद्रिय मूल्यमापन चाचणीनुसार ०.५ टक्के चिटोसन आणि २५° सेल्सिअस तापमानाला पिकवलेल्या आंब्यांना इतर प्रक्रियांपेक्षा सर्वाधिक गुण मिळाले.

फल, सब्जी एवं फूल फसलों का कटाई पश्चात प्रबंधन विभाग
कटाई पश्चात व्यवस्थापन पदव्युत्तर संस्था
डॉ. बाळासाहेब सावंत कोकण कृषि विद्यापीठ, दापोली

प्रबंध का नाम	:	"हापूस आम पकानेपर चिटोसन एवं तापमान का होनेवाले असर का अध्ययन."
छात्र का नाम	:	श्री. मयुरेश अरविंद पुरोहित.
पंजीकरण क्रमांक	:	पी एच एम आर एम – १३८०
विदयोपाधी	:	एम् एस् सी (पी. एच. एम.) डॉ. के. एच. पुजारी
संशोधन मार्गदर्शक का नाम एवं पदनाम	:	सहयोगी अधिष्ठाता काढणी पश्च्यात व्यवस्थापन पदव्युत्तर संस्था, किल्ला – रोहा, जि. रायगड.

<u>प्रबंध सार</u>

डॉ. बाळासाहेब सावंत कोकण कृषि विद्यापीठ, दापोली के फल, सब्जी एवं फूल फसलों का कटाई पश्चात प्रबंधन विभागमें हापूस आम फल पकने मे चिटोसन एवं तापमान का होनेवाले असर यह प्रयोग किया गया। ईस प्रयोग में आम फल ०.५ प्रतिशत चिटोसन द्रावण में डुबाकर भिन्न तापमान जैसे कि २०°, २५°, ३०° सेल्सिअस और साधारण तापमान (२४–३३° सेल्सिअस) मे रखकर पकाये गये। आम फलोको उनके रासायनिक गुणधर्मपर होनेवाले बदलाव, पी.एल.डब्ल्यू , फल पकने का ढंग तथा स्वादिष्ठता पर अध्ययन किया गया।

आम पर कि गयी इस अध्ययन से यह अनुमान निकलता हे की २०° सेल्सिअस तापमान में रखे हुए फलोंकी रासायनिक गुणधर्म में बदलाव, पक्वता, पी.एल.डब्ल्यू और स्वादिष्ठता अन्य फलों के मुकाबले कम होती दिखाई गयी। तथापि २५° और ३०° सेल्सिअस तापमान में पके फलों में अन्य फलों के मुकाबले समपक्वता और टिकाऊपन दिखाई गया। २५° सेल्सिअस तापमान में पके फलों में वजन मे घटाव, रोग और मुरझाने का प्रमाण

अन्य फलों के मुकाबले कम दिखाई गया । रासायनिक गुणधर्म जैसे की संपूर्ण घुलन घटक, चिनी का प्रमाण बढते प्रमाण मे पाये गये तथा आम्लता और पाणी का प्रमाण कम होते हुए दिखाई दिया ।

संवेदी मूल्यांकन के अनुसार ०.५ प्रतिशत चिटोसन एवं २५° सेल्सिअस तापमान में पके हुए आम फलोंने सबसे ज्यादा गुण हासिल किये।

CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.) or king of fruits is a member of *Anacardiaceae* family. The genus *Mangifera* contains several species that bear edible fruit. Most of the fruit trees that are commonly known as mangos belong to the species *Mangifera indica*. The other edible *Mangifera* species generally have lower quality fruit and are commonly referred to as wild mangoes and originating in South East Asia. Mango is one of the major fruit crops of Asia and has developed its own importance all over the world. Being a useful and delicious fruit, it is the part of culture and religion since the time immemorial. Besides taste and good qualities, it is called "The King of Fruits".

Mango (*Mangifera indica* L.) is one of the oldest tropical fruits and originated in Indo-Burma region. It has intimate association with cultural, religious, aesthetic and economic lives of Indians since time immemorial and hence it is a national fruit of India (Chatopadhyay, 1976).

Mango is not only delicious but also have full of nutritional value. The unripe fruit is acidic, astringent and antiscorbutic. (Shrivastava and Kumar, 2002). It is high in beta-carotene a precursor of vitamin A, and is a rich source of the vitamin C, protein, 0.38 g/100g fat, 14.98 g/100g carbohydrate and 11mg calcium/100g. The ripe mangoes are reported to have 83.46 - 86.70 per cent moisture, 0.82 g/100g, 14 mg phosphorus/100g, 0.16 mg iron/100g, 0.135-1.872 IU Vitamin A (mg/100g β-Carotene), 0.038g/100 g riboflavin and 36.4 mg/100g ascorbic acid, 12.0-23.0 TSS (0 B) and 0.12-0.38 percent acidity (Anon., 2010).

Mango is currently being grown in more than 111 countries spread over five continents in current FAO statistics. World scenario indicates that mango is grown on an area of 2784185 ha with total annual production of 22099225 Mt and average productivity is 7.9 Mt/ha. (Anon., 2014).

In the year 2013-2014, Indian mango production was 22.0 m Mt and the other countries which follow India in mango annual production were China (44), Thailand (2.65), Pakistan (1.95), Mexico (1.76), Indonesia (2.37), Brazil (1.17), Bangladesh (0.94) and and Nigeria (0.86) (Anon., 2014).

India ranks first in the world with total production of 18.00 m Mt from about 2.516 ha area, and productivity is 7.3 M tonnes/ha. In India the mango crop occupies 37.8 per cent of total fruit crop area and 22.1 per cent of total fruit crop production. Andhra Pradesh is leading state having (2737.01) Mt production of mango, followed by Uttar Pradesh (4300.98), Karnataka (1755.56), Telangana (1718.87),(Bihar (1367.57), Maharashtra (1212.50), Gujarat (1125.61), Orissa (751.00), West Bengal (430.71), Tamil Nadu (785.50), Jharkhand (517.92), and Kerala (441.09) which are the major mango growing states in India. India is producing about 50 per cent of world mango (Anon., 2014).

In Maharashtra state currently mango crop occupying the area of 4.85 lakh ha which is 19.29 per cent of total area with a total production of over 1212.50 metric tonnes 3.5 per cent of country's mango production. (Anon., 2014).

Konkan is the major and famous Alphonso mango producing region on the west coast of Maharashtra, crop occupying the area of 1.80 lakh ha which is 7.2 per cent of total area in country. Ratnagiri and Sindhudurga districts are mango baskets of Maharashtra. Almost 80 per cent area is covered by the single cultivar i.e. Alphonso which is locally called as 'Hapus'. The warm and humid climate throughout the year and rain free season from November to May prevalent in Konkan region is ideal for mango in general and Alphonso in particular. It enjoys virtual dominance both in domestic as well as in the international markets due to its typical sugar-acid blend, pleasant aroma, highly appreciable flavour and taste. Thus, farmers get premium prices.

India exports mango and mango based products to more than 80 countries, so it is an important foreign exchange earner, with an earning of Rs. 28543 lakh from export of 41280 Mt of fresh fruits in year 2014 (Anon., 2014).

Development of postharvest technologies related to quality maintenance and postharvest life extension is of great importance to consumer acceptability and marketing considerations (Zhong *et al.*, 2006 and Chien *et al.*, 2007). Among the compounds used for this purpose is chitosan, a high molecular weight cationic polysaccharide derived from chitin (Zhong and Xia, 2007) that happens to be nontoxic, biocompatible and biodegradable

(Shigemasa *et al.*, 1994) and was reported to delay ripening of mango fruits up to 9 days (Srinivasa *et al.*, 2002). Chitosan is soluble in dilute organic acids and has the potential to prolong storage life by controlling decay of many fruits, such as longan, pear, table grape, strawberry, litchi and chestnut (Zhang and Quantick, 1997; Jiang and Li, 2001; Pen and Jiang, 2003; Lin *et al.* 2008 and Hermandz-Munoz *et al.*, 2008). It has been reported that chitosan had antimicrobial activity through interactions between its positively charged molecules and the negatively charged microbial cell membrane. This interaction causes the disruption and death of the microbial cell (Young and Kauss, 1983 and Helander *et al.* 2001).

Mango ripening is a complex physiological process resulting in softening, colouring, sweetening and increases its aroma compounds so that ripening fruits are ready to eat or process. The associated physiological or biochemical changes are increased rate of respiration and ethylene production, loss of chlorophyll and continued expansion of cells and conversion of complex metabolites into simple molecules. Temperature plays an important role while ripening. High and low temperatures during ripening of mangoes affect quality.

Temperature affects the changes that occur during ripening results in the quality of ripe fruit and the marketable life of mango fruit. Apart from this, Alphonso mangoes have demand in the international market due to its flavour and taste. However, the export of these fruits to different countries is done by air, which is costly affair. To reduce the costs, the sea-transportation is the only alternative, but transportation by sea takes longer time and fruits are to be maintained in good quality and glossy appearance for long time. In order to increase the shelf life of mango use of chitosan and appropriate ripening temperature will boost up the export potential of this crop. With this view the research work on “Studies on effect of chitosan and temperature on ripening behaviour of Mango (*Mangifera indica* L.) Cv. Alphonso” was undertaken with following objectives.

1) To study the effect of chitosan on increasing shelf life of mango Cv. Alphonso.

2) To study the effect of temperature on ripening behaviour of mango Cv. Alphonso

CHAPTER - II

REVIEW OF LITERATURE

Mango fruits have comparatively shorter shelf life. Hence, the fruits have to be carefully handled during long distance transport and marketing both within the country and for export. The extension of shelf life of mangoes with minimum losses during storage would enable efficient marketing and export of these fruits. Several methods have been reported in the literature to increase the shelf life of mangoes. A brief review of literature related to physico-chemical composition, changes during ripening by chitosan treatment and controlled temperature storage conditions is presented in following pages under the heads as below.

2.1 Effect of chitosan and temperature on physical parameters mango Cv. Alphonso.

2.2 Effect of chitosan and temperature on ripening behaviour of mango Cv. Alphonso.

2.3 Effect of chitosan and temperature on chemical composition of mango Cv. Alphonso.

2.4 Effect of chitosan and temperature on sensory qualities of mango Cv. Alphonso.

2.1 Effect of chitosan and temperature on physical parameters of mango Cv. Alphonso.

2.1.1 Colour (L*, a* and b*)

Ethylene synthesis increases in climacteric fruits during ripening, and fruit ripening is accelerated. Synthesis of carotenoids increases as fruits ripen because ethylene stimulates synthesis of pigments such as anthocyanin and carotenoids and degradation of chlorophyll. As a result of increased carotenoid concentration during ripening, the L* value and hue angle decrease, but a* (redness), b* (yellowness) increase since colour of yellow pulp fruit such as mango develops from greenish-white to yellow during ripening, and pulp color changes from lighter (higher L* value) to deeper colour (lower L* value). (Kim 2005).

Wanwisa and Waraporn (2010) studied the mango pulp characteristics and noticed that the change in L*, a* and b* values was related to the visible changes over time, the pulp colour changed from light white-green to dark yellow/orange as the L* value decreased from bright to darker, and as the a* and b* values increased from green to red and light yellow to strong yellow, respectively.

Padda *et al.* (2011) studied that, the mesocarp tissue colour changed throughout ripening of Keitt mango variety, exhibiting a progressive decrease in L* value. Flesh a* value increased consistently during 14th day of ripening compared to b* value that showed significant changes only for the first 4 days of ripening.

Palafox H Carlosa *et al.* (2012) studied that the mango pulp colour a* value ranges from the negative (green) to the positive (red) scale while the b* value ranges from negative (blue) to positive (yellow) scale.

2.1.2 Physiological loss in weight (PLW)

Kapse *et al.* (1979) reported that the physiological loss in weight (PLW) of Malda, Mulgoa and Neelum cultivars of mango stored at room temperature was 15.20, 16.33 and 13.19 per cent, respectively at the end of shelf life.

Joshi and Roy (1985) reported that in Alphonso mango fruits during storage after attaining peak the physiological loss in weight (PLW) of the fruits was continuously increased.

Gole (1986) stored the fruits Alphonso, Pairi varieties of mango at lower temperature (12.70-15°C, 85-89 %RH). He further, reported that the physiological loss in weight (PLW) was least in all varieties at cold storage, but their palatability was lower than those stored at room temperature.

Kalra *et. al.* (1986) noticed that the physiological loss in weight (PLW) of Dashehari mangoes after 10 days of storage was highest (26.2%) at 30°C and the lowest (13.0 %) was at 25°C temperature.

Sethi (1987) reported that chausa mango ripened at 11.5 days storage recorded 14.0 per cent physiological loss in weight (PLW) at ambient temperature condition.

Patil (1990) studied that at ambient temperature storage, Alphonso, Ratna, Kesar and Pairi mango fruits showed physiological loss in weight (PLW) of 16.21, 15.13, 14.66 and 17.19 per cents, respectively after 20 days of storage period.

El-Ghaouth *et al.* (1991) reported that the weight loss of bell peppers and cucumbers coated with chitosan was lower compared to uncoated fruits.

Rangavalli *et al.* (1993) noticed that the per cent of physiological loss in weight (PLW) gradually increased during ambient temperature storage and reached maximum of 11.50 per cent at 8th day in Baneshan mango fruits.

Sahani *et al.* (1994) reported that in Amrapali mangoes, physiological loss in weight (PLW) was 12 per cent at 15th day of storage at ambient temperature.

Jiang and Li (2001) reported that the chitosan was found to be more effective at delaying weight loss in longan fruit.

Dong *et al.* (2004) noticed that the chitosan was found to be more effective at delaying weight loss in peeled litchi fruit.

Mahajan *et al.* (2005) studied the ripening behaviour of mango Cv. Chausa and reported that the weight loss level was considerably high at the end of ripening after three weeks of storage at 23°C temperature.

Ratanachinakorn *et al.* (2005) reported that the chitosan coating did not affect the weight loss of pummelo fruit.

Chien *et al.* (2007) observed that the chitosan coating retarded the weight loss of sliced organic mango fruit. After seven days of storage, the weight losses of the control and 2 per cent chitosan-coated sliced mango were 19.86 per cent (highest) and 10.27 per cent (lowest), respectively.

Chien *et al.* (2007) observed that the weight losses of chitosan-coated and uncoated organic citrus fruit increased continuously. However, the weight loss associated with coating treatments was slower than that of the uncoated citrus fruit.

Ribeiro *et al.* (2007) noticed that chitosan was found to be more effective at delaying weight loss in strawberry fruit.

Zhou *et al.* (2008) reported that when compared with the control samples, the coated pears also showed a significantly reduced weight loss during storage.

Hermandz-Munoz *et al.* (2008) observed that chitosan was found to be more effective at delaying weight loss in strawberry fruit.

Nongtaodum and Jangchud (2009) reported that the chitosan can retard weight loss of fresh cut mango significantly.

González-Aguilar *et al.* (2009) observed that the treatments also considerably delayed the weight loss of papaya cubes.

Abbasi *et al.* (2009) observed that the minimum weight loss occurred in fruits treated with crab chitosan as compared with untreated summer bahisht chausa mango fruits. It was found that as the storage time proceeded, the weight loss percentage was also increased and the maximum weight loss was recorded after 6 weeks of storage.

Figueroa *et al.* (2011) reported that the weight loss level was low at the fruit stored for 21 days at 22 °C and 80 to 85 per cent RH in mango cv. Ataulfo.

Jafarizadeh *et al.* (2011) observed in banana that low concentration of glycerol and an increasing concentration of chitosan reduced weight loss.

Bartolomeu *et al.* (2011) observed that after 45 days of storage, uncoated mangoes presented a higher mass loss in comparison with chitosan coated Tommy Atkins mangoes.

Wongmetha and Ke (2012) reported that the chitosan insignificantly reduced weight loss of mango fruits during cold storage.

Hanani *et al.* (2012) observed that chitosan coating reduced weight loss and could extend the post harvest life of star fruits up to 20 days as compared to the control samples which had a post harvest life of 12 days.

Hajirasouliha *et al.* (2012) observed in strawberry fruits that in storage period, a greatest weight loss of uncoated fruits was recorded than the coated samples with different chitosan concentrations.

Eman *et al.* (2013) reported that the chitosan with concentrations of 1.0 and 2.0 mM.l-1 significantly reduced weight loss per cent, compared to the control fruits in both investigated seasons.

2.2 Effect of chitosan and temperature on ripening behaviour of mango Cv. Alphonso.

Ramana *et al.* (1984) studied the low temperature storage and ripening behaviour of early and late harvested (15 days after early harvest) Alphonso mangoes. Further, they reported that the total storage life of 28 days (22 days at 12.8°C) and 6 days at room temperature (22 to 30 °C) for early and 20 days (15 days at 12.8 °C and 5 days at 22 to 30°C) was recorded for late harvested mangoes as compared to 16 and 14 days at room temperature stored fruits, respectively. The overall quality of fruits stored at low temperature ranged between fair and good at the end of storage of Alphonso.

Naik (1985) reported that the mango fruits stored at ambient temperature were more palatable than those at cool chamber.

The zero energy cool chamber delayed ripening, shriveling and disease incidence. However, the fruits ripened at ambient temperature were more palatable than those ripened in cool chamber (Anon.,1985).

Gole (1986) observed that the cool chamber delayed ripening and reduced disease incidence as compared to ambient temperature storage in mango.

Kalra *et. al.* (1986) studied the ripening behaviour of Dashehari mangoes at room temperature (25°C and 30°C) and observed that after 8 days, the fruits ripened well under ambient conditions.

Medlicott *et al.* (1986) reported that the mango fruits (Cv. Tommy Atkins) stored at 12°C did not ripen to full eating quality within 16 days of experiment. The best temperature range was 21 to 24 °C (69.8 to 75.2 °F). Mangoes ripened at 27 ^{0}C (80.6 °F) and higher temperatures had strong flavours and molted skin.

Badar (1990) carried out storage studies on Ratna and Kesar fruits of mango in cool chamber and at ambient temperature and found that the cool chamber reduced shrivelling and disease incidence and delayed ripening.

Patil (1996) studied storage of Alphonso, Ratna, Kesar, Pairi and Amrapali cultivars of mango and reported that pairi mango fruits recorded

fastest rate of ripening, followed by Amrapali, Ratna, Kesar and Alphonso at ambient temperature.

Padhye (1997) observed that the Alphonso mango fruits stored at cold storage (12.7-15.0°C, 85-89 %RH) condition had maximum shelf life (24-26 days) and minimum shrivelling and spoilage as compared to ambient temperature (28.4-31.3°C, 77% RH) and cool chamber storage (26.3-27.4°C, 95% RH).

Kader and Mitcham (2008) concluded that holding the fruit between 15.5 to 18°C during ripening provides the most attractive skin colour, however, the flavour remains tart unless the fruit are held an additional 2-3 days at 21-24°C (70-75°F). If mangoes are held at 27-30°C (80-86°F) during ripening, the skin of the fruit becomes mottled and the fruit acquire a strong flavour.

2.2.1 Spoilage

Muzzarelli and Rocchetti (1985) reported that the chitosan has itself ability to control some fungal diseases, which deteriorate fruit quality during storage.

El-Ghaouth *et al.* (1991a) reported that chitosan coated tomatoes were prevented by attack of *Penicillium* spp., *Aspergillus* spp., *Rhizopus stolonifer* and *Botrytis cinerea*. Using chitosan-derived coatings to delay ripening and reduce decay incidence in tomato fruit.

Chitosan might be attributed to its antifungal (Hernandez *et al.* 2008) and antimicrobial (Gil *et al.*, 2004) properties reported. Such properties have been reported to be due to the disruption and death of the microbial cell as a result of interactions between its positively charged molecules and the negatively charged microbial cell membrane (Helander *et al.,* 2001).

Chitosan have been reported to control decay of many fruits such as mango, pear, table grape and strawberry (Wongmetha and Ke, 2012; Lin *et al.,* 2008 and Munoz *et al.* 2008).

Wang *et al.* (2007) and Zhu *et al.* (2008) reported that the pathogenic microorganisms were diminished when mango fruits were coated with chitosan.

Abbasi *et al.* (2009) attributed chitosan's decay control to its induction of chinitase, a defense enzyme, which catalyzes the hydrolysis of chinitin, a common component of fungal cell walls, thus preventing fungi growth on fruits. It was found that the decay control of irradiated chitosan on mango fruits was better as compared to uncoated fruits. Chitosan treated fruit inhibited the growth of a wide variety of bacteria and fungi as compared to the control treatments. The fruit-spoiling fungi (*Colletotrichum gleosporioides*) were observed in untreated control fruits after 2 weeks and in irradiated chitosan coated fruits after 5 weeks of storage.

Bartolomeu *et al.* (2011) observed that after 45 days of storage, uncoated mangoes had also a damaged and wrinkled appearance, showing evidence of microbial spoilage and the flesh exhibited a slightly brownish colour in comparison with the chitosan coated Tommy Atkins mangoes.

Hajirasouliha *et al.* (2012) observed in strawberry fruits that after 7 days of storage, all uncoated samples showed visible signs of fungi while no sign of fungal decay could be detected by visual inspection of fruits coated with chitosan.

2.3 Effect of chitosan on chemical composition of mango Cv. Alphonso fruits.

2.3.1. Moisture (%)

Peter *et al.* (2007) studied that, moisture content underwent slight but insignificant reduction during ripening mango fruit (Cv. Dodo).

Othman and Mbogo (2009) analyzed Dodo and Virige mango varieties grown in, Tanzania found that, they had a moisture content ranging from 56.3- 86.1 per cent.

It is reported that the mango fruit contains nearly 81 per cent moisture up to the shelf life (Anon., 2013).

Okoth *et al.* (2013 a) studied that the at the unripe stage, mango fruit contained lowest moisture content of 79.96 per cent and the highest moisture content of 86.32 per cent in Ngowe and Kent cultivars of mango.

Sarkiyayi *et al.*(2013) reported that among the three varieties of mango namely Durshea (Big Seeded), Peter (Middle Seeded) and Julie (Small seeded),

the middle seeded (Peter) variety had the highest moisture content of 79.76 per cent, while the small seeded (Julie) had the lowest value of 72.04 per cent.

2.3.2. Total soluble solids (° B)

Joshi and Roy (1985) reported that in Alphonso mango fruits during storage, a rise followed by decline in T.S.S. was observed.

Naik (1985) reported that the changes in T.S.S. of Alphonso fruits at cool chamber were slower than those at ambient temperature.

Gole (1986) studied that during storage, T.S.S. of fruits was increased irrespective of varieties and storage conditions. At ripe stage, it was maximum (18.2 %) in Alphonso mango, followed by Pairi fruits. During post-ripening storage, T.S.S. was decreased till the end of storage period. In fruits, stored at cold storage (12.7-15.0^0 C) a slower development of T.S.S. was observed as compared to ambient temperature storage (28.4-31.3^0 C). However, towards the end of storage period better retention of T.S.S. was noticed.

Nagaraju (1989) reported that the fruits stored in cool chamber recorded delay in rate of increase in total soluble solids, compared to rapid change in T.S.S. of fruits stored at ambient temperature.

Badar (1990) carried out storage study on Ratna and Kesar varieties of mango fruits, and observed that the T.S.S. was higher at ambient temperature (28.4-31.3^0 C) in both the varieties; it was 22.5 per cent in Ratna and 18.5 per cent in Kesar at ripe stage. In cool chamber (25.8-27.0^0 C), the rate of increase in T.S.S. was slower in both the varieties. At the end of shelf life, T.S.S. decreased in both the storage conditions in both varieties.

Medlicott *et al.* (1990) reported that the T.S.S. of Amelic mangoes was 11.9 per cent after 21 days ripened at 12^0 C.

Medlicott *et al.* (1990) observed that the T.S.S. of Tommy Atkins magoes was maximum 11.3 per cent at 12^0 C compare to 8 per cent at 10^0 C.

Padhye (1997) carried out storage study on Alphonso mangoes and observed that the T.S.S. of mango fruit was maximum 18.73 per cent at ambient temperature (28.4-31.3^{0}C), compared to cool chamber (26.3-27.4^{0}C)

and cold storage (12.7-15.0 ^{0}C). However, the development of T.S.S. in cold storage was slower than the ambient and cool chamber condition.

Carrillo-Lopez *et al.* (1999) reported that the Haden mangoes stored at 13^{0}C exhibited increase in T.S.S. during ripening, reached a peak after 16 to 24 days and then decreased .The highest level of T.S.S. was 16.5 per cent and at the end of shelf life TSS level was in between 13 and 15 per cent.

Kulkarni (2000) observed that the T.S.S. in mango Cv. Ratna was maximum at ambient temperature condition as compared to cool chamber and cold storage conditions.

Mahajan *et. al.* (2005) reported that the TSS of Chausa mangoes after 21 days was maximum (23.88 %) when ripened at 28^{0}C temperature, where as it was 20.60 per cent in the fruits ripened at 23^{0}C temperature.

Ratanachinakorn *et al.* (2005) stated that the chitosan had no effect on TSS in pummelo fruits.

Munoz *et al.* (2008) stated that chitosan had no effect on TSS in strawberry fruits.

Nongtaodum and Jangchud (2009) reported that the fresh-cut mango slices that were not treated with chitosan contained higher total soluble solids than chitosan-coated mango slices.

Abbasi *et al.* (2009) reported that for all chitosan coated mangoes, there was an increase in TSS during storage as compared for the unirradiated chitosan treatment and control.

Bartolomeu *et al.* (2011) observed that after 45 days of storage, uncoated mangoes presented a higher total soluble solids in comparison with chitosan coated Tommy Atkins mangoes.

Jafarizadeh *et al.* (2011) observed in banana that the TSS was increased during the ripening process. The coated banana had minimum TSS at high concentration of chitosan.

Wongmetha and Ke (2012) stated that the chitosan had no effect on TSS in mango fruits.

2.3.3. Titratable acidity (%)

Verma and Bajpai (1971) studied the low temperature storage of Fazil Kalan, Taimuriya, Lucknow Safeda and Summer Bahist Chausa variety of mango which were stored at 20^0F and analysed at fortnightly interval of 3 months. They observed that the acidity decreased continuously regardless of cultivar.

Mann and Singh (1975 a, b) stored Langra and Dashehari fruits of mango at 45-48^0F and 85-90 per cent relative humidity. Dashehari fruits were cold stored immediately after harvest or after 2-4 days holding at ambient temperature. The fruits immediately cold stored and after 2 days were in good condition for up to 35 days while those stored after 4 days were good in condition up to 25 days. There was a decrease in acid content as the storage period increased in all treatments.

Kapse *et al.* (1979) reported that Malda, Mulgoa and Neelum varieties of mango stored at low temperature exhibited less reduction in acid content during entire period of storage.

Yuniarthi (1980) reported that the local mangoes stored (Cv. Arumanias) at room temperature (26^0C) for 14 days showed significant difference in acidity.

Joshi and Roy (1985[b]) reported that in Alphonso mango fruits during storage the continuous decline was observed in titratable acidity.

Naik (1985) studied the storage of Alphonso and Ratna fruits in cool chamber and reported that the titratable acidity of fruit went on declining throughout the storage in both varieties.

Gole (1986) observed that titratable acidity declined during storage in both the varieties (Alphonso and Pairi) at all storage conditions till the end of storage period. Ambient temperature (28.4-31.3^0C) storage exhibited greater reduction in acidity than cool chamber (26.3-27.4^0C) and cold storage (12.7-15.0^0C), of mango fruits. At harvest it was high (3.35%) & (3.60%) where as it was 0.20% and 0.15%, in Alphonso and Pairi fruits, respectively at ambient temperature.

Medilcolt *et al.* (1986) reported that mango fruits (Cv. Tommy Atkins) stored at 12^{0}C did not ripen to full eating quality within 16 days of experiment. The acid levels in these fruits were quite high.

Sethi (1987) recorded that a decrease in the titratable acidity of Chaunsa mango at ambient temperature.

Badar (1990) carried out storage study on Ratna and Kesar varieties of mango and reported that the titratable acidity decreased during storage at ambient temperature, in both varieties.

Chaplin *et al.* (1991) stored Kensington mangoes upto 4 weeks at 15, 10, 5 or 1^{0}C and then ripened at 20^{0}C. Storage at low temperature resulted, into an increase in acid content of fruits.

El-Ghaouth *et al.* (1991a) reported that chitosan coated tomatoes were higher in titratable acidity

Padhye (1997) observed that the titratable acidity declined throughout the storage at all storage conditions. The ambient temperature storage (28.4-31.3^{0}C, 77% RH) exhibited greater reduction in acidity than storage of mango fruits in either big size cool chamber (26.3-27.4^{0}C, 95% RH) and cold storage (12.7-15.0^{0}C, 85-89 %RH).

Carrillo-Lopez (1999) carried out study on Haden mangoes stored at 13^{0}C for 32 days and reported a continuous decline in titratable acidity, from 0.83 to 0.1%, during the first 12 to 16 days of storage.

Kulkarni (2000) observed that the titratable acidity continuously decreased at all storage conditions. Cold storage (12.0-15.0°C, 85-90% R.H.) showed slower reduction of acid content than ambient condition (20.4-28.6°C, 78% R.H.), and cool chamber (19.0-23.0°C, 95 %R.H.) storage.

Jiang *et al.* (2004) reported that the effect of chitosan coatings on longan fruit found that titratable acidity decreased during storage.

Mahajan *et. al.* (2005) reported that the acid content of chausa mangoes was 0.12 per cent after 14 days stored at 23^{0}C temperature

Nongtaodum and Jangchud (2009) reported that the coating with chitosan did not affect the total acidity of samples for all storage durations

in mango fruits.

Pongphen *et al.* (2010) recorded that 0.83 per cent of titratable acidity in Mango Cv. Nam Dok Mai. They reported that chitosan treatment at 0.5 per cent is good for maintainance of titratable acidity.

Jafarizadeh *et al.* (2011) observed in banana that the concentration of chitosan had significant effect on titratable acidity of coated banana.

Wongmetha and Ke (2012) stated that the titratable acidity of mango slightly increased and application of all treatments did not delay the reduction of titratable acidity during storage.

Bartolomeu *et al.* (2011) observed in mango that the acidity of uncoated and coated mangoes was 0.77 and 0.80 per cent respectively, at the beginning period and decreased until 45 days of storage to different significantly values 0.12 and 0.40 per cent, respectively. The uncoated mangoes presented a lower titratable acidity in comparison with chitosan coated Tommy Atkins mangoes.

Eman *et al.* (2013) found that all chitosan concentrations reduced titratable acidity of mango fruits compared to control fruits in both seasons, but this reduction was insignificant in the first season only for the 0.5 per cent chitosan concentration.

2.3.4. Sugars (Reducing and total sugars)

Verma and Bajpai (1971) studied the low temperature storage of Fazli Kalan, Taimuriya, Lucknow Safeda and Summer Bahist Chausa, which were stored at 20^0F and analysed at fortnightly interval of 3 months. In Fazli Kalan, reducing sugars decreased gradually in storage and reverse was true for non reducing sugars. In Summer Bahist Chausa, Taimuriya, Lucknow Safeda both the sugars were high for some time and then decreased.

Mann and Singh (1975 a) stored Langra and Dashehari fruits of mango at 45-48^0F and 85-90 per cent relative humidity and observed an increase in total sugars as the storage period increased in all treatments.

Laxminarayana (1977) observed that in mango fruits of cultivars Haden Irwin and Kent stored at 25^0C the total sugars was found to increase.

Kapse *et al.* (1979) reported that Malda, Mulgoa and Neelum varieties of mango stored at low temperature had no proper development of sugars during entire period of storage.

Joshi and Roy (1985) reported that in Alphonso mango fruits during storage a rise followed by a decline in reducing and total sugars was observed.

Naik (1985) studied the storage of Alphonso and Ratna fruits in cool chamber and reported that the sugars were increased irrespective of varieties during storage.

Gole (1986) observed that the sugars were increased during all storage conditions irrespective of varieties of mango. The fruits at ambient temperature (28.4-31.3^0 C) recorded the maximum content of sugars than either cool chamber (26.3-27.4^0 C) or cold storage (12.7-15^0 C).

Sethi (1987) reported an increase in the reducing sugar content in Chausa mango ripened under ambient temperature storage condition.

Badar (1990) carried out a storage study on Ratna and Kesar varieties of mango and reported that the sugars were increased during storage at ambient temperature, irrespective of varieties.

Padhye (1997) reported a gradual increase in sugar content till peak during ripening, followed by a decline towards the end of storage irrespective of storage conditions. The fruits at ambient temperature (28.4-31.3^{0}C, 77% RH) recorded maximum sugars content and reported low in either big size cool chamber (26.3-27.4^{0}C 95% RH) or cold storage (12.7-15.0^{0}C, 85-89 % RH).

Kulkarni (2000) observed that sugars were increased up to peak ripening period and then declined towards the end of shelf-life irrespective of storage condition. The sugars were maximum at ambient temperature (20.4-28.6°C, 78 % R.H.) followed by cool chamber (19.0-23.0 °C, 95 % R.H.) and cold storage (12.0-15.0°C, 85-90 % R.H.).

Abbasi *et al.* (2009) reported that the gradual increase in reducing sugars in coated mango fruits as compared to control treatment might be due to its slow ripening process.

Eman *et al.* (2011) reported that the chitosan also reduced total sugar per cent in chitosan-treated fruits compared to the control, but significant reductions were only recorded for the 1.0 and 2.0 mM.l^{-1} concentrations in season 2012. This effect of chitosan might be attributed to its role in reducing

weight loss (to be discussed latter in this study) and consequently maintaining humidity in fruits leading to reduced total sugar per centage.

2.4 Effect chitosan and temperature on sensory qualities of mango Cv. Alphonso

Jiang and Li (2001) reported that the chitosan treated longan fruit had good eating quality even after 30 days of storage at 2° C. Chitosan retained fruit quality and no off flavour was developed than control.

Dong *et al.* (2004) reported that the chitosan coating improved the quality and extended the shelf life of peeled litchi fruit.

Devlieghere *et al.* (2004) reported that the chitosan coating on organic fruits delayed the decrease in sensory quality and extended the shelf-life. However, some authors have described that the use of edible coatings such as chitosan negatively affected the flavour and aroma of fruit.

Munoz *et al.* (2006) who reported the influence of the chitosan on strawberries stored at 20°C for 4 days showing better maintenance of eating quality.

Chien *et al.* (2007) observed that both the control and the chitosan-coated sliced mango fruit were still commercially satisfactory after they had been stored for three days. However, after being stored for seven days, the control became unacceptable for the market whereas the good quality of the chitosan-coated sliced fruit was retained.

Chien *et al.* (2007) observed that the taste and the color scores of red pitaya pulp also declined quickly during storage. After 7 days, the control became unacceptable, while the chitosan-coated fruit retained acceptable quality.

Zhou *et al.* (2008) observed that the taste score of coated Huanghua pears were also generally higher than the uncoated pears.

Hernandez Munoz *et al.* (2008) who reported that the chitosan coating improved the quality and extended the shelf life of strawberry fruit. The chitosan coating delayed the sensory quality and deterioration of peeled litchi fruit (Dong *et al.*, 2004) and the change in eating quality (Jiang and Li, 2001).

Simoes *et al.* (2009) reported that whiteness and consequently overall visual quality of carrot sticks were strongly affected by the edible coating. White surface discoloration was significantly controlled by the edible coating and thus, the overall visual quality of coated carrot sticks was higher than that of uncoated carrot.

Ali *et al.* (2011) observed that the chitosan has been proved one of the best preservative material that delay the ripening process by inhibiting the respiration rate in the Eksotika II papaya fruit during cold storage.

Hajirasouliha *et al.* (2012) observed in strawberry fruits that at the first day, no significant differences were notified between coated and control samples. Over the time, consumers showed a preference of coated fruits by the higher mean acceptance scores achieved owing to the more glossy appearance but no changes in colour for coated samples. By the 7^{th} day of storage, uncoated fruits fell below the limit of suitability. Coating concentration dramatically impressed the sensory quality of fruits due to more protection of flavour, texture, aroma, sweetness and inhibition spoilage occurred by chitosan. Overlay, all the coated fruits showed a greater visual acceptance than that of control samples. The greater visual acceptance for coated strawberries by consumers contributed to the lower levels of wilting and darkening.

Patil (2012) reported that the mango fruits stored at 20^0 C storage condition showed poor performance in organoleptic score. The mango fruits ripened at 30^0 C temperature storage had more palatability as compared to these ripened at 20^0 C, 25^0 C and ambient temperature storage condition.

Munde (2014) observed that the mango fruits ripened at 25^0 C and 30^0 C temperature storage had better colour, flavour and texture than those ripened at either 20^0 C or room temperature.

CHAPTER – III

MATERIAL AND METHODS

The present investigation "Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso" was undertaken in the Department of Post Harvest Management of Fruit, Vegetable and Flower Crops,Post Gratuate Institute of Post Harvest Management Killa-Roha. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (M.S.) during the summer season of 2015. The material used and the methods adopted during the investigation are as given below.

3.1 General description

3.1.1 Location

The experiment was carried out at PGI-PHM Laboratory, Dr. B.S.K.K.V, Dapoli. The orchard is located at 17^{0} 45', North latitude and 73^{0} 12', East longitude and at an elevation of 280 meters above MSL. The climate of Dapoli is warm and humid with the mean annual rainfall of 4721.1 mm, mostly received from 1st June to 15th October.

3.1.2 Experimental material

The physiologically mature, mango fruits Cv. Alphonso were harvested during morning hours (from 9.00 a.m. to 11.00 a.m.) from mango orchard (plot No.11) of the Department of Horticulture, College of Agriculture, Dapoli. (M.S.). Harvested fruits were treated with 0.5 per cent concentrations of chitosan for five minutes. Then, the fruits were kept in temperature controlled chambers at 20^{0}C, 25^{0}C, 30^{0}C with 80% relative humidity and at ambient temperature (27.7 ^{0}C to 33.3 ^{0}C with 56.83-83.83 % R.H.) for further investigation. Thirty six fruits for each replication were used for each treatment.

3.1.3 Experimental details

Experimental Design : Factorial Completey Randomized Design

No. Of treatments : Four

No. Of replication : Four

3.1.4 Treatments details

The fruits were kept for ripening at following temperature in temperature controlled chamber.

(A) Factor A: Temperature

T_1 : 20˚ C

T_2 : 25˚ C

T_3 : 30˚ C

T_4 : Ambient temperature

(B) Factor B : Storage period

3.2 Observations recorded

3.2.1 Physical parameters (colour L*, a* and b*)

The mango pulp colour L*, a* and b* values were measured by Konica Minolta handheld colourimeter.

3.2.2 Physiological loss in weight (PLW)(%)

Ten fruits were selected from each treatment for studying physiological loss in weight. The loss in weight was calculated by reading the difference between two consecutive weights recorded from initial day and every three days interval and finally per cent physiological loss in weight was recorded by using the formulae as given bellow.

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

3.2.3 Ripening behaviour of mango fruits

To record the ripening pattern, the fruits were categorized into five groups.

1) Green (harvesting stage).
2) Turning (when a slight tinge of yellow colour appeared on the peel).

3) Half ripe (when 50 per cent of fruit peel turned yellow).

4) Ripe (when fruit fully turned yellow).

5) Spoilage percentage of fruits (%) & shriveling

Each fruit thoroughly examined by every three days interval. for any visible symptoms of spoilage and shriveling during storage at ambient temperature conditions and accordingly spoilage percentage was calculated.

3.3 Changes in chemical composition of mango Cv. Alphonso fruits during ripening

Randomly selected 4 fruits from each treatment were employed for estimating the following chemical constituents of the fruit.

3.3.1 Moisture (%)

The moisture content of mango fruits was determined by using a Contech moisture analyser (model CA-123) at 100^0C.

3.3.2 Total soluble solids (^{0}Brix)

Total soluble solids (T.S.S.) were determined with the help of automated refractometer (Erma Japan, 0-32° B) and all the values were measured at 25°C temperature.

3.3.3 Titratable acidity (%)

A known quantity of pulp titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. In case of solid sample, a known sample was blended in mortar and pestle with 20-25 ml of distilled water. It was then transferred to 100 ml volumetric flask, made up the volume and filtered. A known volume of aliquot (10 ml) was titrated against 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator (Ranganna, 1997). The results will be expressed as per cent anhydrous citric acid.

$$\textbf{Total acidity}(\%) = \frac{\text{Normality of alkali X Titre reading X Volume made X Equivalent weight of acid}}{\text{Weight of sample taken X Volume of sample taken for estimation X 1000}} X100$$

3.3.4 Reducing sugars (%)

The reducing sugars were estimated by using Lane and Eynon (1923) method with modification suggested by Ranganna (1997). A known weight (5 g) of sample will be blended with distilled water using lead acetate (45%) for precipitation of extraneous material and potassium oxalate (22%) to delead the solution. This lead-free extract was used to estimate reducing sugars by titrating against standard Fehling's mixture (Fehling's A and B) using methylene blue as an indicator to a brick red end point.

$$\textbf{Reducing sugars}\ (\%) = \frac{\text{Factor X Dilution X 100}}{\text{Titre reading X Weight of sample}}$$

3.3.5 Total sugars (%)

The total sugars were estimated by the same procedure of reducing sugars after acid hydrolysis of an aliquot of deleaded sample with 35 per cent hydrochloric acid, followed by neutralization with sodium hydroxide (40%). This filtrate will be used for titration against standard Fehling's mixture (Fehling's A and B) using methylene blue as an indicator to brick red end point (Ranganna, 1997).

$$\textbf{Total sugars}\ (\%) = \frac{\text{Factor X Dilution}}{\text{Titre reading X Weight of sample}} \text{X100}$$

3.4 Sensory evaluation

The ripe fruits were examined for their sensory qualities when they were ripe for accessing the colour, flavour and texture. It was carried out by a panel of 5 judges with 9 point Hedonic scale score (Amerine *et al.,* 1965) as given below.

Organoleptic score	Rating
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately

2	Dislike very much
1	Dislike extremely

The overall rating was obtained by averaging score of evaluation. The fruits with score of 5.5 and above were rated as acceptable.

3.5 Statistical analysis

The data obtained was analysed statistically as per the method suggested by Panse and Sukhatme (1995).

CHAPTER- IV

RESULTS AND DISCUSSION

The present investigation "Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso", was carried out in the Department of Post Harvest Management of Fruit, Vegetable and Flower Crops, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (Maharashtra State), India during the year 2014-15. The results of the investigation are presented and discussed in this chapter under following headings:

4.1 Effect of chitosan and different temperatures treatment on physical parameters of mango Cv. Alphonso fruits.

4.2 Effect of chitosan and different temperatures treatment on ripening behaviour of fruits at different storage conditions.

4.3 Effect of chitosan and different temperatures treatment on chemical composition of mango Cv. Alphonso fruits

4.4 Effect of chitosan and different temperatures treatment on sensory evaluation of mango Cv. Alphonso fruits.

4.1 Effect of chitosan and different temperatures on physical parameters of mango Cv. Alphonso fruits

4.1.1 Effect of chitosan and temperature on peel colour (L*, a* and b*) of mango Cv. Alphonso fruits.

4.1.1.1 L* value for peel colour

The data on the changes in L* value for peel colour of mango fruit Cv. Alphonso due to effect of temperature during ripening are presented in Table 1 and graphically depicted in Fig.1 The positive L* value represents lightness of the peel while negative L* represents darkness of the peel. It is observed from the data that the lightness of the mango fruit peel showed an increasing trend as ripening process progressed.

It was observed from the data that on an average maximum (38.55) L* value was observed in the treatment T_4 while minimum mean L* value (36.45) was recorded in T_1 i.e. 20°C. It was also noticed from the results that the L* value

was increased significantly with increase in the storage temperature. The treatment T_1 and T_2 are at par with each other.

As regards the storage, there was an increase in the L* value was observed during 16 days of storage period. The average minimum L* value was observed at initial stage irrespective of the treatments while average maximum L* value (45.30) on 16th day stage.

The interaction effects between various temperatures and the storage were statistically significant. The average minimum L* value (32.02) of mango peel was recorded in treatment T_1 at initial stage while the maximum (46.26 to 45.20) mean L* value was observed after 16 days stage in all the treatments except the treatment T_3.

4.1.1.2 a* value for peel colour

The data on the changes in a* value for peel colour of mango fruit Cv. Alphonso due to effect of temperature during ripening are presented in Table-2 and graphically depicted in Fig.-2. It was observed from the data that the treatments had significant effect on the a* value for peel colour of the Alphonso mango fruits.

It is observed from the data that on an average maximum (1.92) a* value for peel colour for alphonso mango was observed in the treatment T_4 while minimum (-2.13) mean a* value was recorded in treatment T_1 i.e. 20°C. The treatments T_1 and T_2 were at par with each other and treatments T_3 and T_4 were at par with each other.

With respect to storage, an increasing trend in a* value for colour of mango Cv. Alphonso fruits was noticed during 16 days storage period. The average minimum a* value (-9.03) was observed at initial stage while average maximum a* value (15.48) on 16th day stage.

The interaction effects between various temperatures and the storage were statistically significant. After 16 days storage, the maximum mean for a* value of peel of mango fruit was recorded irrespective of the treatments and the minimum mean for a* value was observed at initial stage and at 4 days of storage period irrespective of the treatments.

4.1.1.3 b* value for peel colour

The data pertaining to the b* value for peel colour of Alphonso mango fruits are presented in the Table 3 and graphically illustrated in Fig. 3. The positive b* value represents yellowness of peel.

There was a significant effect of treatment on the colour of mean b value for peel colour of Alphonso mango. It was observed from the data that on an average maximum (65.05) b* value was observed in the treatment T_4 which was at par with the treatment T_3 while minimum (61.71) mean b* value was recorded in T_1 i.e. 20° C but at par with treatment T_2.

As regards the storage, there was an increase in the b* value during 16 days storage period. The average minimum b* value (49.14) was observed at initial stage while average maximum b* value (77.13) was recorded on 16th day stage.

The interaction effects between various temperature and the storage were statistically non significant.

The similar trend in colour change in mango peel of fruit was also reported by Thomas *et. al.* (2005), Padda *et. al.* (2011) in mango fruit and Zagade (2012) in mango Cv. Alphonso.

4.1.2 Effect of chitosan and temperature treatment on pulp colour (L*, a* and b*) of mango Cv. Alphonso fruits.

4.1.2.1 L* value for pulp colour

The data on changes in L* value for colour of mango pulp Cv. Alphonso due to temperature during ripening are presented in Table 4 and graphically depicted in Fig. 4 The positive L* value represents lightness of the pulp while. It was observed from the data that the lightness of the mango fruit pulp showed decreasing trend with increase in ripening process during the storage period. It was observed from the data that on an average maximum 52.12 L* value was observed in the treatment T_1 which was significantly superior to the rest of the treatments followed by the treatment T_4 (50.71). The minimum mean L* value (50.72) was recorded in T_2 i.e. 25^{0}C. It was also noticed from the results that the L* value was decreased significantly with increase in storage period. The treatments T_2, T_3 and T_4 were at par with each other.

As regards the storage there was a decrease in the L* value during 16 days of storage period. The average maximum L* value (56.26) was observed in at initial stage while average minimum L* value (47.73) on 16th day stage.
The interaction effects between various temperatures and the storage were statistically significant. After 12th and 16th day storage, the minimum mean for L* value of mango pulp fruit was recorded in all the treatments and it was also at par with the treatment T_3 and T_4 on 8th day of storage while the maximum (57.30) mean L* value was observed in all the treatments at initial stage as well as in the treatment T_1 and T_2 on 4th day of storage.

4.1.2.2 a* value for pulp colour

The data on the changes in a* value for pulp colour of mango Cv. Alphonso due to temperature during ripening are presented in Table 5 and graphically depicted in Fig. 5. It was observed from the data that the treatments had significant effect on the a* value for pulp colour of the Alphonso mango fruits. It is observed from the data that on an average maximum (16.13) a* value for pulp colour alphonso mango was observed in the treatment T_4 which was significantly superior to all the treatment followed by the treatment T_3 (15.94) which was at par with treatment T_2 (14.90).The minimum (13.53) mean a* value was recorded in T_1 i.e. 20°C. The treatment T_1 and T_2 were at par with each other.
With respect to storage, an increasing trend in a* value for colour of mango Cv. Alphonso fruits was noticed with the increase in the temperature and storage period. The average minimum a* value (6.46) was observed at initial stage while average maximum a* value (25.39) on 16th day stage.
The interaction effects between temperature and the storage were statistically non significant.

4.1.2.3 b* value for pulp colour

The data pertaining to the b* value for pulp colour of Alphonso mango fruits are presented in the Table 6 and graphically illustrated in Fig. 6. The positive b* value presents yellowness of pulp.
There was a significant effect of temperature on b* value for colour of mango Cv. Alphonso mango. It was observed from the data that on an average maximum 74.46 b* value was observed in the treatment T_4 which was at par

with treatment T_3 (74.18).The minimum (71.17) mean b* value was recorded in T_2 i.e. 25^0C. The treatments T_1 and T_2 were at par with each other.
As regards the storage, a increase in the b* value was observed during 16 days of storage period. The average minimum b* value (63.33) was observed at initial stage while average maximum b* value (79.71) on 16th day stage
The interaction effects between various temperatures and the storage were statistically significant. After 12 and 16 days storage, the maximum mean b* value for colour of mango pulp was recorded in the treatments as well as on 8th day it was maximum in the treatments T_2 ,T_3 and T_4. The minimum (63.05) mean for b* value was observed at 0 day in all the treatments and in the treatments T_1 and T_2 at 4th day of storage.
The similar trend in colour change in mango pulp of fruit was also reported by Thomas *et. al.* (2005), Padda *et. al.* (2011) in mango fruit and Zagade (2012) in mango Cv. Alphonso.

4.1.3 Physiological loss in weight (PLW)(%)

The data on the effect of chitosan and different temperature treatments on physiological loss in weight of mango Cv. Alphonso fruits during storage are presented in Table 7 and depicted in Fig.7. It could be revealed from the data that PLW increased continuously till the end of storage period irrespective of storage conditions. The significant differences were observed between the treatments throughout the storage. It was observed from the data that the treatment T_4 i.e. ripening at ambient temperature recorded maximum (13.15%) mean PLW which was significantly superior to rest of the treatments, followed by the treatments T_3 and T_2. The treatment T_1 recorded the lowest (5.03%) mean physiological loss in weight of mango Cv. Alphonso. Thus, it is cleared from the data that the physiological loss in weight increased with increase in the ripening temperature.
As regards to storage, there was an increase in the physiological loss in weight as the storage period was increased. At 4th day of storage, the mean PLW was 4.18 per cent however and at 16th day, it was increased to 16.97 per cent irrespective the treatments.
The interaction effects between the treatments and storage period were found to be statistically significant. The lowest PLW was recorded (2.06 %) in the treatment T_1 (20°C) on 4th day while highest PLW was recorded (24.31 %) in

the treatment T_4 (ambient storage) on 16th Day. The fastest and maximum increase in PLW was observed at ambient temperature storage. The continuous increase in PLW values at all storage condition could be as a result of loss of moisture from the fruit peel through respiration and transpiration. The observations in accordance with this findings were also reported by Joshi (1983), Naik (1985), Gole (1986), Badar (1990), Padhye (1997) and Kulkarni (2000) in mango. The fruits at 20°C showed minimum physiological loss in weight (PLW), followed by those kept at 25°C, 30°C and ambient temperature conditions. The low temperature and high humidity prevalent in 20°C and 25°C would be responsible for reduction in PLW by reducing moisture loss due to decrease in respiration rates. Joshi (1983) and Gole (1986) reported similar observations while working on cold storage of mango Cv. Alphonso and Naik (1985), Gole (1986) and Badar (1990) while working on cool chamber storage of certain varieties of mango. At the end of storage period the mango fruits recorded the maximum PLW while minimum was recorded in fruits at 20°C storage. So as far as reduction in weight loss of mango fruits was concerned the ripening of mango fruits at 20°C was better over other ripening temperatures.

4.2 Effect of chitosan and different temperature on ripening, shriveling and spoilage

The data on ripening, shriveling and spoilage of mango fruits Cv. Alphonso during storage under different temperatures are presented in Table 8 to 11. It was revealed from the data that the ripening was fastest at ambient temperature (T_4), followed by 30°C (T_3), 25°C (T_2), and 20°C (T_1) temperatures. Further, it was interesting to note that the ripening was delayed at 20°C temperature, followed by 25°C and 30°C when compared with ambient temperature. The ripening peak was noticed on 8 day at ambient temperature and 30°C temperature. At 20°C and 25°C temperature, it was on 12th day. This could be due to low temperature and high humidity prevalent in the treatments T_1 (20°C temperature) and T_2 (25°C temperature) hindered or slowed down the ripening process.

This finding was in conformity to the observations reported by Joshi (1983), Gole (1986) and Badar (1990), Padhye (1997) on cold storage of mango fruits and Naik (1985), Gole (1986), Kulkarni (2000) on cool chamber storage of

mango fruits. The ripening process was commenced earliest in fruits at ambient temperature and 30°C (4th day) while at 25°C, the ripening was begun on 8th day with 52.5 per cent fruits at half ripe stage. At 20°C temperature, the ripening was started on 12th day which was too late compared to ambient, 25°C, and 30°C temperatures.

As far as spoilage was concerned, the maximum spoilage was occurred in the treatment T_4 i.e ambient temperature both in terms of shriveled and diseased fruits. The shriveling percentage was found maximum at ambient temperature.

At 20°C storage condition, the fruits remained firm which resulted in minimum shrivellage, where as fruits stored at the 25°C for ripening exhibited a substantially reduced and delayed shriveling of fruits as compared to ambient temperature. Such a significant reduction in shriveling at 20°C storage as well as 25°C storage condition might be due to low temperature and high humidity conditions prevalent under these storages which reduced moisture loss and hence, the shriveling of mango fruits was minimum at 20°C storage condition, followed by 25°C storage condition. The observations analogous to this finding were also reported by Mann and Singh (1975b), Joshi (1983), Ramana *et al.* (1984), Gole (1986) with respect to cold storage and Naik (1985), Gole (1986), Badar (1990) regarding cool chamber storage of mango fruits.

The 25°C storage condition also reduced the disease incidence as compared to that of at 30°C and ambient temperature. The spoilage was not only reduced but also delayed at 25°C storage condition. The findings was in conformity with the observations reported by Joshi (1983), Ramana *et al.* (1984), Gole (1986) in case of cold storage while Naik (1985), Gole (1986), Badar (1990), Padhye (1997) regarding the cool chamber storage of mango fruits.

4.3 Effect of chitosan and different temperatures on changes in chemical composition of mango fruits Cv. Alphonso

4.3.1. Moisture (%)

The data for moisture content of the Alphonso mango fruits during ripening are presented in the Table-12 and graphically depicted in Fig.8. A decreasing

trend was observed in the moisture content of Alphonso fruits during fruit ripening and storage period advancement.

It was observed from the data that on an average maximum (79.52 %) moisture content was observed in the treatment T_1 which was significantly superior to rest of the treatments followed by the treatment T_2 (77.40 %). The minimum (73.26 %) moisture content was recorded in the treatment T_4 i.e. control, followed by the treatment T_2.

As regards the storage, there was decrease in the moisture content during 16 days of storage period. The moisture decreased from 80.85 per cent (at initial stage) to 71.48 per cent (on 16th day stage).

The interaction effects between various temperatures and the storage were statistically significant. After 16 days of storage, the minimum (66.47%) mean moisture content of mango fruit was recorded in the treatment T_4 and the maximum (81.63 %) mean moisture content was observed at 0 day of storage in the treatment T_1.

The similar trend in moisture content in mango fruits was also reported by Satyavati (1972), Ghosh *et al.* (1985) in Bombay green, Sardar pasand cultivars of mango, Patil (1996) in Alphonso, Ratna, Kesar, Pairi and Amrapali cultivars of mango and Kshirsagar (2004) in Suvarnarekha, Ratna and Totapuri cultivars of mango.

4.3.2 Total soluble solids

The data on changes in total soluble solids (°B) content of mango fruit cv. Alphonso due to temperature during ripening are presented in Table 13 and graphically depicted in Fig. 9.

It was noticed from the data that on an average maximum (14.44°B) mean TSS was observed in the treatment T_4 i.e. Control, which was significantly superior to all the treatments except the treatment T_3 which was at par with the treatment T_4. The minimum (13.34°B) mean TSS was recorded in T_1 i.e. 20°C but it was at par with treatment T_2 and T_3.

As regards storage, an increasing trend in TSS content of mango Cv. Alphonso was noticed up to 16 days of storage. At initial stage, the mean T.S.S was 8.26° Brix which increased up to 18.38 ° Brix at 16th day.

The interaction effects between various temperatures and the storage were statistically non significant.

The slower increase in T.S.S. of the mango fruits either at 25°C and 20°C than 30°C and ambient temperature storage, could be attributed to lower temperature and high humidity during storage resulting in slower rate of ripening. The observations analogous to this finding were also reported by Joshi (1983), Ramana *et al.* (1984) at cold storage and Naik (1985), Gole (1986) at cool chamber storage (26.3- 27.4°C).

4.3.3 Titratable acidity

The data pertaining to titratable acidity noted at four days intervals up to fully ripened stage of mango fruits Cv. Alphonso are presented in Table 14 and graphically illustrated in Fig.10.

It was observed from the data that the treatments showed a significant effect on the titratable acidity of mango Cv. Alphonso during ripening.

It was observed from the data that on an average highest (1.93 %) mean acidity was recorded in the treatment T_1 which was statistically superior to all the treatments, followed by the treatments T_2 and T_3 (1.75 & 1.68 %, respectively). The lowest (1.58 %) mean titratable acidity was observed in T_4 i.e. ambient temperature. It was noticed from the results that the titratable acidity decreased significantly with increase in the temperature during ripening. The 20°C storage treatment exhibited lesser change in titratable acidity level of mango Cv. Alphonso than other treatments.

As regards storage, decreasing trend in titratable acidity content of mango Cv. Alphonso was noticed and the mean acidity significantly decreased from 3.59 at initial stage to 0.15 per cent after 16 days of storage.

The interaction effects between various temperatures and the storage were statistically significant. The maximum (3.67 %) titratable acidity in mango fruit was recorded in the treatment T_1 i.e. 20°C at initial stage while minimum titratable acidity was observed in all the treatments after 16 days of storage. However, on the 12^{th} day of storage, the lowest (0.33 %) acidity was observed in the treatment T_4 i.e ambient temperature storage and maximium (1.00 %) in the treatment T_1.It is also clear from the data the titratable acidity decline with increase in the storage temperature.

This decline in acidity throughout the storage period as shown could be attributed to degradation of organic acids during ripening and post ripening storage. Identical observations were also reported by Verma and Bajpai

(1971), Mann and Singh (1975a), Kapse *et. al.*(1979). The slower decrease in acidity during 20°C and 25°C storage could possibly be due to delay in ripening and slower degradation of organic acids as result of low temperature and high humidity prevalent at these conditions. This findings was in conformity to the observations reported by Joshi (1983), Gole (1986), Padhye (1997) on cold storage and Naik (1985), Gole (1986), Badar (1990) and Kulkarni (2000) on cool chamber storage of mango.

4.3.4 Reducing sugars

The data on reducing sugar content recorded at four days interval up to fully ripened stage of mango Cv. Alphonso are presented in Table 15 and graphically depicted in Fig. 11. It was observed that there was a significant difference among the treatments with respect to reducing sugar content. The treatment T_4 recorded highest (2.33%) mean reducing sugar content of mango Cv. Alphonso, which was followed by the treatment T_3. The minimum (2.04%) reducing sugar content was observed in mango fruits at 20° C and 25°C temperature.

The interaction effects between treatments and storage were statistically significant. Maximum (3.33%) reducing sugars was observed on 16^{th} day in the mango fruit in the treatment T_2 which was statistically higher than rest of treatments except the treatment T_1 on 16^{th} day, T_3 and T_4 on 12^{th} day of storage. While lowest reducing sugar content was recorded in all the treatment at initial stage, and T_2 on 4^{th} day of storage. A significant increase in reducing sugar content from 1.01 to 3.11 per cent was noticed up to 16 days of storage at various temperatures.

The increase in reducing sugars content till peak period of ripening could be attributed to conversion of starch into sugars during ripening. The similar observations were also reported by Verma and Bajpai (1971), Laxminarayan (1975), Padhye (1997). A decline in the reducing sugars after attaining a peak at ripe stage could be attributed to their utilization during respiration. Identical observations were reported by Joshi (1983), Gole (1986), Badar (1990), Kapse *et.al.*(1979) and Kulkarni (2000) in mango.

4.3.5 Total sugars

The changes in total sugar content as influenced by the different temperatures as post harvest treatments from mature green stage up to fully

ripened stage of mango fruit Cv. Alphonso are presented in Table 16 and graphically shown in Fig. 12.

It was observed from the data that, the highest (10.04%) mean total sugar content was observed in the mango fruits Cv. Alphonso from the treatment T_4 while lowest (6.35%) total sugars were observed in the treatment T_1.

As regards the storage an increase in the total sugar content was observed during 16 days of storage period. The total sugars increased from 3.41 per cent (at initial stage) to 12.58 per cent (on 16th day stage).

Moreover, the treatments and storage interaction effects were also statistically significant. After 16 days of storage, maximum (14.26%) total sugar content was recorded in the treatment T_4 i.e. Control while minimum total sugar content (3.02 %) was recorded in the treatment T_1 (20°C), T_2 and T_3 at 0 day and T_1 also at 4th stage.

The increase in total sugars during ripening could be attributed to hydrolysis of starch into sugars. Similar observations were also reported by Joshi and Roy (1985), Gole (1986), Padhye (1997), Kulkarni (2000). After attaining a peak during ripening, the total sugars declined till the end of storage period. This could probably be due to utilization of sugars during respiration and exhaustion of precursor (starch) after ripening. Identical observations were also reported by Naik (1985), Gole (1986) and Badar (1990). The maximum total sugars recorded at 30°C storage condition could possibly be due to greater moisture loss in fruits than those at 20°C and 25°C storage conditions. However, better retention of sugars was observed in 20°C and 25°C than 30°C storage. The similar observations were also reported by Kapse *et.al.* (1979), Joshi (1983), Gole (1986) and Badar (1990) on cold storage and Naik (1985), Gole (1986), Padhye (1997) and Kulkarni (2000) on cool chamber storage of mango fruits.

4.4 Effect of chitosan and temperature treatment on sensory evaluation of mango Cv. Alphonso fruits.

The mango fruit ripened with 0.5 per cent chitosan and different temperature condition were evaluated for their organoleptic characteristics by a panel of experienced judges on 9 point score card and the results are as below. The

data (scores) on sensory evaluation of Alphonso mango fruits are presented in Table 17 and graphically depicted in Fig.13.

4.4.1 Colour

It was observed that the colour of the ripe mango fruit under the treatment T_2 was liked by judges the most and treatment T_2 fetched the mean maximum score of (8.00), followed by the treatment T_3 (7.63) and T_1 (7.13). The treatment T_4 obtained mean minimum score for colour i.e. 7.00. The result was found to be statistically significant.

4.4.2 Flavour

The ripened mango fruits from the treatment T_2 and T_3 recorded the maximum flavour score (7.75) while the treatment T_4 rated lowest score for flavour i.e. 6.25. The treatments T_2 and T_3 were at par with each other. The results were statistically significant.

4.4.3 Texture

The treatment T_2 was rated numerically highest (8.25) for texture while treatment T_4 rated numerically lowest score (7.50). The results were statistically non significant.

4.4.4 Overall acceptability

The treatment T_2 was rated highest sensory score (8.00) for overall acceptability but at par with the treatment T_3. The treatment T_4 rated lowest sensory score (6.91) which was at par with the treatment T_2 (7.29). The results were statistically significant.

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation entitled "Studies on effect of chitosan and temperature on ripening behaviour of mango Cv. Alphonso" was carried out in the Department of Post Harvest Management of Fruit, Vegetable and Flower Crops, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli (M.S.). The study was carried out during the year 2014-2015. The experimental material, Alphonso fruits were obtained from mango orchard (plot No.11) of the Department of Horticulture, College of Agriculture, Dapoli. During the course of investigation, the storage behaviour of Alphonso mango fruits at different storage conditions was studied. During storage, the mango fruits were analyzed for different chemical constituents, physiological loss in weight, ripening behaviour of the fruits and sensory evaluation. The important findings of this investigation are summarized as given below.

5.1 Effect of chitosan and different temperatures on physical parameters of mango Cv. Alphonso fruits.

5.1.1 Effect of chitosan and temperature on peel and pulp colour (L*, a* and b*) of mango Cv. Alphonso fruits.

Increasing trend was observed in the mean L* (36.45 to 38.55) and a* value (-2.97 to 1.92) for colour of mango peel, while the b* value (61.71 to 65.05) for colour was observed variable but increased towards the end of the shelf life of fruits.

A decreasing trend was observed in the mean L* value (52.12 to 50.71) for colour of mango pulp while a* value for colour increased (13.53 to 16.13) with the advancement in the ripening of mango fruits, while the b* value for colour was increased (71.17 to 74.46) towards the end of shelf life of fruits.

5.1.2 Effect of chitosan and temperature on the physiological loss in weight (PLW)(%)

The physiological loss in weight (PLW) of mango fruits increased steadily throughout the storage period irrespective of storage conditions. Among different storage conditions, the minimum (5.03) mean physiological loss in weight (PLW) was recorded under 20^0C storage while maximum mean physiological loss in weight (PLW)(13.15) was observed in the treatment T_4 i.e. ambient condition. In general, the mango fruits stored at 20^0C storage condition exhibited less than 10 per cent physiological loss in weight (PLW) till 16^{th} day of storage. However, 15.18 per cent physiological loss in weight (PLW) was recorded at 16^{th} day of storage under 25^0 C storage condition and 19.48 per cent PLW at 16^{th} day of storage under 30^0 C storage.

5.2 Effect of chitosan and different temperatures on ripening behaviour of mango fruits

During the storage, the ripening was found to be faster at ambient temperature, followed by 30^0C storage (T_3), 25^0C storage (T_2) and 20^0C storage (T_1) conditions. Minimum visible shriveling was observed in mango fruits stored in 20^0C storage condition, followed by 30^0C storage condition, while the maximum shriveling was observed at ambient temperature storage. Regarding spoilage, the maximum spoilage was observed in fruits at ambient temperature.

5.3 Effect of chitosan and different temperatures on chemical composition of mango fruits during ripening

5.3.1 Moisture (%)

The moisture content declined throughout the storage period at all storage conditions. After 16 days storage, the minimum mean (71.48 %) moisture content for mango fruit was recorded and the maximum mean (80.85 %) moisture content was observed at 0 day of storage.

5.3.2 Total Soluble Solids (° B)

The T.S.S. of mango fruits increased till peak of ripening and then declined towards the end of storage irrespective of storage conditions. Though the T.S.S. of mango fruits at beginning of storage was high and reached to maximum value (18.85 ° B) the better retention of T.S.S. was observed in the treatment T_2, followed by the treatment T_1.

5.3.3 Titratable acidity (%)

The titratable acidity declined throughout the storage period at all storage conditions. Ambient temperature storage exhibited greater reduction in acidity than either 20^{0}C, 25^{0}C and 30^{0}C storage conditions. The mean maximum (1.93 %) acidity was observed in the treatment T_1 while mean minimum (1.58 %) acidity was observed in the treatment T_4.

5.3.4 Reducing sugars (%)

There was a gradual increase in the reducing sugars (%) content till peak during ripening, followed by a decline towards the end of storage irrespective of storage conditions. The fruits at ambient temperature recorded average maximum (2.33 %) reducing sugars while average minimum (2.04 %) reducing sugar was recorded in fruits stored at 25^{0}C and 20^{0}C.

5.3.5 Total sugars (%)

After attaining a peak during ripening, the total sugars also declined towards the end of storage period like reducing sugars. The mean maximum total sugars content was observed in the fruits at ambient temperature (10.04 %) while mean minimum (6.35 %) was observed at 20^{0}C storage conditions.

5.4 Sensory evaluation

The fruits stored at ambient condition showed poor performance in sensory score. The fruits ripened at 25^{0}C and 30^{0}C both obtained highest sensory score for flavour (7.75) where as mango fruits ripened at 25^{0}C temperature had highest sensory

score for colour (8.00) as well as texture (8.25). The mango fruits ripened at 25^{0}C temperature storage recorded highest overall acceptability (8.00), followed by 30^{0}C temperature storage (7.79), 20^{0}C temperature storage (7.29) and ambient temperature storage condition (6.91).

CONCLUSION

From the present investigation, it was observed that the changes in chemical constituents, ripening, PLW, spoilage and shriveling were markedly reduced in 25^{0}C temperature storage condition as compared to other storage conditions, but showed considerable delay in ripening. However, the fruits ripened at 25^{0}C or 30^{0}C temperature exhibited uniformity in ripening, better shelf life than those ripened at ambient condition. As regards the organoleptic evaluation, fruits ripened at 25^{0}C and 30^{0}C both obtained highest sensory score for flavour (7.75). The mango fruits ripened at 25^{0}C temperature has highest sensory score for colour (8.00) as well as texture (8.25). The fruits ripened at 25^{0}C obtained highest sensory score (8.00) for overall acceptability. Thus, it is suggested to ripen the mango fruits Cv. Alphonso by dipping in 0.5% chitoson solution for five minutes and storage at 25^{0}C temperature for optimum ripening, quality and shelf life of the fruits.

LITERATURE CITED

Abbasi, N. K., Iqbal Z, Maqbool M. and Hafiz I. A. (2009). "Post harvest quality of mango (*Mangifera indica* L.) fruit as affected by chitosan coating," *Pakistan J. Bot.,* vol. 41, pp. 343-357.

Ali, A., Muhammad, M. T. M., Sijam, K. and Sidduqui, Y. (2011). Effect of Chitosan Coatings on the Physicochemical Characteristics of Eksotika II Papaya (*Carica papaya* L.) Fruit during Cold Storage. *Food Chem.*, 124: 620-626.

Amerine, M.A.; R.M. Pangborn and E.B. Rocssler (1965). Principle of Sensory Evaluation of Food. Academic Press, London, 65-67

Anonymous (1985). Zero Energy Cool Chamber *Research Bulletin No.43 IARI (ICAR)* pp. 11-23.

Anonynous (2010). National Horticulture Board, Govt. of India, Database file.

Anonynous (2014). National Horticulture Board, Govt. of India, Database file.

Badar, R.S. (1990). Studies on maturity indices, grading and storage of mango (Mangifera indica L.) fruits Cv. Ratna and Kesar. M.Sc. (Agri.) thesis submitted to Konkan Krishi Vidyapeeth, Dapoli, Dist.Ratnagiri.

Bartolomeu, G. de S. Medeiros a, b, Ana C. Pinheiro a, Maria G. Carneiro-da-Cunha b, António A. Vicente a,. (2011). Development and characterization of a nanomultilayer coating of pectin and chitosan – Evaluation of its gas barrier properties and application on 'Tommy Atkins' mangoes. *Journal of Food Engineering,* 110 (2012) 457–464.

Carrillo-Lopez A., F.Ramirez-Bustamante, J.B.Valdez-Torres and R.Rojas-Uillegas (1999). Ripening and quality changes in Mango fruit as affected by coating with an edible film. *Journal of food quality*. 23 : 479-486.

Chaplin, G.R., R.L. McBridge, Aminah Abdulla and P.A. Nuevo (1991). Sensory and physico-chemical quality of Kensington mangoes after storage at low temperature. ASEAN *Food Journal.***6** (3) : 109-113.

Chattopadhyay,S.B. (1976). Mango and Indian life, *Indian Fd. Packer*. **30**(5):110-115.

Chien, P. J., Sheu, F. and Lin, H. R. (2007). Coating Citrus (*Murcott tangor*) Fruit with Low Molecular Weight Chitosan Increases Postharvest Quality and Shelf Life. *Food Chem.,* 100: 1160–1164.

Chien, P., Sheu, F., Yang, F. (2007). Effects of edible chitosan coating on quality and shelf-life of sliced mango fruit. *Journal of Food Engineering* 78, 225–229.

Devlieghere, F., A. Vermeulen and J. Debevere. (2004). Chitosan: antimicrobial activity, interactions with food components and applicability as a coating on fruit and vegetables. *Food Microbiol.*, 21: 703-714.

Dong, H., L. Cheng, T. Jiahou, Z. Kunwang and J. Yueming. (2004). Effects of chitosan coating on quality and shelf life of peeled litchi fruit. *J. Food Eng*. **64** (3): 355–358.

El-Ghaouth, A., J. Arul, R. Ponnampalam and M. Boulet. (1991). Chitosan coating effect on storability and quality of fresh strawberries. *J. Food Sci.*, 56: 1618-31.

El-Ghaouth, A., R. Ponnampalam, F. Castaigne and J. Arul. (1991a). Chitosan coating to extend the storage life of tomatoes. *Hort Sci.*, 27: 1016-18.

Eman A.A. Abd El-Monem, Ahmed A. Zahran, Ayman E. Shaban (2013). Role of some postharvest treatments in maintaining mango fruit quality during cold storage. *Journal of Applied Sciences Research,* **9**(3): 2355-2366.

Figueroa, M.S., W.I.A. Gómez, E.H. Ortiz, J.A.V. Ovando and M.D.L.A. Anaya, (2011). Effect of chitosan coating on some characteristics of mango (*Mangifera indica* L.) "Ataulfo" subjected to hydrothermal process. *African Journal of Agricultural Research*, **6**(27): 5800-5807.

Ghosh S. K., R. S. Dhua and S. K. Mitra (1985). Studies on physio-chemical characteristic of some mango cultivars grown at West Bengal. *Indian Fd. Packer* **39** (1):46-50

Gil, G., D.S. Monaco, P. Cerruti and M. Galvagano, (2004). Selective antimicrobial activity of chitosan on beer spoilage bacteria and brewing yeast. *Biotechnol. Lett.,* **26**(7): 569-574.

Gole, R.S. (1986). Studies on fruit development and some aspects of post harvest handling of mango (*Mangifera indica* L.) fruits. A M.Sc. (Agri.) thesis submitted to Kokan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri.

González-Aguilar, G.A., Valenzuela-Soto, E., Lizardi-Mendoza, J., Goycoolea, F., Martínez-Téllez, M.A., Villegas-Ochoa, M.A., Monroy-García, I.A., Ayala-Zavala, J.F. (2009). Effect of chitosan coating in preventing deterioration and preserving the quality of fresh-cut papaya 'Maradol'. *Science Food Agriculture*, 89, 15–23.

Hajirasoulihaa M, M. jannesaria, F. Soheili Najafabadi*a, M. Hashemib (2012). Effect of novel chitosan nano-particle coating on postharvest qualities of strawberry. Proceedings of the *4th International Conference on Nanostructures* (ICNS4) 12-14 March, Kish Island, I.R. Iran: 840-842

Hanani N., M. Z., Halimahton Zahrah, M. S. and Zaibunnisa, A. H. (2012). Effect of chitosan-palm stearin edible coating on the post harvest life of star fruits (*Averrhoa carambola* L.) stored at room temperature *International Food Research Journal* **19**(4): 1433-1438.

Helander, I.M., E.L.N. Lassila, R.N. Ahvenainen, J. Rhoades and S. Roller, (2001). Chitosan disrupts the barrier properties of the outer membrane of Gram-negative bacteria. *Int. J. Food Microbiol.,* **71**(2-3): 235-244.

Hernandez-Munoz, E. Almenar, V. D. Valle, D. Velez, and R. Gavara, (2008). Effect of chitosan coating combined with postharvest calcium treatment on strawberry (*Fragaria* x *ananassa*) quality during refrigerated storage. *Food Chem.*, vol. 110, pp. 428-435.

Jafarizadeh Malmiri, H., Osman, A., Tan, C.P. and Abdul Rahman, R. (2011). Development of an edible coating based on chitosan-glycerol to delay 'Berangan' banana (*Musa sapientum* cv. Berangan) ripening process *International Food Research Journal* **18**(3): 989-997.

Jiang, Y., J. Li and W. Jiang. (2004). Effect of Chitosan coating on shelf life of cold-stored Litchi fruit at ambient temperature LWT, 38:757-761.

Jiang, Y.M. and Li, Y.B. (2000/2001). Effects of chitosan coating on post harvest life and quality of longan fruit. *Food Chem.* 73: 139-143.

Joshi, G.D. (1983). Studies on changes in Alphonso mango (*Mangifera indica* L.) fruits during transport and storage. A Ph.D. thesis submitted to Indian Agricultural Research Institute, New Delhi.

Joshi, G.D. and S.K. Roy (1985). Effect of integrated post harvest handling on biochemical changes in Alphonso mango fruits. *Prog. Hort.* **17**(1) : 56-63.

Kader, A. and B. Mitcham. (2008). Optimum Procedures for Ripening Mangoes. In: Fruit Ripening and Ethylene Management: 47-48. Univ. Calif. *Postharvest Technology Research and Information Center Publication Series* #9

Kalra, S.K. and D.K. Tandon and H.C. Lohani (1986). Improving quality of Dashehari mangoes through pre packaging. *Indian Fd.Packer.***40** (1) : 59-63.

Kapse, M.B.; D.A. Rane, D.N. Kulkarni and U.M. Ingale (1979). Biochemical changes in Totapuri mango during ripening and storage. *South Indian Horticulture*. **25** (3) : 119-120.

Kim (2005). changes in polyphenolics and resultant antioxidant capacity in 'tommy atkins' mangos (*Mangifera indica* L.) by selected postharvest treatments the Graduate School of the University of Florida.

Kshirsagar P. B. (2004). Studies on fruiting and some aspects of post harvest handling of some promising varieties of mango (*Mangifera indica* L). A M.Sc.(Agri.) thesis submitted to Dr B. S. K. K. V. Dapoli, Dist. Ratnagiri (M. S.).

Kulkarni, M.M. (2000). Studies on some aspects of post harvest handling and processing of mango (*Mangifera indica* L.). A M.Sc. (Agri) thesis submitted to Dr. B.S.K.K.V., Dapoli, Dist. Ratnagiri.

*Lane, J. H. and Eynon, (1923). Determination of reducing sugars by Fehlings solution and methylene blue as internal indicator. J. Soc. Chem. India., **42**:327.

*Laxminarayana, S. (1977). Effect of low temperature on ripening quality of mango. *Scientia Horticulturae.* **5** (6) : 252-257.

Lin, L., B. Wang, M. Wang, J. Cao, J. Zhang and W. Jiang. (2008). Effects of a chitosan-based coating with ascorbic acid on post-harvest quality and core browning of Yali pear (*Pyrus bertschneideri* Rehd.). *J. Sci. Food Agri.* **88** (5): 877-884.

Mahajan, B.V.C., A. S. Dhatt, Satish Kumar and Manohar L. (2005). Studies on behaviour of chausa mango during cool storage and ripening. Proceedings: International Conference on Mango and Date palm. pp:151-156.

*Mann, S.S. and Singh, R.M. (1975 a). Ripening of Dashehari and Langra cultivars of mango (*Mangifera indica* L.). at different stages of maturity by various methods. *Haryana J. Hort. Sci.* **4** (1/2) : 31-39.

*Mann,S.S. and R.N. Singh (1975 b). Studies on cold storage of mango fruits (*Mangifera indica* L.) Cv. Langra. *Indian J. Hort.***32** (1/2) : 7-14.

Medlicott, A.P. J.M.M. Sigrist, O.Sy (1990). Ripening of Mangos Following Low-temperature Storage *J.Amer.Soc.Hort.Sci.***115** (3) :430-434.

Medlicott, A.P.; S.B. Reynolds and a.K. Thomas (1986). Effect of temperature on ripening of mango (*Mangifera indica* L.) var. Tommy Atkins. *J.Sci.Fd. agric.* **37** (5) : 469-474.

Munde S.P. (2014).Studies on effect of ethrel and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso. A thesis submitted to Dr.B.S.K.K.V.,Dapoli.

Munoz, P.H., E. Almenar, V.D. Valle, D. Velez and R. Gavara, (2008). Effect of chitosan coating combined with postharvest calcium treatment on

strawberry (*Fragaria x ananassa*) quality during refrigerated storage. *Food Chem,* **110**(2): 428-435.

Muzzarelli, R.A.A. and R. Rocchetti. (1985). Determination of the degree of acetylation of chitosans by first derivative ultraviolet spectrophotometry. Carbohydr. Polym. 5: 461-72.

Nagaraju C.G. (1989). Post harvest response of Mango, Banana and Sapota to cool chamber storage. A M.Sc. (Hort.) thesis submitted to university of Agricultural sciences, Bangalore.

Naik S.K. (1985). Studies on physico-chemical changes in Alphonso and Ratna mango (*Mangifera indica* L.) fruits during growth, development and storage. An M.Sc.(Agri.) thesis submitted to Konkan Krishi Vidyapeeth, Dapoli, Dist.Ratnagiri.

Nongtaodum, S. and A. Jangchud, (2009). Effects of edible chitosan coating on quality of fresh-cut mangoes (Fa-lun) during storage. Kasetsart *J. (Nat. Sci.)* 43: 282-289.

Okoth E.M., Sila D.N,,Onyango C.A., Owino W.O., Musyimi S.M., MathookoF. M.(2013). Evaluation of chemical and nutritional quality attributes of selected mango varieties at three stages of ripeness, grown in lower Eastern province of *Kenya Journal of Animal &Plant Sciences,* 2013. **Vol.17**, Issue 3: 2619-2630.

Othman O.C. and G.P. Mbogo (2009). Physico-chemical characterstics of storage ripened mango fruits varieties of estern tanzania. University of Dar es Salaam, P.O. Box 35061, Dar es Salaam, Tanzania, The National Institute for Medical Research (NIMR), P.O. Box 9653, Dar es Salaam.

Padda Malkeet S., Cassandro V.T. do Amarante, Raphael M. Garcia, David C. Slaughter, Elizabeth J. Mitcham (2011). Methods to analyze physico-chemical changes during mango ripening: A multivariate approach *Postharvest Biology and Technology* **62** 267–274.

Padhye, P.B. (1997). Studies on some aspects of post harvest handling of mango (*Mangifera indica* L.) fruits Cv. Alphonso. A M.Sc.(Agri.) thesis submitted to Dr. B.S.K.K.V., Dapoli, Dist.Ratnagiri (M.S.).

Palafox H.-Carlos E. Yahia, M.A. Islas-Osuna, P. Gutierrez-Martinez, M. Robles-Sánchez, G.A. González-Aguilar (2012). Effect of ripeness stage of mango fruit (*Mangifera indica* L., Cv. Ataulfo) on physiological parameters and antioxidant activity, *Scientia Horticulturae* **135** 7–13.

Panse, V. G. and P. V. Sukhatme (1995). Statistical Methods For Agriculture Workers. I.C.A.R., New Delhi.

Patil, M.N. (1996). Studies on physico-chemical composition and processing of mango (*Mangifera indica* L.) Cv. Alphonso, Ratna, Kesar, Pairi and Amrapali. A M.Sc.(Agri.) thesis submitted to Dr. B.S.K.K.V.,Dapoli., Dist.Ratnagiri (M.S.).

Patil, S.A. (1990). Evaluation of mango (*Mangifera indica* L.) Cv. Alphonso, Ratna, Pairi and Kesar fruits for physico-chemical composition and processing. A M.Sc. (Agri.) thesis submitted to Dr.B.S.K.K.V.,Dapoli., Dist.Ratnagiri (M.S.).

Patil, D.G (2012) Studies on effect of temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso A thesis submitted to Dr.B.S.K.K.V.,Dapoli.

Pen, L.T. and Y.M. Jiang. (2003). Effects of chitosan coating on shelf life and quality of fresh-cut Chinese water chestnut. Lebensm.-Wiss. U. - Technol. **36** (3): 359-364.

Peter M, Fweja Leonard, Chove Bernard, Kinabo Joyce, George Victor, Mtebe Kaswija (2007). Physical and chemical characteristics of off vine ripened mango (*Mangifera indica* L.) fruit (Dodo) *African Journal of Biotechnology* **6** (21), 2477-2483.

Pongphen Jitareerat,Sudkanueng Paumchai, Sirichai Kanlayanarat & Somsiri Sangchot (2010). Effect of chitosan on ripening, enzymatic activity, and disease development in mango (*Mangifera indica*) fruit Published online: 19 Feb 2010.

Ramana, K.V.R.; D. Aravind Prasad; C.V. Krishna Prasad; M.V. Patwardhan; S. Dhanraj and S.M. Ananthakrishna (1984). Temperature storage

and the ripening behaviour of Alphonso. *Indian Fd. Packer*. **38** (1) : 58-66.

Ranganna, S. (1997). Hand book of Analysis and Quality control for fruit and vegetable Products. Second Edition. *Tata-Mc. Graw-Hill Publishing Company Ltd.*, New Delhi, India.

Rangavalli K.; C. Ravisagar and M. Hariprasad (1993). Post harvest changes in mango (*Mangifera indica* L.) Cv. Baneshan. *South Indian Hort.* **41**(3): 169-170.

Ratanachinakorn B., W. Kumsiri, Y. Buchsapawanich and J. Singto, (2005). Effect of chitosan on the keeping quality of pummelos. *Acta Hort.*, **682**, 1769-1772 [Proc. 5th IPS, Italy, p. 695].

Ribeiro, C., Vicente, A.A., Teixeira, J.A., Miranda, C., (2007). Optimization of edible coating composition to retard strawberry fruit senescence. *Postharvest Biology and Technology* 44, 63–70.

Sahani, C.K.; D.S. Khurdiya and M.A. Dalal (1994). Effect of ripening aids on the quality of Amrapali mango, Maharashtra *J. Hortic.* **8** (1) : 72-77.

Sarkiyayi S., M. Mohammed and A.Yakubu (2013). Comparative Analysis of Nutritional and Anti Nutritional Contents of Some Varieties of Mango (*Mangifera indica*) in Kaduna Metropolis-Nigeria *Research Journal of Applied Sciences, Engineering and Technology* **5**(4): 387-391, 2013 ISSN: 2042-4868; e-ISSN: 2042-4876.

Satyavati V. K., B. K. Bhat, A. George Varke and K. K. Mukherjee (1972). Studies on suitability of different varieties of mangoes for processing. *Indian Fd. Packer*, 26 (4): 8-12.

Sethi, Vijaya (1987). Quality characteristics of Chausa mango ripened with calcium carbide treatment for pulp storage. *Indian Fd. Packer.* **41** (3) : 14-18.

Shigemasa, Y., K. Saito, H. Sashiwa and H. Saimoto, (1994). Enzymatic degradation of chitins and partially deacetylated chitins. *Int. J. Biol. Macromol.*, **16**(1): 43-49.

Shrivastava R. P. and Kumar Sanjeev, (2002). Fruit and vegetable Preservation, principles and practices published by *International book distributing co. 3rd edition.*

Simoes, A.D.N., J.A. Tudela, A. Allende, R. Puschmann and M.I. Gil. (2009). Edible coatings containing chitosan and moderate modified atmospheres maintain quality and enhance phytochemicals of carrot sticks. *Postharv. Biol. Technol.* **51** (3): 364-370.

Srinivasa, P., R. Baskaran, M. Ramesh, K.H. Prashanth and R. Tharanathan, (2002). Storage studies of mango packed using biodegradable chitosan film. *Eur. Food Res. Technol.,* **215**(6): 504-508.

Thomas P. (1975). Effect of post harvest temperature on quality, carotenoid and ascorbic acid content of Alphonso mangoes on ripening. *J. Food Science* **40** (4): 704-706.

Thomas ,A.,Raymond J.S,Alan W.M.,Michel W.C and Steven B.(2005) Determination of colour and fruit traits of half-sib families of mango (*Mangifera indica* L.) *Proc.Fla.State Horti. Soc.***118**: 253-257

Verma, T.S. and P.N. Bajpai (1971). Physico-chemical changes in mangoes (*Mangifera indica* L.) during low temperature storage. *Prog. Hort.* **3** (3) : 5-14.

Wang J, Wang B, Jiang W, Zhao Y (2007). Quality and shelf life of mango (*Mangifera indica* L. cv. Tainong) coated by using chitosan and polyphenols. *Food Sci. Technol. Int.*, **13**(4): 317-322.

Wanwisa Sriwimon, WarapornBoonsupthip (2010). LWT - Food Science and Technology xxx19, Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, Ladyaow, Jatujak, Bangkok 10900, Thailand.

Wongmetha, O., and L.S. Ke, (2012). The quality maintenance and extending storage life of mango fruit after postharvest treatments. *World Academy of Science, Engineering and Technology*, 69: 936-941.

Young, D.H. and H. Kauss. (1983). Release of Calcium from suspension-cultured glycine max cells by chitosan, other polycations and

polyamines in relation to effects on membrane permeability. *Plant Physiol.*, **73** (3): 698-702.

*Yuniarthi (1980). Physico-chemical changes in Anamanis mangoes during storage at ambient temperature. Bulletin *Penelitian Horticultura*. **8** (11) : 11-17.

Zagade V.V. (2012). Effect of period of maturity on quality and shelf life of Mango (*Mangifera indica* L.) Cv. Alphonso. A thesis submitted to Dr.B.S.K.K.V.,Dapoli. Dist. Ratnagiri (M.S.)

Zhang, D., and Quantick, P., (1997). Effects of chitosan coatings on enzymatic browning and decay during postharvest storage of litchi (*Litchi chinensis* Sonn.) fruit. *Postharvest Biology Technology*, 12, 195–202.

Zhong, Q.P. and W.S. Xia, (2007). Effect of 1-methylcyclopropene and/or chitosan coating treatments on storage life and quality maintenance of Indian jujube fruit. LWT- *Food Sci. Technol.*, **40**(3): 404-411.

Zhong, Q.P., W.S. Xia and Y. Jiang, (2006). Effects of 1-methylcyclopropene treatments on ripening and quality of harvested sapodilla fruit. *Food Technol. and biotechnol.*, **44**(4): 535-539.

Zhou, R., Mo, Y., Li Y., Zhao Y., Zhang G., Hu, Y. (2008). Quality and internal characteristics of Huanghua pears (*Pyrus pyrifolia Nakai*, Cv. Huanghua) treated with different kinds of coatings during storage. *Postharvest Biology and Technology*, 49, 171–179.

Zhu X, Wang Q, Cao J, Jiang W (2008). Effects of chitosan coating on postharvest quality of mango (*Mangifera indica* L. cv. Tainong) fruits. *J. Food Process. Pres.*, **32**(5): 770-784.

---

*Original not seen

APPENDIX - I

Temperature and relative humidity recorded at ambient temperature under Dapoli conditions during the course of investigation (2014-2015)

DATE	Temperature ^{0} C		Realative Humidity (%)	
	Max	Min	Max	Min
16.04.15	34	29	70	37
17.04.15	34	29	84	46
18.04.15	33	28	89	67
19.04.15	34	29	79	55
20.04.15	34	29	79	59
21.04.15	34	28	89	59
22.04.15	33	29	89	67
23.04.15	33	29	87	65
24.04.15	34	24	85	63
25.04.15	32	28	84	59
26.04.15	32	26	86	50
27.04.15	39	28	84	54
28.04.15	31	27	83	50
29.04.15	33	26	86	57
30.04.15	32	27	88	54
01.04.15	33	29	79	56
02.04.15	32	28	84	63
03.04.15	33	27	84	62
Average	33.3	27.7	83.83	56.83

Appendix – II

Abbreviations used

SR. NO.	ABBREVIATIONS	MEANING
1.	%	Per cent
2.	@	At the rate of
3.	^{0}B	Degree Brix
4.	^{0}C	Degree centigrade
5.	µl/l	Micro liter per liter
6.	Anon.	Anonymous
7	CFB	Corrugated Fiberboard Packaging
8	C.D.	Critical difference
9.	Cv.	Cultivar
10.	*et al.*	And others
11.	*etc.*	et cetera (and so on)
12.	FCRD	Factorial Completely Randomized Design
13.	Fig.	Figure
14.	g	Gram
15.	h^0	Hue angle
16.	ha	Hectare (Unit of area)
17.	hrs	Hours
18.	*i.e.*	id est (That is)
19.	kg	Kilogram
20.	kg/cm^2	Kilogram per square centimeter
21.	M. S.	Maharashtra State
22.	MSL	Mean sea level
23.	MT	Million tones
24.	mg	Mili gram
25.	mg/g^{-1}	Milligram per gram
26.	mg/l^{-1}	Milligram per liter

27.	ml/l	Milliliter per liter
28.	ml l^{-1}	Milliliter per liter
29.	NS	Non-significant
30.	PLW	Physiological loss in weight
31.	ppm	Part per million
32.	RH	Relative humidity
33.	S.Em.	Standard error of mean
34.	TSS	Total soluble solids
35.	TA	Tritratable acidity
36.	Var.	Variety
37.	*viz.*,	Videlicet (Namely)

VITAE

MAYURESH ARAVIND PUROHIT

A candidate for the degree of

M.Sc. (Post Harvest Management)

Title of thesis — Studies on effect of chitosan and temperature on ripening behaviour of mango (*Mangifera indica* L.) Cv. Alphonso.

Major Field — Post Harvest Management of Fruit Vegetable and Flower Crops.

Biographical Information

-Personal data — Born at Guhagar, on October 3, 1991.

\ Son of shri. - Aravind Madhusudan Purohit.

-Education — Attended secondary school at A.G.High School Dapoli and higher secondary school at A.G.High School Dapoli. The Bachelor's Degree in Agriculture in First class, From the Dr.B.S.K.K.V., Dapoli, Dist-Ratnagiri, in 2013.

Plate 1: Effect of chitosan and different temperature treatments at initial stage

T_1 T_2 T_3 T_4

Plate 2: Effect of chitosan and different temperature treatments on 4th day

T_1 T_2 T_3 T_4

Plate 3: Effect of chitosan and different temperature treatments at 8th Day

T_1 T_2 T_3 T_4

Plate 4: Effect of chitosan and different temperature treatments at
12th Day

T_1 T_2 T_3 T_4

Plate 5: Effect of chitosan and different temperature treatments at

T_1 T_2 T_3 T_4

16th Day

Plate 6: Effect of chitosan and different temperature treatments on
Pulp

T_1

T_2

T_3

T_4

Table 1. : Effect of chitosan and temperature on L* value for peel colour of mango Cv. Alphonso

Treatments	L* value for peel colour					
	Storage period (days)					
	0	4	8	12	16	Mean
T_1	32.02	32.80	33.75	38.50	45.20	36.45
T_2	32.07	32.87	34.15	40.80	45.47	36.75
T_3	32.93	33.48	33.53	43.25	44.28	37.49
T_4	32.98	34.10	36.08	43.33	46.26	38.55
Mean	32.50	33.31	34.37	41.46	45.30	
			S.Em. ±		C.D. at 5 %	
Different temperatures (T)			0.24		0.69	
Storage (S)			0.27		0.77	
Interaction (T X S)			0.54		1.54	

Fig 1. : Effect of chitosan and temperature on L* value for peel colour of mango Cv. Alphonso

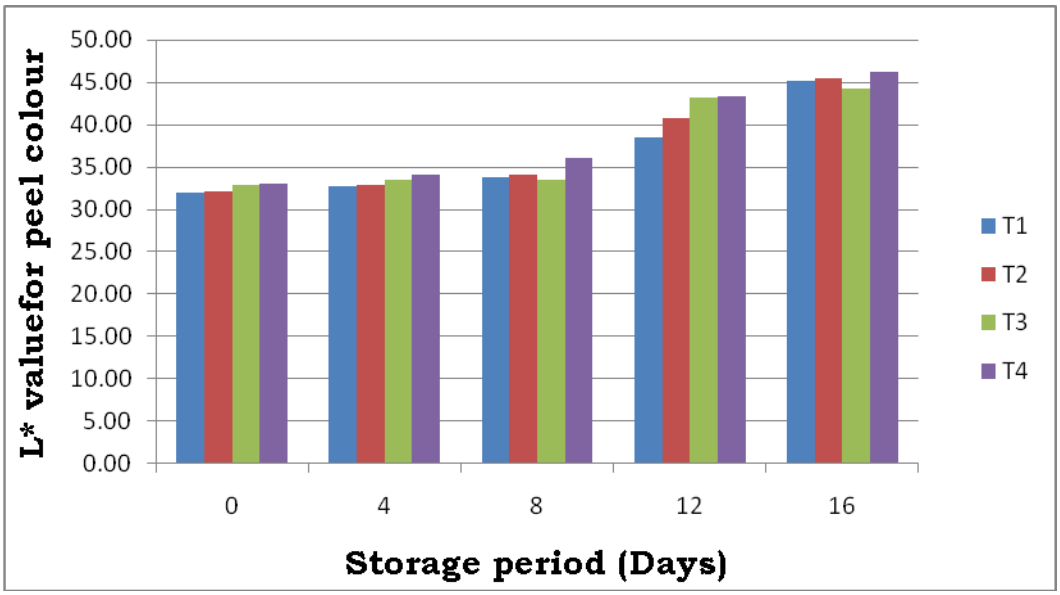

Table 2. Effect of chitosan and temperature on a* value for peel colour of mango Cv. Alphonso.

Treatments	a* value for peel colour					
	Storage period (days)					
	0	4	8	12	16	Mean
T_1	-9.02	-7.92	-7.22	-1.2	14.72	-2.13
T_2	-8.92	-7.46	-4.12	3.05	15.97	-2.97
T_3	-9.32	-7.53	-2.4	10.3	14.82	1.17
T_4	-8.85	-6.92	-6.10	-15.1	16.4	1.92
Mean	-9.03	-7.46	-4.96	6.81	15.48	
			S.Em. ±		C.D. at 5 %	
Different temperatures (T)			0.67		1.89	
Storage (S)			0.75		2.12	
Interaction (T X S)			1.49		4.23	

Fig. 2. Effect of chitosan and temperature on a* value for peel colour of mango Cv. Alphonso fruits.

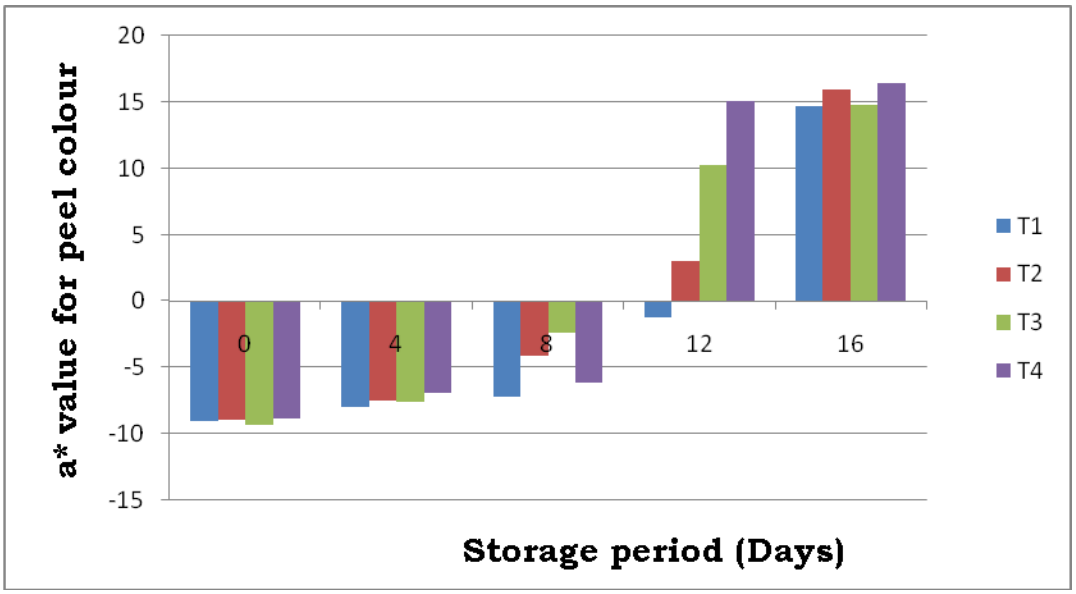

Table 3. Effect of chitosan and temperature on b* value for peel colour of mango Cv. Alphonso

Treatments	b* value for peel colour					
	Storage period (days)					
	0	4	8	12	16	Mean
T_1	47.46	51.40	65.05	71.97	75.67	61.71
T_2	48.42	51.42	63.15	72.85	76.80	62.53
T_3	49.77	51.80	66.20	72.95	77.17	63.57
T_4	50.93	53.35	68.70	73.40	78.87	65.05
Mean	49.14	51.99	65.02	72.79	77.13	
			S.Em. ±		C.D. at 5 %	
Different temperatures (T)			0.74		2.09	
Storage (S)			0.82		2.34	
Interaction (T X S)			1.65		NS	

Fig. 3. Effect of chitosan and temperature on b* value for peel colour of mango Cv. Alphonso

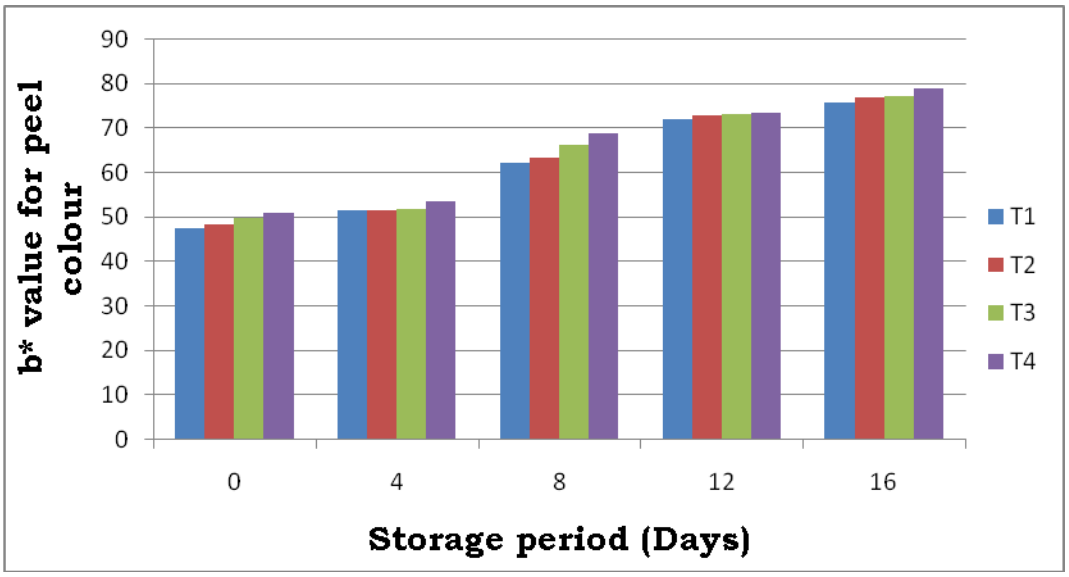

Table 4. Effect of chitosan and temperature on L* value for colour of mango pulp Cv. Alphonso fruits

Treatments	L* value for colour of mango pulp					
	Storage period (days)					
	0	4	8	12	16	Mean
T_1	57.30	56.45	51.30	48.10	47.45	52.12
T_2	55.8	55.25	46.70	48.30	47.57	50.72
T_3	55.62	54.45	49.05	48.05	48.00	51.03
T_4	56.32	52.00	49.47	47.82	47.92	50.71
Mean	56.26	54.53	49.13	48.06	47.73	
			S.Em. ±		C.D. at 5 %	
Different temperatures (T)			0.33		0.92	
Storage (S)			0.36		1.03	
Interaction (T X S)			0.73		2.06	

Fig. 4. Effect of chitosan and temperature treatment on L* value for colour of mango pulp Cv. Alphonso fruits

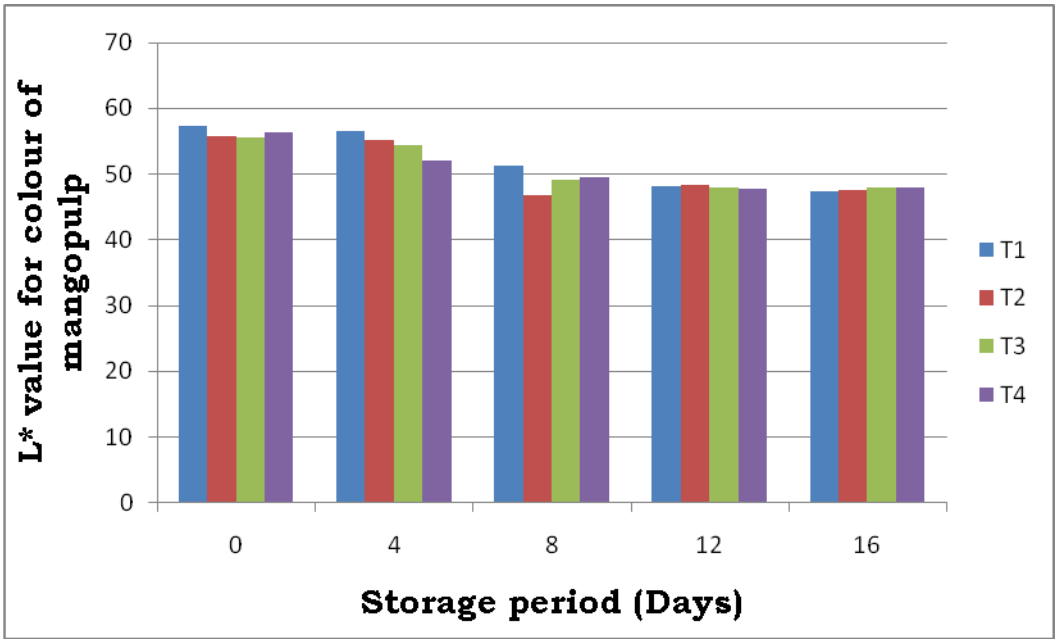

Table 5. Effect of chitosan and temperature on a* value for colour of mango pulp Cv. Alphonso fruits

Treatments	a* value for colour of mango pulp					
	Storage period (days)					
	0	**4**	**8**	**12**	**16**	**Mean**
T_1	6.75	6.50	11.80	19.20	23.4	13.53
T_2	6.30	4.90	13.72	24.67	24.9	14.90
T_3	6.30	8.92	14.45	24.77	25.27	15.94
T_4	6.50	11.85	17.40	26.90	28.00	16.13
Mean	6.46	8.04	14.34	23.88	25.39	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.50**		**1.53**	
Storage (S)			**0.64**		**1.71**	
Interaction (T X S)			**1.21**		**3.42**	

Fig. 5. Effect of chitosan and temperature on a* value for colour of mango pulp Cv. Alphonso fruits

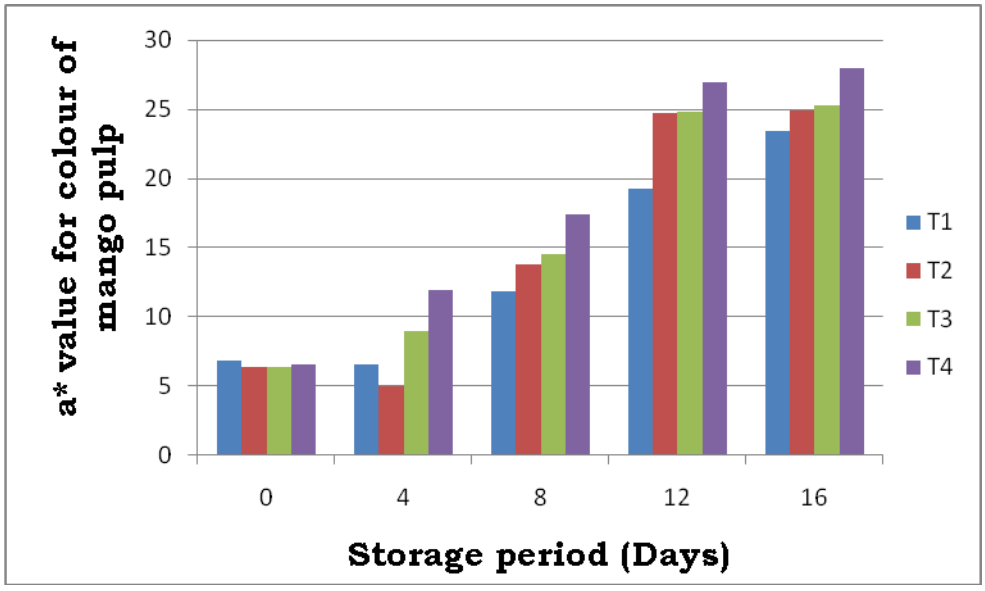

Table 6. Effect of chitosan and temperature on b* value for colour of mango pulp Cv. Alphonso fruits

Treatments	b* value for colour of mango pulp					
	Storage period (days)					
	0	4	8	12	16	Mean
T_1	63.82	64.30	73.72	77.87	79.50	71.84
T_2	63.37	58.30	76.55	77.80	79.85	71.17
T_3	63.05	73.15	75.80	78.95	79.97	74.18
T_4	63.07	75.45	76.72	77.55	79.52	74.46
Mean	63.33	67.80	75.70	78.04	79.71	
			S.Em. ±		C.D. at 5 %	
Different temperatures (T)			0.70		1.98	
Storage (S)			0.78		2.21	
Interaction (T X S)			1.56		4.42	

Fig. 6. Effect of chitosan and temperature on b* value for colour of mango pulp Cv. Alphonso fruits

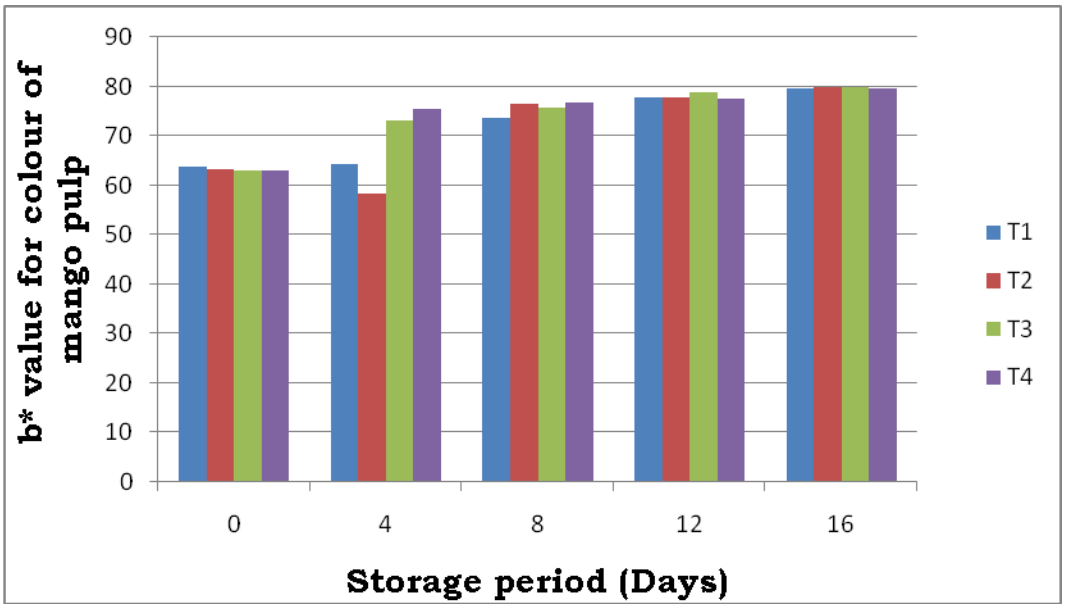

Table 7. Effect of chitosan and temperature on the physiological loss in weight (PLW) of mango Cv. Alphonso fruits

Treatments	Physiological loss in weight (%)					
	Storage period (days)					
	0	**4**	**8**	**12**	**16**	**Mean**
T_1	0.00	2.06	5.38	8.78	8.92	5.03
T_2	0.00	2.98	7.25	11.27	15.18	7.33
T_3	0.00	3.72	9.42	15.70	19.48	9.66
T_4	0.00	7.95	13.55	19.94	24.31	13.15
Mean	0.00	4.18	8.90	9.66	16.97	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.12**		**0.34**	
Storage (S)			**0.13**		**0.38**	
Interaction (T X S)			**0.27**		**0.76**	

Fig. 7. Effect of chitosan and temperature on the physiological loss in weight (PLW) of mango Cv. Alphonso fruits

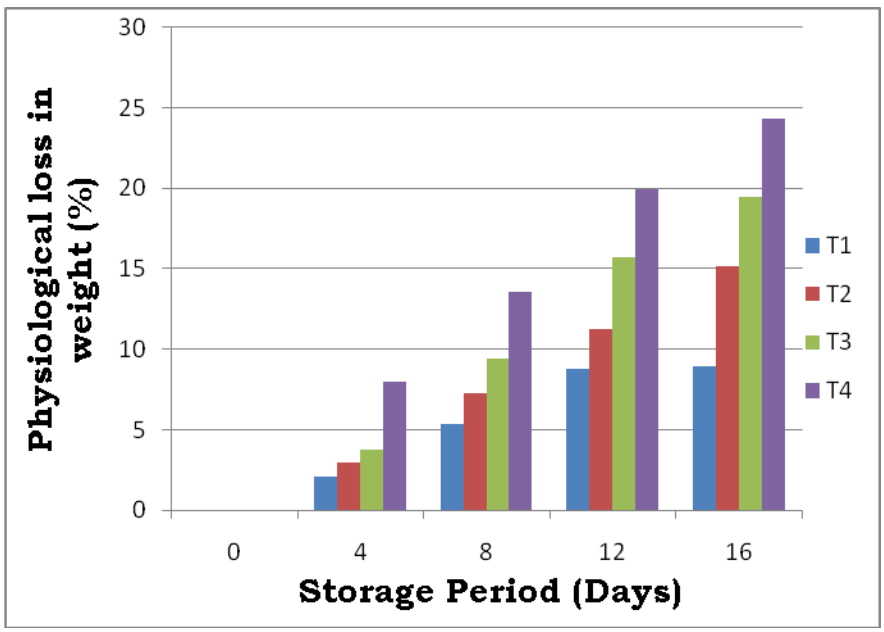

Table 8. Ripening, shriveling and spoilage of Alphonso mango fruits during storage at 20°C temperature and 80 per cent RH (T_1)

Parameters	Days of storage

	0	4	8	12	16
Ripening					
Green	40 (100)	26 (65)	7 (17.5)	0 (0)	0 (0)
Turning	0	14 (35)	10 (25)	3 (7.5)	0 (0)
Half ripe	0	0	23 (57.5)	19 (47.5)	11 (27.5)
Ripe	0	0	0	17 (42.5)	27 (67.5)
Spoilage					
Diseased	0	0	0	1 (2.5	1 (2.5)
Shrivelled	0	0	0	0	1 (2.5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

(Figures in parenthesis indicate percent values)

Table 9.Ripening, shriveling and spoilage of Alphonso mango fruits during storage at 25^{0}C temperature and 80 per cent RH (T_2)

Parameters	Days of storage				
	0	**4**	**8**	**12**	**16**
Ripening					
Green	40 (100)	24 (60)	8 (20)	0 (0)	0 (0)
Turning	0	16 (40)	11 (27.5)	2 (5)	0 (0)
Half ripe	0	0	21 (52.5)	17 (42.5)	7 (17.5)
Ripe	0	0	0	21 (52.5)	31 (77.5)
Spoilage					
Diseased	0	0	0	0	0 (0)
Shrivelled	0	0	0	0	2 (5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

Table 10. Ripening, shriveling and spoilage of Alphonso mango fruits during storage at 30^{0}C temperature and 80 per cent RH (T_3)

Parameters	Days of storage				
	0	**4**	**8**	**12**	**16**

Ripening					
Green	40 (100)	23 (57.5)	7 (17.5)	0	0
Turning	0	17 (42.5)	9 (22.5)	1 (2.5)	0
Half ripe	0	0	15 (37.5)	13 (32.5)	4 (10)
Ripe	0	0	9 (22.5)	24 (60)	33 (82.5)
Spoilage					
Diseased	0	0	0	1 (2.5)	1 (2.5)
Shrivelled	0	0	0	1 (2.5)	2 (5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

(Figures in parenthesis indicate percent values)

Table 11. Ripening, shrivelling and spoilage of Alphonso mango fruits during storage at ambient temperature (24-33^{0}C) (T_4)

Parameters	**Days of storage**				
	0	**4**	**8**	**12**	**16**
Ripening					
Green	40 (100)	12 (30)	0 (0)	0 (0)	0 (0)
Turning	0	11 (27.5)	8 (20)	0 (0)	0 (0)
Half ripe	0	17 (42.5)	13 (32.5)	2 (5)	0 (0)
Ripe	0	0	17 (42.5)	26 (65)	20 (50)
Spoilage					
Diseased	0	0	2 (5)	5 (12.5)	9 (22.5)
Shrivelled	0	0	0	7 (17.5)	11 (27.5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

Table 12: Effect of chitosan and temperature on moisture content of mango Cv. Alphonso fruits.

Treatments	**Moisture (%)**
	Storage period (days)

	0	4	8	12	16	Mean
T_1	81.63	80.60	79.50	78.35	77.55	79.52
T_2	80.83	79.60	77.50	75.40	73.70	77.40
T_3	80.56	77.51	74.39	71.53	68.22	74.44
T_4	80.37	76.65	73.43	69.37	66.47	73.26
Mean	80.85	78.59	76.20	73.66	71.48	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.04**		**0.11**	
Storage (S)			**0.04**		**0.12**	
Interaction (T X S)			**0.09**		**0.24**	

Fig. 8. Effect of chitosan and temperature on moisture content of mango Cv. Alphonso fruits.

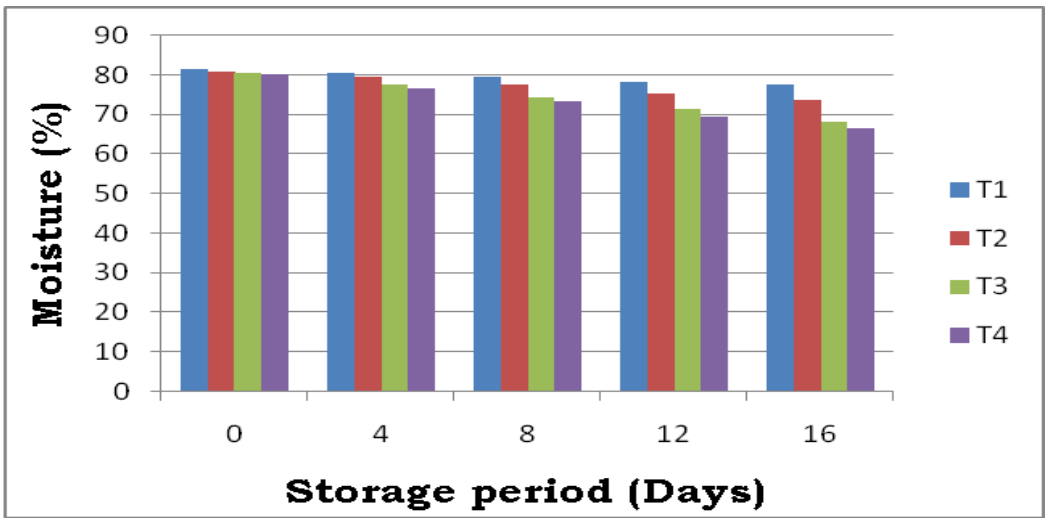

Table 13. Effect of chitosan and temperature on total soluble solids (^{0}B) content of mango Cv. Alphonso fruits

Treatments	**TSS (^{0}B)**
	Storage period (days)

	0	4	8	12	16	Mean
T_1	8.1	11.07	13.05	16.15	18.32	13.34
T_2	8.65	11.05	13.1	15.95	18.85	13.52
T_3	8.07	12.5	14.05	16.3	18.25	13.83
T_4	8.25	12.3	14.75	18.8	18.12	14.44
Mean	8.26	11.73	13.73	16.8	18.38	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.23**		**0.66**	
Storage (S)			**0.26**		**0.74**	
Interaction (T X S)			**0.52**		**NS**	

Fig 9. Effect of chitosan and temperature on total soluble solids (^{0}B) content of mango Cv. Alphonso fruits

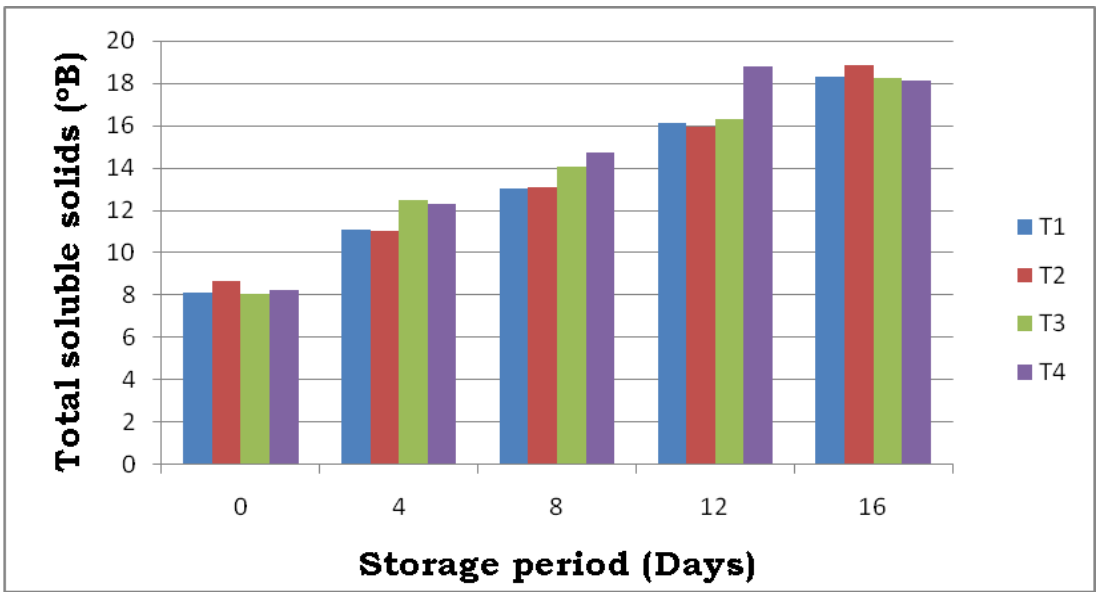

Table 14. Effect of chitosan and temperature on titratable acidity (%) content of mango Cv. Alphonso fruits

Treatments	**Titratable acidity (%)**
	Storage period (days)

	0	4	8	12	16	Mean
T_1	3.67	2.68	2.11	1.00	0.20	1.93
T_2	3.55	2.47	1.98	0.64	0.18	1.75
T_3	3.54	2.39	1.77	0.55	0.14	1.68
T_4	3.61	2.28	1.61	0.33	0.10	1.58
Mean	3.59	2.45	1.85	0.63	0.15	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.02**		**0.05**	
Storage (S)			**0.02**		**0.06**	
Interaction (T X S)			**0.04**		**0.12**	

Fig 10. Effect of chitosan and temperature on titratable acidity (%) content of mango Cv. Alphonso fruits.

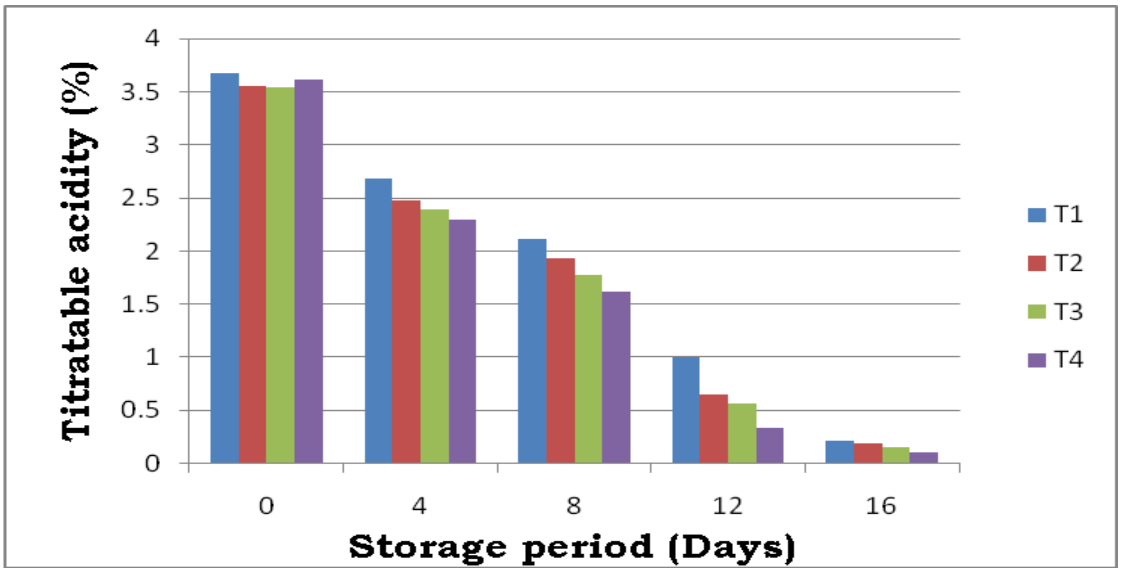

Table 15. Effect of chitosan and temperature on reducing sugar (%) content of mango Cv. Alphonso fruits

Treatments	**Reducing sugar (%)**
	Storage period (days)

	0	4	8	12	16	Mean
T_1	1.01	1.25	2.34	2.41	3.20	2.04
T_2	1.01	1.18	2.06	2.60	3.33	2.04
T_3	1.02	1.34	2.40	3.28	3.02	2.21
T_4	1.02	1.80	2.75	3.21	2.90	2.33
Mean	1.01	1.39	2.39	2.88	3.11	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.03**		**0.08**	
Storage (S)			**0.03**		**0.09**	
Interaction (T X S)			**0.06**		**0.18**	

Fig. 11. Effect of chitosan and temperature on reducing sugar (%) content of mango Cv. Alphonso fruits

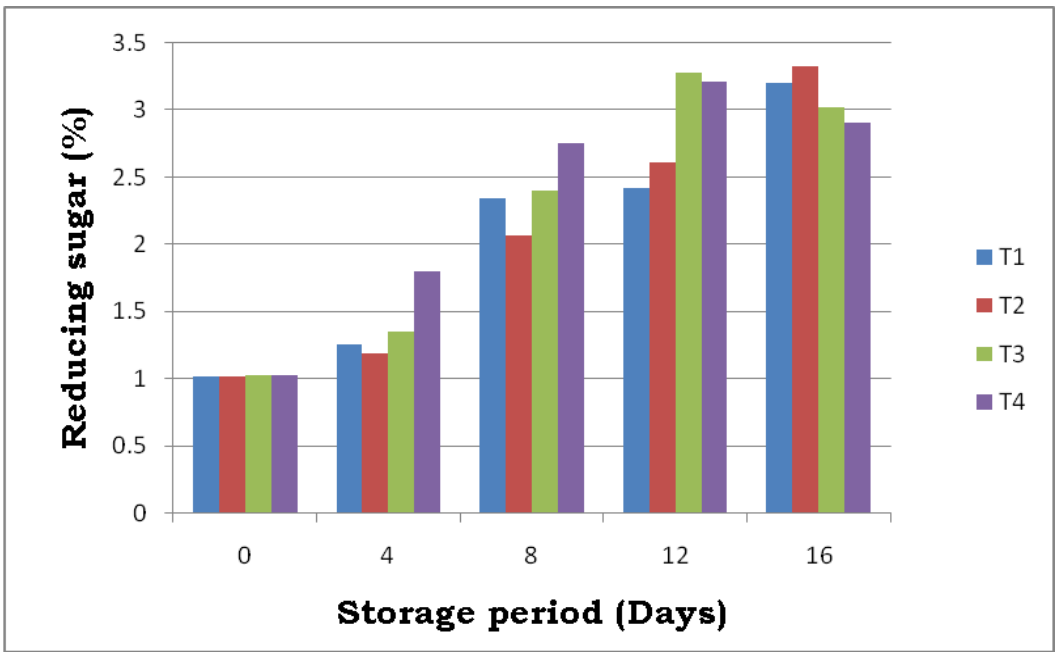

Table 16. Effect of chitosan and temperature on total sugar (%) content of mango Cv. Alphonso fruits

Treatments	Total sugar (%)					
	Storage period (days)					
	0	4	8	12	16	Mean

T_1	3.02	3.44	4.50	9.01	11.77	6.35
T_2	3.31	3.97	9.07	12.74	11.36	8.09
T_3	3.40	3.97	11.17	12.77	12.93	8.85
T_4	3.92	4.10	12.52	15.42	14.26	10.04
Mean	3.41	3.87	9.31	12.49	12.58	
			S.Em. ±		**C.D. at 5 %**	
Different temperatures (T)			**0.09**		**0.25**	
Storage (S)			**0.10**		**0.28**	
Interaction (T X S)			**0.20**		**0.56**	

Fig 12. Effect of chitosan and temperature on total sugar (%) content of mango Cv. Alphonso fruits

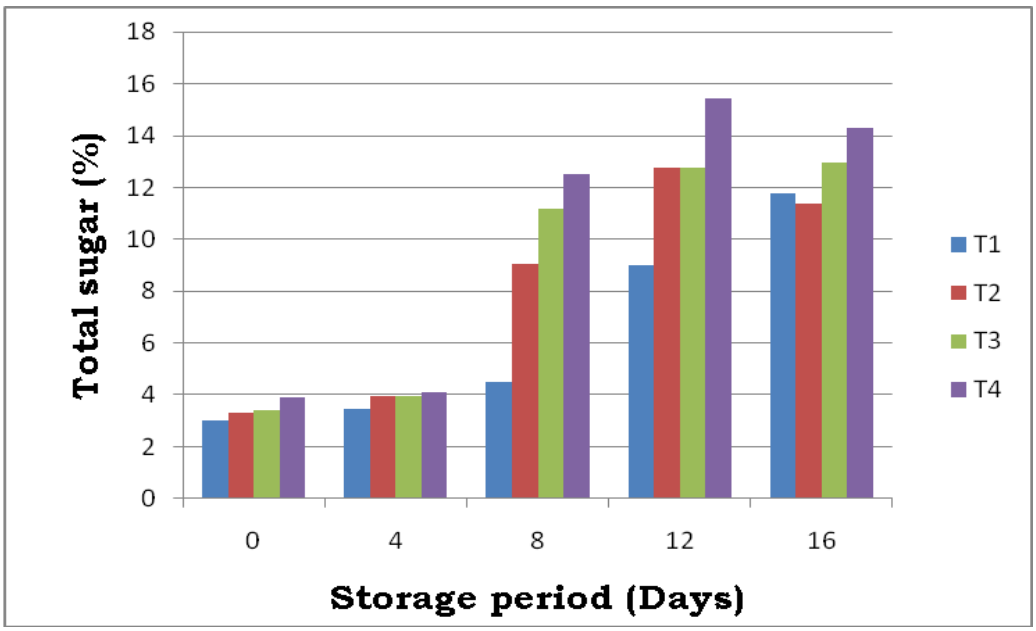

Table 17. Effect of chitosan and temperature on sensory evaluation of mango Cv. Alphonso

Treatments	Sensory score for			Overall acceptability
	Colour	Flavour	Texture	
T_1	**7.13**	**7.00**	**7.75**	**7.29**
T_2	**8.00**	**7.75**	**8.25**	**8.00**

T_3	**7.63**	**7.75**	**8.00**	**7.79**
T_4	**7.00**	**6.25**	**7.50**	**6.91**
Mean	**7.44**	**7.19**	**7.88**	**7.50**
S. Em ±	**O.07**	**0.24**	**0.24**	**0.17**
C. D. at 5%	**0.20**	**0.68**	**NS**	**0.48**

Fig 13. Effect of chitosan and temperature on sensory evaluation of mango Cv. Alphonso fruits.