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CURRICULUMVITAE

EFFECT OF POST HARVEST TREATMENT OF CHITOSAN ON STORAGE BEHAVIOUR OF MANGO (*Mangifera indica* L.) Cv. ALPHONSO

By

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JULY – 2016

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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

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This is to certify that the thesis entitled **"EFFECT OF POST HARVEST TREATMENT OF CHITOSAN ON STORAGE BEHAVIOUR OF MANGO (*Mangifera indica* L.) Cv. ALPHONSO"** *submitted to Department of Post Harvest Management of Fruit, Vegetable and Flower crops, Post Graduate Institute Of Post Harvest Management, Killa-Roha. Faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, (Maharashtra State), in the partial fulfillment of the requirements for the degree of* **MASTER OF SCIENCE (POST HARVEST MANAGEMENT)** *in* **FRUIT, VEGETABLE AND FLOWER CROPS,** *embodies the results of a piece of bona-fide research carried out by* **Mr. AJINKYA RAMESH MANSUTE** *under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.*

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EFFECT OF POST HARVEST TREATMENT OF CHITOSAN ON STORAGE BEHAVIOUR OF MANGO (*Mangifera indica* L.) Cv. ALPHONSO

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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: 18 July, 2016 *(Ajinkya Ramesh Mansute)*

Dedicated to

My respected parents

Pappa and Mummy....

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 world and I feel that I am able to complete this work in time is only and only because of blessings of God, 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.*

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I acknowledge with thanks for the facilities provided by the Director of Research, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli., Dean, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. and the Associate Dean, College of Agriculture, Dapoli during the course of my studies.

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It is friends who share your secret, who provides crutches to crumbling house of confidence and remembrance. The word like thanks should not come in between friends, but it came from the bottom of heart for my beloved, sweet friends ***Anmol, Aniket, Shivam, Siddhesh, Kanchan, Vishakha, Tejashree*** *and all other colleagues for their helping, kind*

co-operation and companionship during the course of study. And my all senior and junior friends for their lovely company during the M.Sc. degree Programme.

No word could do justice to express my sense of respect and gratitude towards my beloved Parents, who molded me to what I am. My dearest mother ***Mrs. Rita Ramesh Mansute****, my dearest father* ***Mr. Ramesh Shravan Mansute****, my lovely sister* ***Ashwini*** *and all my lovely family members for their everlasting love, constant encouragement, prayer support and sacrifice, without which this dream could not have become a reality.*

Once again, I would like to acknowledge all those who I might have left on unknowingly.

Now, I carry this thesis with my head held high.

Place: *Killa-Roha*

Date: *18 July 2016* ***(Ajinkya Ramesh Mansute)***

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

POST GRADUATE INSTITUTE OF POST HARVEST MANAGEMENT, KILLA-ROHA

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

Thesis Title	**:**	Effect of post harvest treatment of chitosan on storage behaviour of mango (*Mangiferaindica* L.) Cv. Alphonso
Name of the student	**:**	Mr. Ajinkya RameshMansute
Regd. No.	**:**	PHMRM-0140090
Degree	**:**	M.Sc.(Post HarvestManagement)
Name and designation of the Guide	**:**	Dr. K. H. Pujari Associate Dean, P. G. Institute ofPost Harvest Management, Killa-Roha.

ABSTRACT

An investigation entitled “Effect of post harvest treatment of chitosan on storage behaviour of mango (*Mangiferaindica* 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,Killa-Roha during the year 2015-2016.

The experiment was conducted in Factorial Completely Randomized Design (FCRD) for different parameters with six main treatments *viz.*, 0.02, 0.04, 0.06, 0.08 and 0.10 per cent chitosan and untreated fruits (control)with storage period and were analyzed for changes in PLW, ripening behavior, chemical parameters and sensory qualities.

It was observed that the chitosan treatment recorded slower rate of ripening than the untreated (control) mango Cv. Alphonso fruits.The chemical parameters such as TSS, reducing and total sugars content exhibited an increasing trend while decreasing trend was observedintitratable acidity of the mango Cv. Alphonso irrespective of treatments during storage.

Further, it was revealed that the changes in chemical constituents, ripening pattern, PLW, spoilage and shriveling were markedly reduced in 0.02 per cent chitosan treatment as compared to other chitosan treatments.

As regards the organoleptic evaluation, the mango fruits ripened at 0.02 per cent chitosan treatment obtained highest sensory score.

फल, सब्जी एवं फूल फसलों का कटाई पश्चात प्रबंधन विभाग

कटाई पश्चात व्यवस्थापन पदव्युत्तर संस्था, किला-रोहा

डॉ. बाळासाहेब सावंत कोकण कृषि विद्यापीठ, दापोली - ४१५ ७१२

जि. रत्नागिरी (महाराष्ट्र)

प्रबंध का नाम	:	"चिटोसन के कटाई पश्चात प्रक्रिया का हापूस आम (म्यांजीफेरा इंडीका एल.) के भंडारण दौरान व्यवहार पर होनेवाला प्रभाव."
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विदयोपाधी	:	एम् एस् सी (पी. एच. एम.)
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<u>प्रबंध सार</u>

कटाई पश्चात व्यवस्थापन पदव्युत्तर संस्था, किला – रोहा के फल, सब्जी एवं फूल फसलों का कटाई पश्चात प्रबंधन विभाग में "चिटोसन के कटाई पश्चात प्रक्रिया का हापूस आम के भंडारण दौरान व्यवहार पर होनेवाला प्रभाव" यह प्रयोग सन २०१५-२०१६ में किया गया।

इस प्रयोग में फ्याक्टोरिअल कम्प्लीटली रान्डोमाएझ्ड डिझाईन (एफ सी आर डी) नुसार छे मूख्य प्रक्रिया जैसे कि ०.०२, ०.०४, ०.०६, ०.०८ और ०.१० प्रतिशत एवं साधारण फल और भंडारण अवधि में आम फलोंको उनके रासायनिक गुणधर्मपर होनेवाले बदलाव, वजन में घटाव, फल पकने का ढंग तथा स्वादिष्ठता पर अध्ययन किया गया।

आम पर कि गयी इस अध्ययन से यह अनुमान निकलता है कि चिटोसन द्वारा प्रक्रिया किये गये हापूस आम साधारण फलोंके मुकाबले देरी से पकते है। फलोंके रासायनिक गुणधर्म जैसे की संपूर्ण घुलन घटक, चिनी का प्रमाण बढते प्रमाण में पाये गये तथा आम्लता का प्रमाण कम होते हुए देखा गया।

आगे यह भी ध्यान में आया की फलोंके रासायनिक गुणधर्म में होनेवाले बदलाव, वजन में घटाव, रोग और मुरझाने का प्रमाण ०.०२ प्रतिशत चिटोसन प्रक्रिया में अन्य प्रकिया के मुकाबले काफी कम दिखाई दिया।

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CHAPTER - I

INTRODUCTION

Mango (*Mangiferaindica* L.), the king of fruits, is a member of *Anacardiaceae* family. The genus *Mangifera* contains several species that bear edible fruit. 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.

Mango (*Mangiferaindica* L.) is one of the oldest tropical fruits and originated in Indo-Burma region and rightly known as “King of Fruits”.This fruit has been in cultivation in Indian continent for well over 4000 years and has been the favourite of the kings and commoners because of its nutritive value, taste, attractive fragrance and health promoting qualities and now it is recognized as one of the best fruits in the world market. 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 (Chattopadhyay, 1976).

Mango is not only delicious but also has full of nutritional value.The unripe fruit is acidic, astringent and antiscorbutic(Shrivastavaand Kumar, 2002). It is high in beta-carotene a precursor of vitamin A and is a good source of the vitamin C. The hundred gram of ripe mangoes are reported to have 83.46 - 86.70 per cent moisture, 0.82 gprotein, 0.38 g fat, 14.98 gcarbohydrate, 11 mg calcium, 14 mg phosphorus, 0.16 mg iron, 0.135-1.872 Vitamin A (mg/100g β-Carotene), 0.038g riboflavin and 36.4 mg ascorbic acid, 12.0-23.0° Brix total soluble solids and 0.12-0.38 per cent 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 2.7 m ha with total annual production of 22 m Mt and average productivity is 7.9 Mt/ha. (Anon., 2014).

In the year 2013-2014, Indian mango production was 18.43 m Mt, followed by the countries like China (4.4), Thailand (0.26), Pakistan (0.19), Mexico (0.17), Indonesia (0.23), Brazil (0.11), Bangladesh (0.09) and Nigeria (0.08) (Anon., 2014).

India ranks first in the world with total production of 18.43 m Mt from about 2.51 m ha area and productivity is 7.3 tonnes/ha. In India, mango crop occupies 34.9 per cent of total fruit crop area and 20.7 per cent of total fruit crop production. Uttar Pradesh is leading state having 4.30 m Mt production of mango; followed by Andhra Pradesh (2.73), Karnataka (1.75), Telangana (1.71), Bihar (1.36), Maharashtra (1.21), Gujarat (1.12), Tamilnadu (0.78),

Orissa (0.75), Jharkhand (0.51), Kerala (0.44) and West Bengal (0.43) (Anon., 2014).

In Maharashtra, mango crop occupies the area of 4.85 lakh ha which is (19.28%) of total area with a total production of over 12.12 lakh MT (Anon., 2014).

Konkan is the major and famous Alphonso mango producing region on the west coast of Maharashtra, 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 only 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 international markets due to its typical sugar-acid blend, pleasant aroma, highly appreciableflavour and taste.

India exports mango and mango based products to more than 80 countries, so it is an important foreign exchange earner, with an earning of ₹ 28543 lakh from export of 41280 Mt of fresh fruits and ₹ 77295 million from the export of 174860 Mt of mango pulp in the year 2014 (Anon., 2014).

Due to successful implementation of horticulture plantation through Employment Guarantee Scheme linked with National Horticulture Development Programme from 1990 onwards, area under mango crop has increased at an alarming rate.

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 increase in the aroma compounds so that the fruits are ready to eat or process. The associated physiological or biochemical changes increase the rate of respiration and ethylene production, loss of chlorophyll and continued expansion of cells and conversion of complex metabolites into simple molecules. The temperature plays an important role while ripening. High and low temperatures during ripening affect the quality of mango.

Chitosan is a linear polysaccharide consisting of β-(1→4)-linked 2-amino-2-deoxy-D-glucose residues, originating from deacetylated derivative of chitin, which is the second most abundant polysaccharide in nature after cellulose. It is non-toxic, biodegradable, biofunctional, and biocompatible. Chitosan has strong antimicrobial and antifungal activities that could effectively control fruit decay. It could easily form coating on fruit and vegetable, and the respiration rate of fruit and vegetable is reduced by adjusting the permeability of carbon dioxide and oxygen.

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, sea-transportation is the only alternative, but movement by sea takes longer time and fruits need to be maintained in good quality and glossy appearance for long time.

Therefore, the aim of this research was to investigate the effect of post harvest treatment of an edible chitosan on storage behaviour of mango fruits at ambient temperature and to determine the optimal chitosan concentration which maintains thephysico-chemical characteristics and prolongs storage life of Alphonso mango. Keeping this in view, the present investigation was carried out with the following objectives.

1) To study the effect of different concentrations of chitosan on PLW and ripening behaviour of Alphonso mango

2) To study the effect of different concentrations of chitosan on chemical composition 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 treatment on physical parameters of different fruits.

2.2 Effect of chitosan treatment on ripening behaviour of different fruits.

2.3 Effect of chitosan treatment on chemical composition of different fruits.

2.4 Effect of chitosan treatment on sensory qualities of different fruits.

2.1 Effect of chitosan treatment on physical parameters of different fruits.

2.1.1. Physiological loss in weight (PLW)

The application of chitosan was found to be more effective at delaying weight loss in longan fruit as reported by Jiang and Li (2001)

Dong *et al.* (2004) reported the effectiveness of chitosan in delaying weight loss in peeled litchi fruit.

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 weight loss 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.

Chien *et al.* (2007a) 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.

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

Hernandz-Munoz *et al.* (2008) reported that the chitosan was found to be more effective in delaying weight loss in strawberry fruit.

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

Abbasi *et al.* (2009) observed that the weight loss occurred in fruits treated with crab chitosan is less 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.

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

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

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.

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

Hajirasouliha *et al.* (2012) observed a great weight loss in uncoated strawberry fruits than coated samples with different chitosan concentrations during storage.

Hanani *et al.* (2012) observed in star fruit 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.

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

Eman *et al.* (2013) observed that the chitosan with concentrations of 1.0 and 2.0 $mM.l^{-1}$ significantly reduced per cent weight loss as compared to that of the control mango fruits in both investigated seasons.

Shinde (2014) observed that the 3% chitosan coated Alphonso mango fruits showed 11.6% physiological loss in weight which was lower as compared to untreated fruits having 19% physiological loss in weight at 20^{th} day of storage.

2.2 Effect of chitosan treatment on ripening behaviour of different fruits.

Shinde (2014) recorded that after the 8^{th} day of storage of Alphonso mango fruits, maximum half ripening of fruits were observed in 0.5% chitosan treatment (66.67%). However, control fruits recorded lowest half ripening (38.89%) of fruits.

Purohit (2015) observed that the 0.5% chitosan treated Alphonso mango fruits ripened faster at ambient temperature, followed by 30°C, 25°C and 20°C temperatures of storage.

Salunke (2015) observed that the ripening was much faster in control and at 30°C temperature, whereas, 0.5% chitosan showed delayed ripening with minimum spoilage in banana fruits.

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.

Chitosan might be attributed to its antifungal and antimicrobial properties. 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).

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 chitinase, a defense enzyme, which catalyzes the hydrolysis of chitin, 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 with 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.

Salunke (2015) reported that the highest spoilage occurred in untreated fruits (100%) and lowest spoilage was in 0.5% chitosan coated banana fruits (16.67%) on 10^{th} day of storage.

2.3 Effect of chitosan treatment on chemical composition of different fruits.

2.3.1. Total soluble solids (°B)

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

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

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.

Bartolomeu *et al.* (2011) observed that after 45 days of storage, uncoated mangoes recorded 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 with high concentration of chitosan.

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

Shinde (2014) found that the highest mean TSS was in untreated fruits (14.71°B) of Alphonso mango. However, 0.5% chitosan treated fruits recorded low levels of TSS content (13.81°B).

2.3.2. Titratable acidity (%)

Jiang and Li (2001) reported the effect of chitosan coatings on longan fruit. They found that the titratable acidity decreased during storage.

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.

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 significant values i.e. 0.12 and 0.40 per cent, respectively. The uncoated mangoes presented a lower titratable acidity in comparison with chitosan coated Tommy Atkins mangoes.

Jafarizadeh *et al.* (2011) observed 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.

Eman *et al.* (2013) found that all chitosan concentrations reduced titratable acidity of mango 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.

Shinde (2014) observed that 2% chitosan treated fruits showed highest content of mean titratable acidity (1.99%). While lowest mean titratable acidity found in the untreated fruits of Alphonso mango (1.48%).

2.3.3. Reducing sugars (%)

Sethi (1987) reported an increase in reducing sugar content in Chausa mango ripened at ambient temperature.

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

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

Shinde (2014) observed that the chitosan coated mango fruits showed low reducing sugars content as compared to untreated fruits.

2.3.4. Total sugars (%)

Laxminarayana (1977) observed that the total sugar content was found to increase in mango fruits of cultivars Haden, Irwin and Kent stored at 25°C

Abbasi *et al.* (2009) reported that during storage of mango fruits, the total sugars significantly increased in all treatments except control.

Eman *et al.* (2013) reported that the chitosan also reduced total sugar content 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 and consequently maintaining humidity in fruits leading to reduced total sugars.

Shinde (2014) observed that the chitosan coated mango fruits showed low total sugars content as compared to untreated fruits.

Purohit (2015) recorded that the 0.5% chitosan treated Alphonso mango fruits at ambient temperature showed high total sugars content as compared to fruits stored at 20°C, 25°C and 30°C.

2.4 Effect of chitosan treatment on sensory qualities of different fruits.

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 as compared to control.

Devlieghere *et al.* (2004) reported that the chitosan coating on organic fruits delayed the decrease in sensory quality and extended the shelf-life.

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

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

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

Hernandez-Munoz *et al.* (2008) reported that the chitosan coating improved the quality and extended the shelf life of strawberry fruit.

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

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) mentioned that the chitosan has been proved one of the best preservative material that delays the ripening process by inhibiting the respiration rate in the Eksotika II papaya fruit in 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. The chitosan coating concentration dramatically impressed the sensory quality of fruits due to more protection of flavour, texture, aroma, sweetness and inhibition of spoilage. 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.

CHAPTER – III
MATERIAL AND METHODS

The present investigation "Effect of post harvest treatment of chitosan on storage 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, Killa-Roha. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (M.S.) during the summer season of 2016. The material used and the methods adopted during the investigation are as given below.

3.1 General description

3.1.1 Location

The Department laboratory of Post Harvest Management of Fruit, Vegetable and Flower Crops, Post Graduate Institute of Post Harvest Management (PGI-PHM), Killa-Roha is located at 18°25'35.54", North latitude and 73°10'45.01", East longitude and at an elevation of 17.50 meters above MSL. The climate of Killa-Roha is warm and humid with the mean annual rainfall 2000-3000 mm, mostly received from 1st June to 15th October.

3.1.2 Experimental material

The physiologically mature, fruits of mango Cv. Alphonso were harvested during morning hours with 2.5 cm stalk from mango orchard (Plot No.- 11) located at 17°45', North latitude and 73°12', East longitude of Department of Horticulture, College of Agriculture, Dapoli (M.S.). Harvested fruits were brought to PGI-PHM Laboratory, Killa-Roha and treated with different concentrations of chitosan and water as per the treatment for five minutes and wiped with dry muslin cloth. After the treatment, the fruits were placed in ventilated CFB boxes and stored at ambient temperature condition for further investigation. The control fruits were also kept at same environment for comparison. Thirty fruits for each replication were used for each treatment.

3.1.3 Experimental details

Experimental Design : Factorial Completely

Randomized Design (FCRD)

No. of Treatments : Six

No. of Replications : Four

No. of Fruits per treatment : One hundred twenty

3.1.4 Treatments details

The fruits were treated with different concentrations of chitosan for a dipping period of 5 minutes.

(A) Factor A: Concentration of chitosan

T_1 : 0.02%

T_2 : 0.04%

T_3 : 0.06%

T_4 : 0.08%

T_5 : 0.10%

T_6 : Control

(B) Factor B: Storage period

3.2 Observations recorded

3.2.1 Physical parameters

3.2.1.1 Physiological loss in weight (PLW) (%)

Forty fruits were selected from each treatment for studying physiological loss in weight. The loss in weight was calculated by noting down the difference between two consecutive weights recorded from initial day and every alternate day at ambient temperature.

Individual fruit was weighed on monopan electronic balance and average weight of these fruits was recorded in grams.

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

3.2.1.2 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 % of fruit peel turned yellow)
4) Ripe (when fruit fully turned yellow)

This ripening pattern under each treatment was studied on alternate days at ambient temperature condition.

3.2.1.3 Spoilage percentage of fruits (%)

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

3.2.2 Chemical composition of mango fruit

Randomly selected four ripened fruits from each replication of every treatment were employed for estimating the following chemical constituents of the fruit.

3.2.2.1 Total soluble solids (°B)

Total soluble solids (TSS) were determined with the help of Hand Refractometer (Atago Japan, 0 to 33°B) and value was corrected at 20°C with the help of temperature correction chart (A.O.A.C., 1975).

3.2.2.2 Titratable acidity (%)

A known quantity of pulp was 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 were expressed as per cent anhydrous citric acid.

Titratable acidity (%)

$$= \frac{\text{Normality of alkali X Titre reading X Volume Made X Equivalent weight of acid}}{\text{Weight of sample taken X Volume of sample taken for estimation X 1000}} \text{ X } 100$$

3.2.2.3 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 was blended with distilled water using lead acetate (45%) for precipitation of extraneous material and potassium oxalate (22%) to de-lead 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.

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

3.2.2.4 Total sugars (%)

The total sugars were estimated by the same procedure of reducing sugars after acid hydrolysis of an aliquot of de-leaded sample with 50 per cent hydrochloric acid, followed by neutralization with sodium hydroxide (40%). This filtrate was 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).

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

3.3 Sensory evaluation

The ripe fruits were examined for their sensory qualities such as 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. The overall rating was obtained by averaging score of evaluation. The fruits with sensory score of 5.5 and above were rated as acceptable.

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

3.4 Statistical analysis

The data collected on physicochemical and physiological parameters of mango were statistically analyzed by using Factorial Completely Randomized Design (FCRD) adopting analysis of variance techniques as described by Panse and Sukhatme (1995). The treatment difference was tested by 'F' test of significance on the basis of null hypothesis. The appropriate standard error (S. Em. ±) was calculated in each case. The critical difference (C. D.) at 5 per cent level of probability was worked out.

CHAPTER – IV

RESULTS AND DISCUSSION

The present investigation entitled "Effect of post harvest treatment of chitosan on storage behaviour of mango (*Mangifera indica* L.) Cv. Alphonso" was undertaken in the Department of Post Harvest Management of Fruit, Vegetable and Flower Crops, Post Graduate Institute of Post Harvest Management, Killa-Roha. during the year 2015-2016. The results of the investigation are presented and discussed in this chapter under following headings.

4.1 Effect of chitosan treatment on physical parameters of mango Cv. Alphonso

4.2 Effect of chitosan treatment on ripening behaviour and spoilage of mango Cv. Alphonso

4.3 Effect of chitosan treatment on chemical composition of mango Cv. Alphonso

4.4 Effect of chitosan treatment on sensory qualities of mango Cv. Alphonso

4.1 Effect of chitosan treatment on physical parameters of mango Cv. Alphonso.

4.1.1. Physiological loss in weight (PLW) (%)

The data on changes in physiological loss in weight of mango fruit Cv. Alphonso due to the effect of chitosan during storage are presented in Table 1 and graphically depicted in Fig. 1. The chitosan treatment and storage interaction exhibited significant impact on physiological loss in weight of mango fruits. It is noticed from the results that the increasing trend in the physiological loss in weight was observed with the advancement of the ripening and storage period.

It was observed from the data that the treatment T_6 i.e. control treatment recorded maximum (8.73%) mean physiological loss in weight,

followed by the treatments T_1 (8.33%), T_2 (8.15%), T_3 (8.00%) and T_4 (7.86%). The treatment T_5 recorded the lowest (7.59%) mean physiological loss in weight of mango Cv. Alphonso. Thus, it is cleared from data that the physiological loss in weight decreased with increase in chitosan concentration.

As regards storage, there was an increase in the physiological loss in weight as the storage period was increased. At 1th day of storage, the mean physiological loss in weight was 1.34 per cent however and at 15th day, it was increased to 14.63 per cent irrespective of the treatments.

The interaction effects between the treatments and storage period were found to be statistically significant. The lowest (1.22%) physiological loss in weight was recorded in the treatment T_5 (0.10% chitosan) on 1th day while highest physiological loss in weight was recorded (15.93%) in the treatment T_6 (control) on 15th Day. The fastest and maximum increase in physiological loss in weight was observed in fruits from control treatment. The continuous increase in physiological loss in weight values at all storage condition could be as a result of loss of moisture from the fruit peel through respiration and transpiration.

Similar trend of increase in the physiological loss in weight values of mango fruits during storage and decrease in physiological loss in weight of mango fruits with increase in concentration of chitosan was observed by Chien *et al.* (2007a), Abbasi *et al.* (2009), Nongtaodum and Jangchud (2009), Bartolomeu *et al.* (2011), Hanani *et al.* (2012), Eman *et al.* (2013), Shinde (2014) and Purohit (2015).

4.2 Effect of chitosan treatment on ripening behaviour and spoilage of mango Cv. Alphonso

The data on ripening behaviour and spoilage of mango fruits Cv. Alphonso during storage are presented in Table 2 to 7 and depicted with Fig. 2 to 7.

At the 5th day of storage, the percentage of mango fruits at turning stage was highest in the treatment T_6 (67.5%), while the treatment T_5 (52.5%) recorded the lowest percentage of mango fruits at turning stage.

After the 9th day of storage among all treatments, maximum mango fruits at half ripe stage were observed in the treatment T_3 (57.5%). However, the treatments T_2 and T_5 (50%) recorded as lowest percentage of half ripened fruits.

As per the result, on the 15th day maximum ripening of fruits was observed in all the treatments. Among the treatments, the treatment T_1 (82.5%) recorded highest, followed by T_4 (75%), T_2 (72.5%), T_3 (70%), T_5 (65%) and the lowest percentage of ripened fruits recorded in treatment T_6 (60%).

On 15th day of storage, shriveling of the fruits was highest in treatment T_6 (25%) followed by T_3 (22.5%), T_5 (22.5%) and T_2 (20%). However, the lowest shriveling was recorded in treatment T_4 (17.5%) and T_1 (12.5%).

As far as spoilage was concerned, the spoilage percentage observed was highest in the treatment T_6 (15%), followed by the treatment T_5 (12.5%), T_4 (7.5%), T_3 (7.5%) and T_2 (7.5%). However, the lower spoilage percentage was observed in the treatment T_1 (5%) on the 15th day of storage.

The treatment T_1 (82.5%) with 0.02 per cent chitosan recorded highest percentage of healthy fruits. Shriveling of fruits was highest in treatment T_6 (25%) and the lowest in treatment T_1 (12.5%), also the treatment T_6 (15%) recorded highest spoilage and it was the lowest in treatment T_1 (5%).

In this study, it was found that the decay control of treated mango fruits was better as compared with untreated fruits. Chitosan treated fruits inhibited the growth of a wide variety of bacteria and fungi as compared to the control treatments. El-Ghouth *et al.* (1991) suggested that chitosan induces chitinase, a defense enzyme (Mauch *et al.*, 1984), which catalyzes the hydrolysis of chitin, a common component of fungal cell walls (Hou *et al.*, 1998). The results suggested that chitosan extend the shelf life, limit the growth of fungi and decrease the spoilage without affecting the ripening characteristics of fruits (Lam and Diep, 2003).

Similar observations on ripening behaviour of mango fruits were recorded by Kalra *et al.* (1986), Patil (1990), Patil (1996), Abbasi *et al.* (2009), Bartolomeu *et al.* (2011), Shinde (2014) and Purohit (2015).

4.3 Effect of chitosan treatment on chemical composition of mango Cv. Alphonso.

4.3.1. Total soluble solids (°B)

The data on changes in total soluble solids (°B) content of mango fruit cv. Alphonso due to effect of chitosan treatment during storage are presented in Table 8 and graphically depicted in Fig. 8.

It was noticed from the data that the total soluble solids increased with increase in the storage of mango fruits and total soluble solids decreased with increase in concentration of chitosan. The chitosan treatment and storage interaction exhibited significant impact on total soluble solids levels of mango fruit.

Among all the treatments, the highest mean total soluble solid was found in T_6 (14.24°B) i.e. Control, which was significantly superior to rest of the treatments but it was at par with treatment T_1 (13.85°B). However, the chitosan treatments recorded low levels of total soluble solids content in the treatment T_2 (13.45°B), followed by T_3 (13.16°B), T_4 (13.12°B) and T_5 (12.93°B) and treatments T_2, T_3 and T_4, were at par with each other. Thus, it is cleared from the data that the total soluble solids decreased with increase in chitosan concentration.

At the end of storage, there was a significant increase in the total soluble solids level irrespective of the treatments. At initial stage i.e. 1st day, the lowest mean total soluble solids (7.93°B) was noticed, while the highest mean total soluble solids (19.23°B) was noticed at 15th day.

The interaction between treatment and storage of total soluble solids level was found statistically non significant.

The chitosan had exhibited significant effect on total soluble solids content of mango. All the chitosan treated mangoes showed less mean total

soluble solids content than that of untreated mango fruits treatments. It could be due to slower respiration rate by chitosan coating on fruits.

Early senescence in the untreated fruits compared to treated fruits, which showed delayed loss of TSS due to delayed senescence. The lower level of total soluble solids in the fruits treated with chitosan may be due to protective O_2 barrier lowering the oxygen supply on the fruit surface which inhibited respiration (Yonemoto *et al.*, 2002).

Similar trends of increase in the total soluble solids values of mango fruit during storage was observed by Joshi and Roy (1985) and decrease in the total soluble solids with increase in chitosan concentrations was observed by Abbasi *et al.* (2009), Bartolomeu *et al.* (2011), Jafarizadeh *et al.* (2011) and Shinde (2014).

4.3.2. Titratable acidity (%)

The data on changes in titratable acidity of mango fruit Cv. Alphonso due to effect of chitosan during storage are presented in Table 9 and graphically depicted in Fig. 9. It is noticed from the results that the significantly decreasing trend in the acidity was observed as storage period increased. The chitosan treatment and storage interaction exhibited significant impact on titratable acidity levels of mango fruits.

Among all the treatments, the treatment T_6 (1.85%) recorded the lowest mean titratable acidity, while the chitosan treated fruits exhibited significantly higher mean acidity than that of control treatment. The chitosan treatments T_1 (2.00%) and T_2 (2.10%) were at par with each other and T_2 (2.10%), T_3 (2.15%), T_4 (2.13%) and T_5 (2.17%) were at par with each other.

At the initial stage of storage i.e. 1st day, the highest mean titratable acidity (3.71%) was noticed while the lowest mean titratable acidity (0.99%) was noticed at 15th day.

The interaction between treatment and storage with respect to titratable acidity level was found statistically non significant.

The chitosan had exhibited significant effect on titratable acidity of mango. All the chitosan treated mangoes showed maximum mean titratable acidity compared to untreated mango fruits. It could be due to slower respiration rate by chitosan coating and less water loss in the fruits due to the effect of chitosan.

The higher level of titratable acidity in the fruits treated with chitosan may be due to protective O_2 barrier or reduction of oxygen supply to the fruits surface which inhibited respiration rate (Jiang and Li, 2001). The reduction in acidity may be due to their conversion into sugars and their further utilization in the metabolic processes of the fruit. Doreyappa and Huddar (2001) reported the similar pattern in different varieties of mango fruits stored at 18-34°C.

Similar trend of decrease in the titratable acidity of mango fruit during storage was observed by Yuniarthi (1980), Jiang and Jiang (2004), Bartolomeu *et al.* (2011), Eman *et al.* (2013), Shinde (2014) and Purohit (2015).

4.3.3. Reducing sugars (%)

The data on the changes in reducing sugar content of mango fruits Cv. Alphonso due to effect of chitosan during storage are presented in Table 10 and graphically depicted in Fig. 10. There was an increasing trend in the reducing sugar content of treated mango fruits during storage period. The chitosan treatment and storage exhibited significant impact on reducing sugar levels of mango fruits.

Among all the treatments, the highest mean reducing sugar content was found in the treatment T_6 (2.59%) which was significantly higher to rest of the treatments, but T_6 was at par with treatment T_1 (2.56%) However, chitosan coated fruits showed the lowest mean reducing sugar content and the treatments T_2 (2.37%), T_3 (2.34%), T_4 (2.34%), and T_5 (2.27%) were at par with each other.

At the end of storage, there was a significant increase in the reducing sugar level. At initial stage i.e. 1st day, the lowest mean reducing sugar

(1.02%) was noticed, while the highest mean reducing sugar (3.90%) was recorded at 15th day of storage.

The interaction between treatment and storage related to the reducing sugar content of mango was found to be statistically significant throughout the storage period. The highest (4.80%) reducing sugar content was recorded in the treatment T_1 at 15th day of storage period and lowest (0.99%) was in the treatment T_3 at 1st day of storage period.

Gradual increase in reducing sugars in treated fruits as compared to control treatment might be due to its slow ripening process (Youssef *et al.,* 2002). Maximum amount of reducing sugars in untreated fruits might be due to rapid conversion of starch to sugars as a result of moisture loss and decrease in acidity by physiological changes during storage (Wills and Riggney, 1979).

The similar trends of increase in reducing sugars of mango fruits were also reported by Sethi (1987), Abbasi *et al.* (2009) and Shinde (2014). Decline in reducing sugars after attaining a peak at ripe stage could be attributed to their utilization during respiration. Identical observations were reported by Badar (1990).

4.3.4. Total sugars (%)

The data on the changes in total sugar content of mango fruit Cv. Alphonso due to effect of chitosan during storage are presented in Table 11 and graphically depicted in Fig. 11. It was observed from the results that the increasing trend in the total sugar content was observed. The chitosan treatment and storage interaction exhibited significant impact on total sugar levels of mango fruits.

Among the treatments, the highest mean total sugar was found in the treatment T_6 (7.37%), but treatment T_1 (7.24%) was at par with treatment T_6, followed by T_2 (6.93%), T_3 (6.82%), T_4 (6.74%) and T_5 (6.55%). The treatments T_2, T_3 and T_4 were at par with each other and treatments T_4, and T_5 were at par with each other.

At initial stage of storage i.e. 1st day, the lowest mean total sugar (2.08%) was noticed while the highest mean total sugar (12.48%) was noticed at 15th day.

The interaction between treatments and storage on total sugar content of Alphonso mango was found to be statistically significant. The lowest total sugar content (2.03 to 2.17%) was recorded in all the treatments at 1st day of storage period and highest total sugar (13.71 and 13.56%, respectively) in the treatments T_1 and T_6 at 15th day of storage period.

The increase in total sugars during ripening could be attributed to hydrolysis of starch into sugars.

Total sugars of the fruit are considered as one of the basic criteria to evaluate the fruit ripening. It is clear from the results that at the time of harvest, the sugars were very low but with the passage of time ripening enhances and ultimately total sugars increased (Gul *et al.,* 1990).

The similar trends of increase in total sugars of mango fruits were also reported by Laxminarayana (1977), Badar (1990), Abbasi *et al.* (2009), Eman *et al.* (2013), Shinde (2014) and Purohit (2015).

4.4 Effect of chitosan treatment on sensory qualities of mango Cv. Alphonso.

The mango fruit ripened with different concentration of chitosan and stored at ambient temperature condition were evaluated for their organoleptic characteristics by a panel of experienced judges on 9 point Hedonic scale score and the results are as below. The data (scores) on organoleptic evaluation of Alphonso mango fruits are presented in Table 12 and graphically depicted in Fig. 12.

4.4.1. Peel colour

The result was found to be statistically significant. It was observed that the peel colour of the ripe mango fruit under the treatment T_1 (7.13) was liked by judges the most, followed by the treatments T_4 (6.50), T_5 (6.50) and T_2

(6.25). The treatments T_3 and T_6 obtained mean minimum score for colour i.e. 6.13. The treatments T_2, T_3, T_4, T_5 and T_6 were at par with each other.

4.4.2. Pulp colour

The results were statistically significant. The treatment T_1 recorded significantly highest score (8.00) for pulp colour while treatment T_4 rated lowest score (7.00). The treatments T_2, T_5, T_3 and T_6 were at par with each other.

4.4.3. Flavour

The results were statistically significant. The ripened mango fruits from the treatments T_1 and T_2 recorded the maximum flavour score (7.75) and were at par with T_3 (7.50) and T_4 (7.25) while the treatment T_5 rated lowest score for flavour i.e. 7.00 but was at par with the treatments T_6 (7.13), T_4 and T_3.

4.4.4. Texture

The results were statistically significant. The treatments T_1 and T_2 rated highest score (7.63) for texture but at par with the treatments T_3 (7.25), T_6 (7.00) and T_4 (6.88) while treatment T_5 rated lowest score (6.00).

4.4.5. Overall acceptability

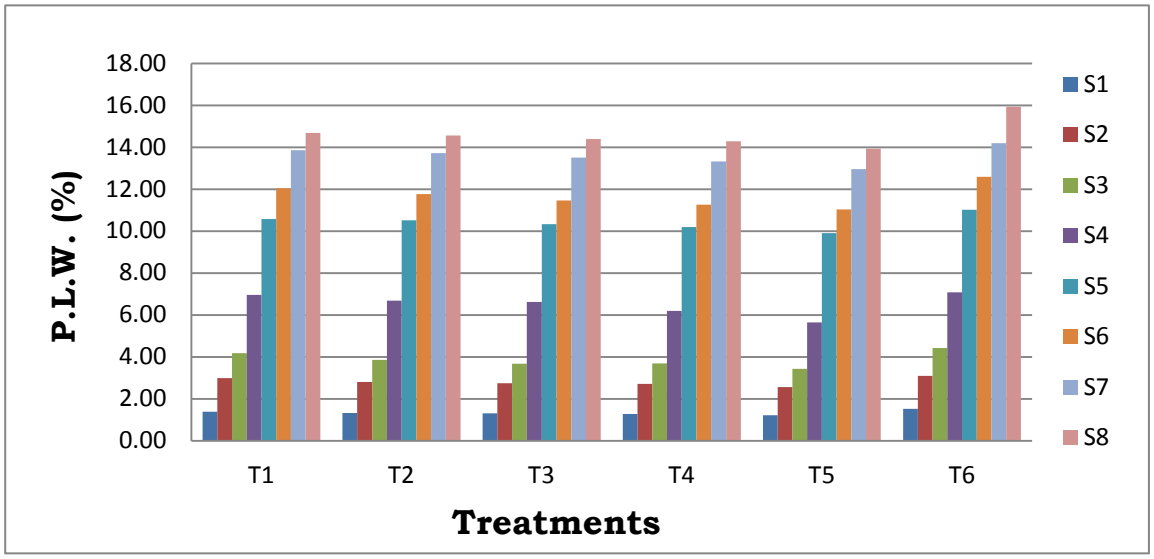
The results were statistically significant. The treatment T_1 rated highest sensory score (7.61) for overall acceptability. T_5 rated lowest sensory score (6.81) but it was at par with the treatments T_4 (6.84) and T_6 (6.97).

Similar trend of organoleptic evaluation of Alphonso mango fruit during storage was observed by Jiang and Li (2001), Chien *et al.* (2007a) and Hernandez-Munoz *et al.* (2008).

Table 1. Effect of chitosan on physiological loss in weight (PLW) (%) of mango Cv. Alphonso during storage at ambient condition

Treat-ments	Physiological loss in weight (%)								
	Storage period (Days)								
	1	3	5	7	9	11	13	15	Mean
T_1	1.38	2.99	4.18	6.96	10.57	12.05	13.86	14.68	8.33
T_2	1.32	2.80	3.86	6.68	10.51	11.76	13.72	14.56	8.15
T_3	1.30	2.74	3.68	6.62	10.33	11.46	13.50	14.40	8.00
T_4	1.28	2.71	3.69	6.20	10.19	11.26	13.32	14.29	7.86
T_5	1.22	2.57	3.44	5.65	9.91	11.03	12.96	13.93	7.59
T_6	1.52	3.09	4.42	7.08	11.02	12.59	14.20	15.93	8.73
Mean	1.34	2.81	3.88	6.53	10.42	11.69	13.59	14.63	
				S.Em. ±			C.D. at 5 %		
Treatment (T)				0.04			0.11		
Storage (S)				0.05			0.13		
Interaction (T X S)				0.11			0.32		

Fig. 1. Effect of chitosan on physiological loss in weight (PLW) (%) of mango Cv. Alphonso during storage at ambient condition



T_1 – 0.02% chitosan

T_2 – 0.04% chitosan

T_3 – 0.06% chitosan

T_4 – 0.08% chitosan

T_5 – 0.10% chitosan

T_6 – control

Table 2. Effect of chitosan treatment (T_1 - 0.02% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

Parameters	T_1 treatment (0.02% chitosan)							
	Days of storage							
	1	3	5	7	9	11	13	15
Ripening								
Green	40 (100)	30 (75)	15 (37.5)	7 (17.5)	0	0	0	0
Turning	0	10 (25)	25 (62.5)	28 (70)	11 (27.5)	4 (10)	0	0
Half ripe	0	0	0	5 (12.5)	22 (55)	17 (42.5)	6 (15)	0
Ripe	0	0	0	0	7 (17.5)	18 (45)	31 (77.5)	33 (82.5)

Spoilage (Figures in parenthesis indicate per cent values)								
Shrivelled	0	0	0	0	0	1 (2.5)	3 (7.5)	5 (12.5)
Spoiled	0	0	0	0	0	0	0	2 (5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

Fig. 2. Effect of chitosan treatment (T_1 - 0.02% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

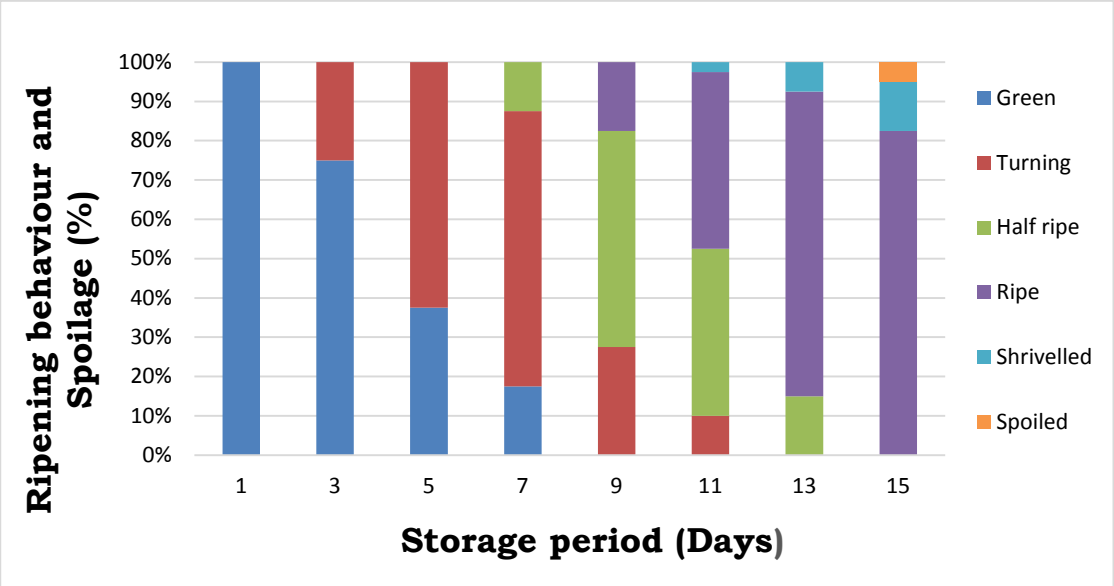


Table 3. Effect of chitosan treatment (T_2 - 0.04% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

Parameters	T_2 treatment (0.04% chitosan)							
	Days of storage							
	1	3	5	7	9	11	13	15

(Figures in parenthesis indicate per cent values)

Ripening								
Green	40 (100)	31 (77.5)	16 (40)	7 (17.5)	0	0	0	0
Turning	0	9 (22.5)	24 (60)	26 (65)	12 (30)	4 (10)	0	0
Half ripe	0	0	0	6 (15)	20 (50)	18 (45)	5 (12.5)	0
Ripe	0	0	0	1 (2.5)	8 (20)	15 (37.5)	29 (72.5)	29 (72.5)
Spoilage								
Shrivelled	0	0	0	0	0	2 (5)	4 (10)	8 (20)
Spoiled	0	0	0	0	0	1 (2.5)	2 (5)	3 (7.5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

Fig. 3. Effect of chitosan treatment (T_2 - 0.04% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

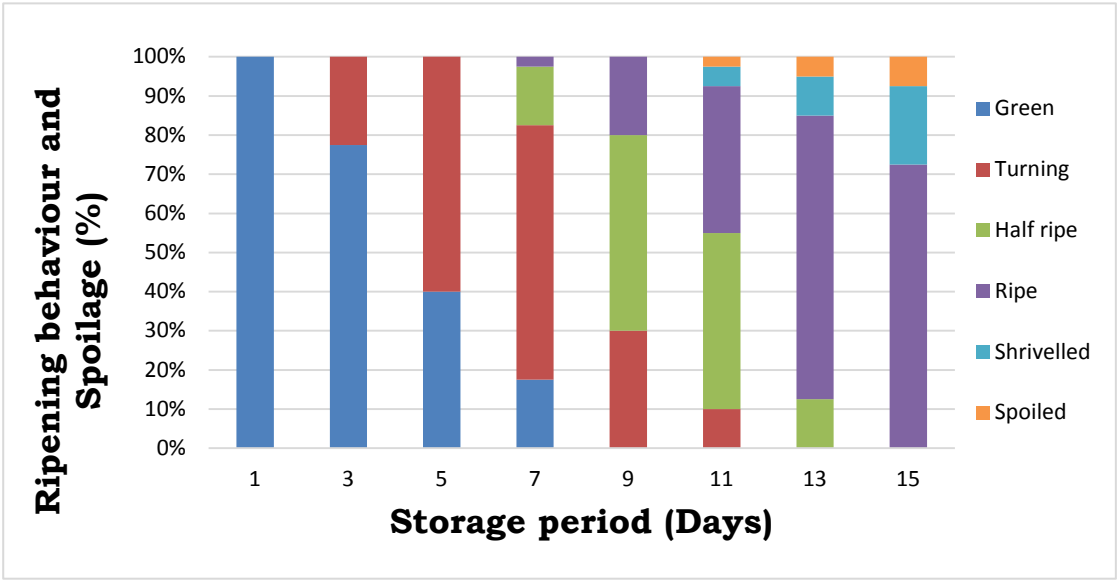


Table 4. Effect of chitosan treatment (T_3 - 0.06% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

Parameters	T_3 treatment (0.06% chitosan)							
	Days of storage							
	1	3	5	7	9	11	13	15
Ripening								
Green	40 (100)	32 (80)	16 (40)	9 (22.5)	0	0	0	0
Turning	0	8 (20)	24 (60)	25 (62.5)	10 (25)	4 (10)	0	0
Half ripe	0	0	0	4 (10)	23 (57.5)	14 (35)	6 (15)	0
Ripe	0	0	0	2 (5)	7 (17.5)	17 (42.5)	25 (62.5)	28 (70)
Spoilage								
Shrivelled	0	0	0	0	0	5 (12.5)	8 (20)	9 (22.5)

Spoiled	0	0	0	0	0	0	1 (2.5)	3 (7.5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

(Figures in parenthesis indicate per cent values)

Fig. 4. Effect of chitosan treatment (T_3 - 0.06% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

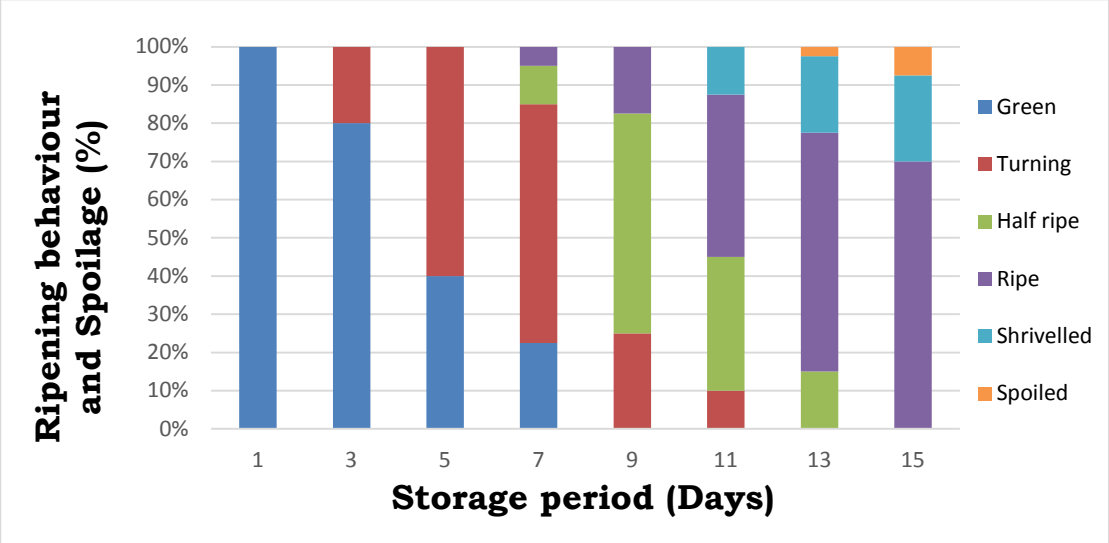


Table 5. Effect of chitosan treatment (T_4 - 0.08% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

Parameters	T_4 treatment (0.08% chitosan)							
	Days of storage							
	1	3	5	7	9	11	13	15
Ripening								
Green	40 (100)	28 (70)	18 (45)	9 (22.5)	0	0	0	0

(Figures in parentheses indicate per cent values)

Turning	0	12 (30)	22 (55)	26 (65)	13 (32.5)	5 (12.5)	0	0
Half ripe	0	0	0	5 (12.5)	20 (50)	16 (40)	5 (12.5)	0
Ripe	0	0	0	0	7 (17.5)	18 (45)	30 (75)	30 (75)
Spoilage								
Shrivelled	0	0	0	0	0	1 (2.5)	3 (7.5)	7 (17.5)
Spoiled	0	0	0	0	0	0	2 (5)	3 (7.5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

Fig. 5. Effect of chitosan treatment (T_4 - 0.08% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

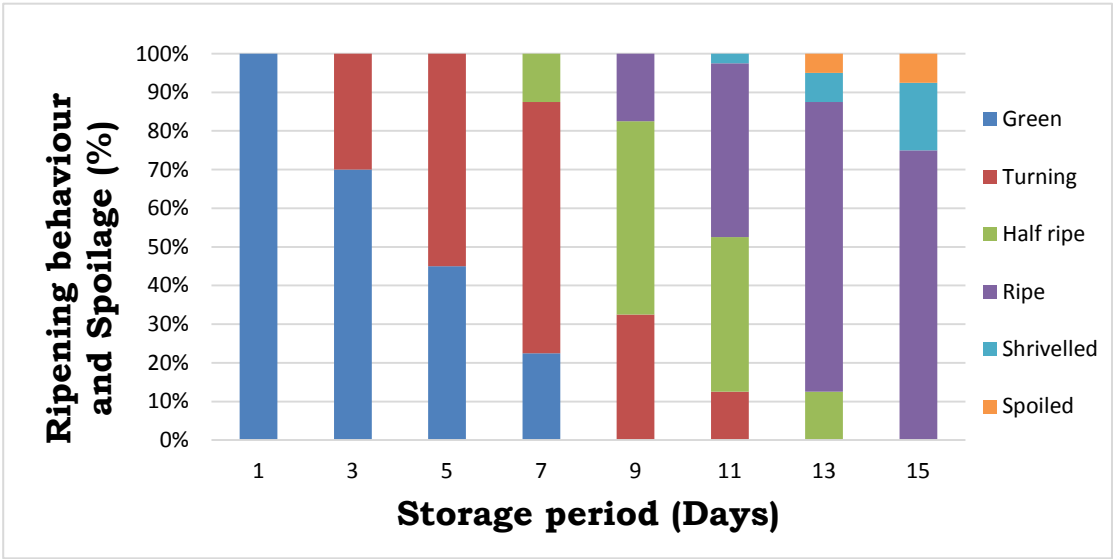


Table 6. Effect of chitosan treatment (T_5 - 0.10% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

Parameters	T_5 treatment (0.10% chitosan)							
	Days of storage							
	1	**3**	**5**	**7**	**9**	**11**	**13**	**15**
Ripening								
Green	40 (100)	27 (67.5)	18 (45)	8 (20)	0	0	0	0
Turning	0	13 (32.5)	21 (52.5)	28 (70)	13 (32.5)	5 (12.5)	0	0
Half ripe	0	0	1 (2.5)	4 (10)	20 (50)	17 (42.5)	8 (20)	0
Ripe	0	0	0	0	6 (15)	10 (25)	21 (52.5)	26 (65)
Spoilage								
Shrivelled	0	0	0	0	0	5 (12.5)	8 (20)	9 (22.5)
Spoiled	0	0	0	0	1 (2.5)	3 (7.5)	3 (7.5)	5 (12.5)
Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

(Figures in parenthesis indicate per cent values)

Fig. 6. Effect of chitosan treatment (T_5 - 0.10% chitosan) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

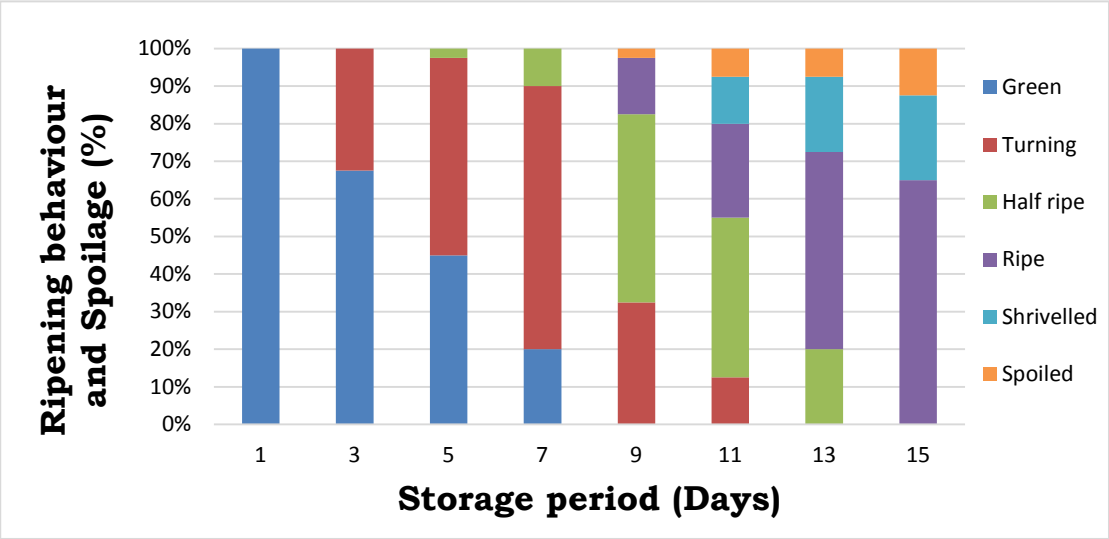


Table 7. Effect of chitosan treatment (T_6 - control) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

Parameters	T_6 treatment (control)							
	Days of storage							
	1	3	5	7	9	11	13	15
Ripening								
Green	40 (100)	24 (60)	13 (32.5)	4 (10)	0	0	0	0
Turning	0	16 (40)	27 (67.5)	26 (65)	9 (22.5)	2 (5)	0	0
Half ripe	0	0	0	7 (17.5)	21 (52.5)	13 (32.5)	4 (10)	0
Ripe	0	0	0	3 (7.5)	10 (25)	22 (55)	29 (72.5)	24 (60)
Spoilage								
Shrivelled	0	0	0	0	0	3 (7.5)	6 (15)	10 (25)
Spoiled	0	0	0	0	0	0	1	6

(Figures)								(2.5)	(15)
	Total	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)	40 (100)

in parenthesis indicate per cent values)

Fig. 7. Effect of chitosan treatment (T_6 - control) on ripening behaviour and spoilage of mango Cv. Alphonso during storage at ambient condition

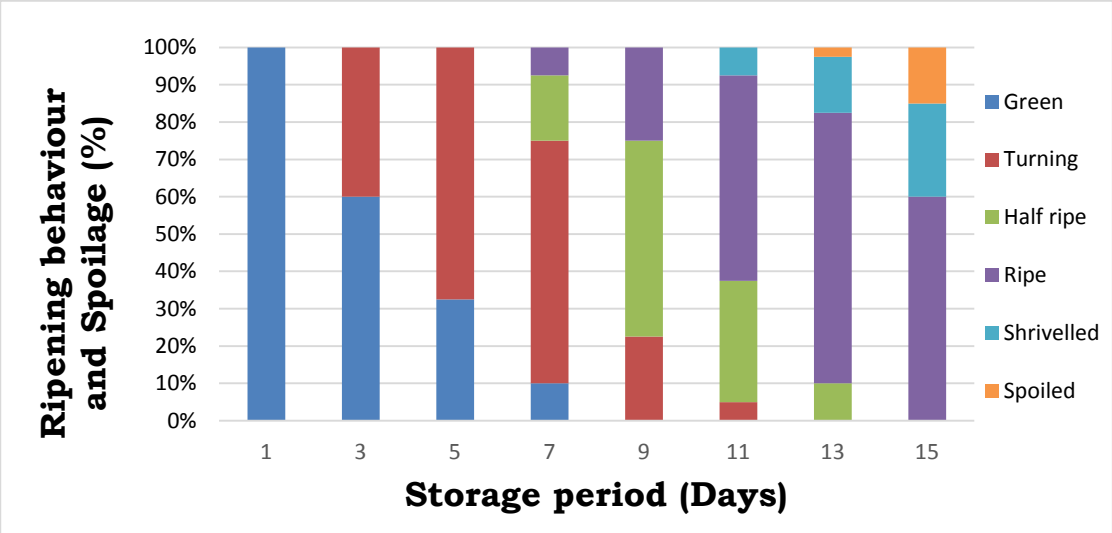


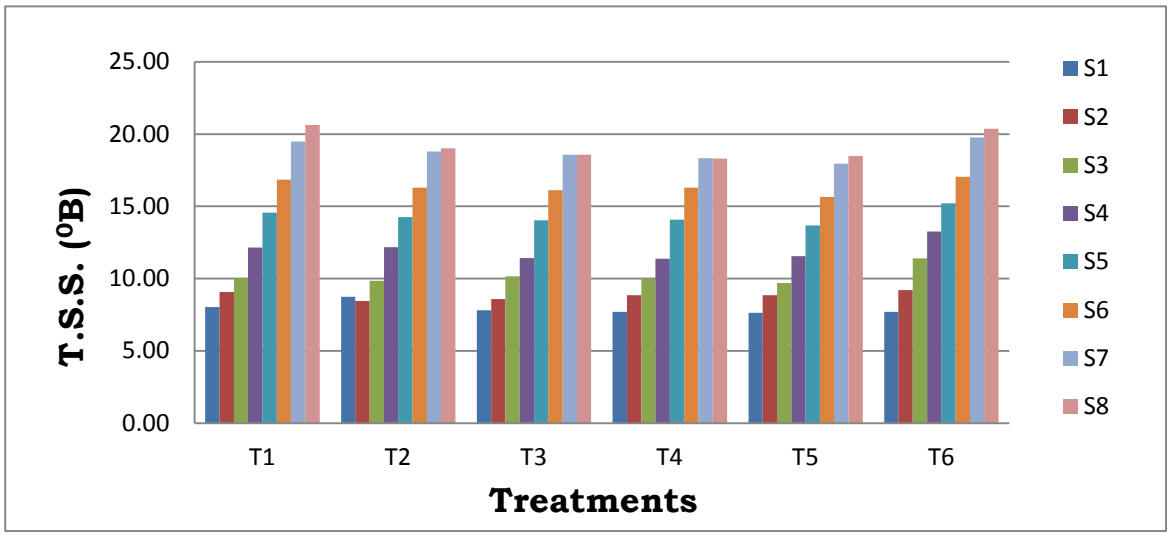
Table 8. Effect of chitosan on total soluble solids (°B) of mango Cv. Alphonso during storage at ambient condition

Treat-ments	Total soluble solids (°B)								
	Storage period (Days)								
	1	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**Mean**
T_1	8.03	9.08	10.00	12.15	14.58	16.85	19.48	20.63	13.85
T_2	8.75	8.45	9.85	12.18	14.25	16.30	18.80	19.03	13.45
T_3	7.80	8.58	10.15	11.43	14.03	16.13	18.58	18.58	13.16
T_4	7.70	8.85	10.00	11.38	14.08	16.30	18.33	18.30	13.12
T_5	7.63	8.85	9.70	11.55	13.68	15.65	17.95	18.48	12.93

T_6	7.70	9.20	11.40	13.25	15.20	17.05	19.78	20.38	14.24
Mean	7.93	8.83	10.18	11.99	14.30	16.38	18.82	19.23	

	S.Em. ±	**C.D. at 5 %**
Treatment (T)	0.15	0.41
Storage (S)	0.17	0.47
Interaction (T X S)	0.41	NS

Fig. 8. Effect of chitosan on total soluble solids (°B) of mango Cv. Alphonso during storage at ambient condition



T_1 – 0.02% chitosan

T_2 – 0.04% chitosan

T_3 – 0.06% chitosan

T_4 – 0.08% chitosan

T_5 – 0.10% chitosan

T_6 – control

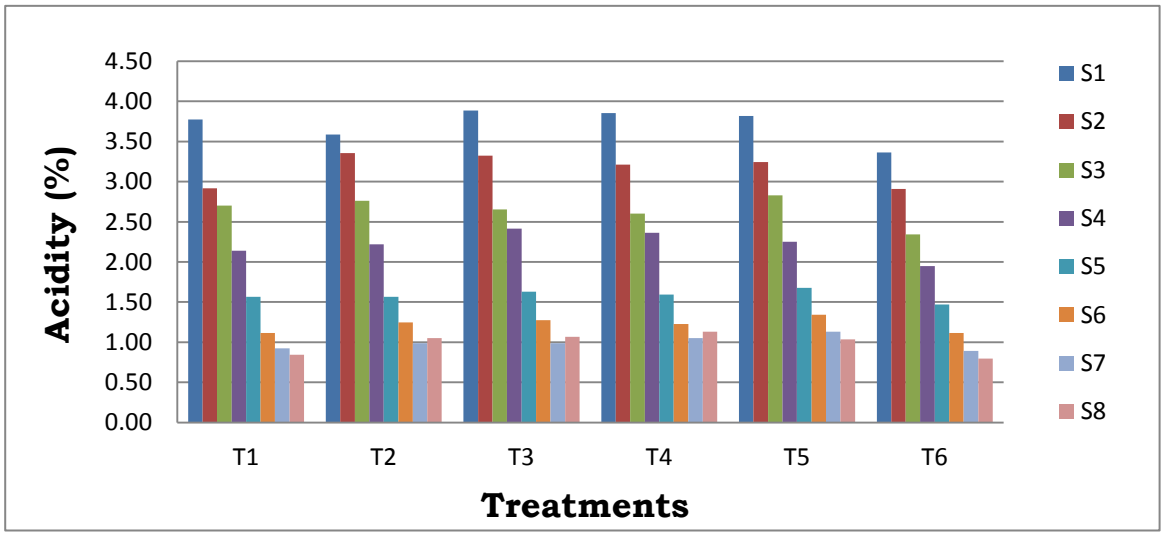
Table 9. Effect of chitosan on titratable acidity (%) of mango Cv. Alphonso during storage at ambient condition

Treat-	**Titratable acidity (%)**

ments	Storage period (Days)								
	1	3	5	7	9	11	13	15	Mean
T_1	3.77	2.92	2.70	2.14	1.57	1.12	0.93	0.85	2.00
T_2	3.59	3.36	2.76	2.22	1.57	1.25	0.99	1.05	2.10
T_3	3.89	3.33	2.65	2.41	1.63	1.28	0.99	1.07	2.15
T_4	3.85	3.21	2.60	2.36	1.60	1.23	1.05	1.13	2.13
T_5	3.82	3.25	2.83	2.25	1.68	1.34	1.13	1.04	2.17
T_6	3.36	2.91	2.34	1.95	1.47	1.12	0.89	0.80	1.85
Mean	3.71	3.16	2.65	2.22	1.58	1.22	1.00	0.99	

	S.Em. ±	C.D. at 5 %
Treatment (T)	0.04	0.12
Storage (S)	0.05	0.14
Interaction (T X S)	0.12	NS

Fig. 9. Effect of chitosan on titratable acidity (%) of mango Cv. Alphonso during storage at ambient condition



T_1 – 0.02% chitosan T_4 – 0.08% chitosan

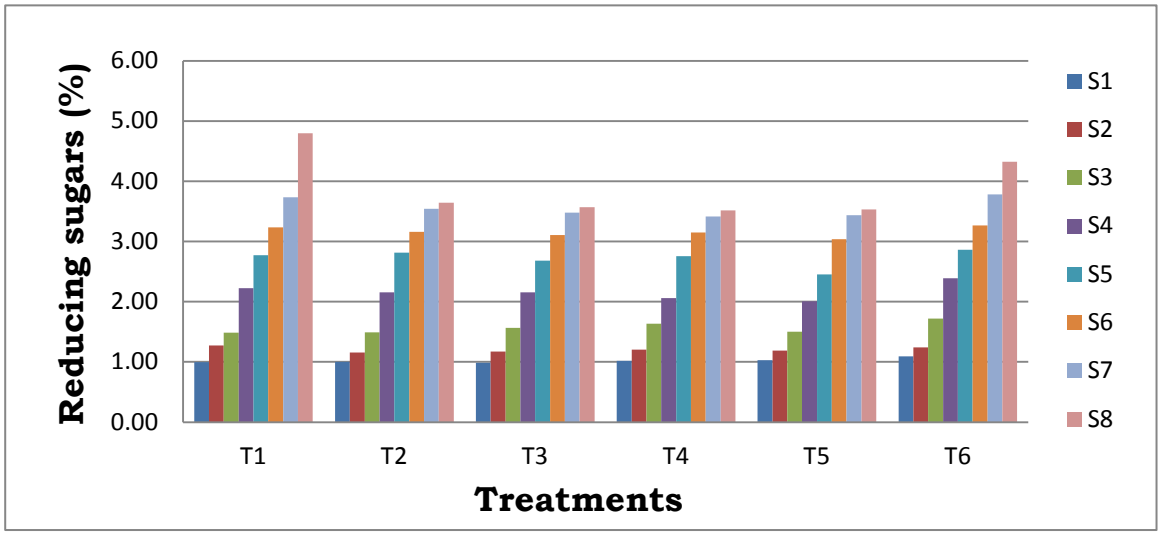
T_2 – 0.04% chitosan T_5 – 0.10% chitosan

T_3 – 0.06% chitosan T_6 – control

Table 10. Effect of chitosan on reducing sugars (%) of mango Cv. Alphonso during storage at ambient condition

Treat-ments	Reducing sugars (%)								
	Storage period (Days)								
	1	3	5	7	9	11	13	15	Mean
T_1	1.00	1.28	1.49	2.22	2.77	3.24	3.74	4.80	2.56
T_2	1.01	1.16	1.49	2.16	2.82	3.16	3.55	3.64	2.37
T_3	0.99	1.17	1.57	2.16	2.68	3.11	3.48	3.57	2.34
T_4	1.02	1.21	1.64	2.06	2.76	3.15	3.42	3.52	2.34
T_5	1.03	1.19	1.50	2.01	2.46	3.04	3.44	3.54	2.27
T_6	1.09	1.24	1.72	2.39	2.87	3.27	3.79	4.33	2.59
Mean	1.02	1.21	1.57	2.17	2.72	3.16	3.57	3.90	
				S.Em. ±			C.D. at 5 %		
Treatment (T)				0.04			0.11		
Storage (S)				0.04			0.12		
Interaction (T X S)				0.11			0.30		

Fig. 10. Effect of chitosan on reducing sugars (%) of mango Cv. Alphonso during storage at ambient condition



T_1 – 0.02% chitosan

T_2 – 0.04% chitosan

T_3 – 0.06% chitosan

T_4 – 0.08% chitosan

T_5 – 0.10% chitosan

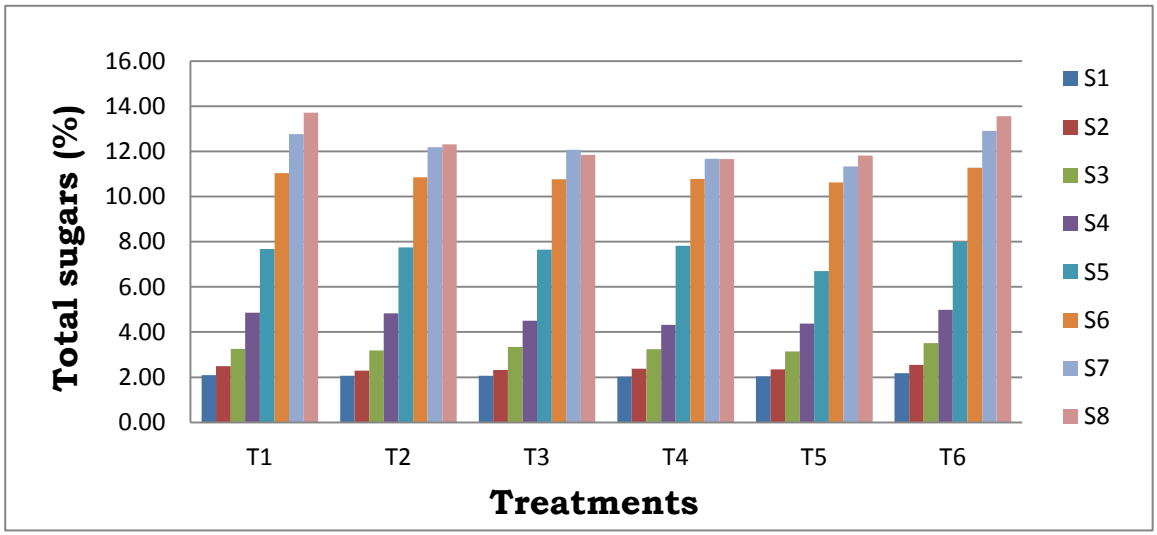
T_6 – control

Table 11. Effect of chitosan on total sugars (%) of mango Cv. Alphonso during storage at ambient condition

Treat-ments	Total sugars (%)								
	Storage period (Days)								
	1	3	5	7	9	11	13	15	Mean
T_1	2.09	2.50	3.26	4.85	7.68	11.04	12.77	13.71	7.24
T_2	2.07	2.29	3.17	4.83	7.74	10.84	12.18	12.30	6.93
T_3	2.06	2.31	3.34	4.51	7.65	10.77	12.07	11.85	6.82
T_4	2.03	2.38	3.24	4.32	7.81	10.78	11.68	11.66	6.74
T_5	2.03	2.34	3.13	4.36	6.70	10.62	11.33	11.81	6.55
T_6	2.17	2.55	3.51	4.97	8.00	11.27	12.90	13.56	7.37
Mean	2.08	2.40	3.28	4.64	7.60	10.89	12.16	12.48	
				S.Em. ±			C.D. at 5 %		
Treatment (T)				0.07			0.20		

Storage (S)	0.08	0.23
Interaction (T X S)	0.20	0.56

Fig. 11. Effect of chitosan on total sugars (%) of mango Cv. Alphonso during storage at ambient condition



T_1 – 0.02% chitosan

T_2 – 0.04% chitosan

T_3 – 0.06% chitosan

T_4 – 0.08% chitosan

T_5 – 0.10% chitosan

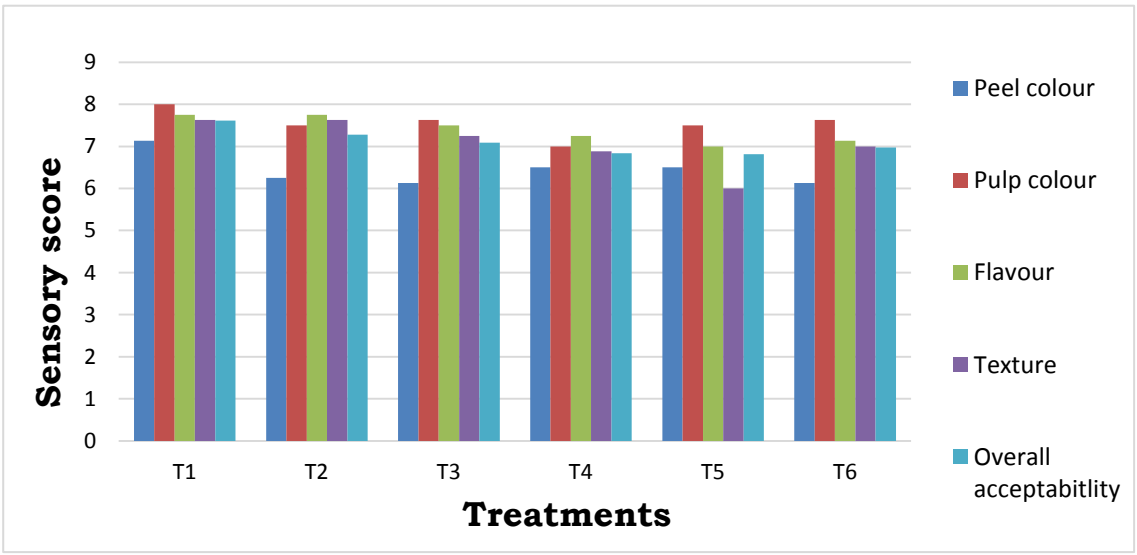
T_6 – control

Table 12. Effect of chitosan on sensory evaluation of mango Cv. Alphonso during storage at ambient condition

Treatments	**Sensory evaluation**				
	Sensory score for				**Overall acceptability**
	Peel colour	**Pulp colour**	**Flavour**	**Texture**	

T_1	7.13	8.00	7.75	7.63	7.61
T_2	6.25	7.50	7.75	7.63	7.28
T_3	6.13	7.63	7.50	7.25	7.09
T_4	6.50	7.00	7.25	6.88	6.84
T_5	6.50	7.50	7.00	6.00	6.81
T_6	6.13	7.63	7.13	7.00	6.97
Mean	6.44	7.54	7.40	7.07	7.10
S.Em. ±	0.14	0.07	0.18	0.30	0.10
C.D. at 5 %	0.40	0.21	0.55	0.88	0.28

Fig. 12. Effect of chitosan on sensory evaluation of mango Cv. Alphonso during storage at ambient condition



T_1 – 0.02% chitosan

T_2 – 0.04% chitosan

T_3 – 0.06% chitosan

T_4 – 0.08% chitosan

T_5 – 0.10% chitosan

T_6 – control

T_1 - 0.02 per cent chitosan

T_2 - 0.04 per cent chitosan

T_3 - 0.06 per cent chitosan

T_4 - 0.08 per cent chitosan

T_5-0.10 per cent chitosan

T_6- Control

Plate 1. Effect of chitosan on Mango Cv. Alphonso at 15th day of storage at ambient condition

CHAPTER – V

SUMMARY AND CONCLUSION

The present investigation entitled "Effect of post harvest treatment of chitosan on storage behaviour of mango (*Mangifera indica* L.) Cv. Alphonso" was carried out in the Department of Post Harvest Management of Fruit, Vegetable and Flower Crops, PGI PHM, Killa-Roha. The study was carried out during the year 2015-2016. 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 concentrations of chitosan 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 treatment on physical parameters of mango Cv. Alphonso.

5.1.1. Physiological loss in weight (PLW) (%)

The data indicate that there was decrease in the physiological loss in weight with increase in the concentration of chitosan. Among all the treatments, the lowest mean physiological loss in weight was noticed in the treatment T_5 (7.59%) with (0.10% chitosan) which was significantly superior to rest of the treatments. The highest mean physiological loss in weight was found in the treatment T_6 (8.73%) i.e. control.

At the end of storage days, there was a significant increase in the physiological loss in weight level with respect of the treatments. At initial stage i.e. 1st day, the lowest mean physiological loss in weight (1.34%) was noticed and the highest mean physiological loss in weight (14.63%) at 15th day.

5.2 Effect of chitosan treatment on ripening behaviour and spoilage of mango Cv. Alphonso

During the storage, the ripening was found to be slower in treatment T_5 (0.10% chitosan), followed by treatments T_4, T_3, T_2 and T_1 at 13 days after harvesting. The minimum ripening was observed in treatment T_5 (52.5%) and the maximum ripening was recorded in the treatment T_1 (77.5%). The increase in concentration of chitosan retarded the process of ripening. The slower ripening process indicates that the chitosan increases shelf life of mango.

Minimum shrivelling was observed in mango fruits treated with 0.02 per cent chitosan treatment T_1 (12.5%), followed by treatment T_4 (0.08% chitosan) and T_2 (0.04% chitosan). Maximum shrivelling was observed in the treatment T_6 (25%) i.e. control and treatments T_5 and T_3 (22.5%) with 0.10 and 0.06 per cent chitosan, respectively at 15th day of storage.

Regarding spoilage, the maximum spoilage was observed in fruits which are untreated i.e. control treatment T_6 and minimum in 0.02 per cent chitosan in treatment T_1 (5%). The treatment T_1 (0.02% chitosan) observed as optimum concentration and better than the other higher concentrations at 15th day of storage.

5.3 Effect of chitosan treatment on chemical composition of mango Cv. Alphonso.

5.3.1. Total soluble solids (°B)

The data indicate that there was a significant difference in TSS content of Alphonso mango due to the chitosan treatments. Among all the treatments, the highest mean TSS was found in the treatment T_6 (14.24°B) in control treatment which was significantly superior to rest of the treatments. The lowest mean TSS was noticed in the treatment T_5 (12.93°B) with 0.10 per cent chitosan concentration.

At the end of storage days, there was a significant increase in the TSS level irrespective of the treatments. At initial stage i.e. 1st day, the lowest mean TSS (7.93°B) was noticed and the highest mean TSS (19.23°B) was at 15th day.

5.3.2. Titratable acidity (%)

Among all the treatments, the highest mean titratable acidity was found in treatment T_5 (2.17%) i.e. 0.10 per cent chitosan treatment which was significantly superior to rest of the treatments. The lowest mean titratable acidity was noticed in the treatment T_6 (1.85%) i.e. control.

At the end of storage days, there was a significant decrease in the titratable acidity level irrespective of the treatments. At initial stage i.e. 1st day, the highest mean titratable acidity (3.71%) was noticed and the lowest mean titratable acidity (0.99%) at 15th day.

5.3.3. Reducing sugars (%)

There was a gradual increase in the reducing sugar (%) content till peak during ripening, followed by a decline towards the end of storage irrespective of the treatments. The lowest mean reducing sugar (1.02%) content was observed initially at 1st day of storage, while the highest mean reducing sugar (3.90%) content was recorded at 15th day of storage.

Among all the treatments, the highest mean reducing sugar content was found in the treatment T_6 (2.59%) i.e. control which was significantly superior to rest of the treatments. The lowest mean reducing sugar content was noticed in the treatment T_5 (2.27%) i.e. 0.10 per cent chitosan concentration.

5.3.4. Total sugars (%)

The highest mean total sugar content was found in the treatment T_6 (7.37%) i.e. control. The lowest mean total sugar was noticed in the treatment T_5 (6.55%) with 0.10 per cent chitosan concentration.

As regards the storage, there was an increase in the total sugar content irrespective of the treatment during storage. The lowest mean total sugar (2.08%) content was observed initially at 1st day of storage, while the highest mean total sugar (12.48%) was recorded at 15th day of storage.

5.4 Sensory evaluation

As regards the sensory evaluation for peel colour, pulp colour, flavour, texture and overall acceptability, the treatment T_1 (0.02% chitosan) treated fruits were observed significantly superior having 7.61 score for overall acceptability compared to all other treatments. The treatments T_1 (0.02% chitosan) and T_2 (0.04% chitosan) both are superior in flavour (7.75) as well as in texture (7.63). The treatment T_1 (0.02% chitosan) is also best for peel and pulp colour with score of 7.13 and 8.00, respectively. The higher concentration of chitosan showed poor performance of mango fruits which obtained lesser score from the panellist.

CONCLUSION

From the present investigation, it could be concluded that the shelf life of mangoes can be increased up to 15 days by treating the fruits with chitosan @ 0.02 per cent at ambient temperature. The coating of mango fruits with chitosan modified the surrounding atmosphere, reduced spoilage percentage and delayed the ripening process of fruits as compared to untreated control mango Cv. Alphonso fruits.

As regards the organoleptic evaluation, the mango fruits treated with 0.02 per cent chitosan recorded the maximum sensory score for peel colour, pulp colour as well as flavour and texture of the fruits. Thus, it is suggested that 0.02 per cent of chitosan coating is optimum for improving the shelf life of mango.

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_____*Original not seen

APPENDIX – I

Temperature and relative humidity recorded under Killa, Roha conditions during the course of investigation (2015-2016)

DATE	Temperature °C		Relative Humidity (%)	
	Max	Min	Max	Min
03.05.16	34	29	70	37
04.05.16	34	29	84	46
05.05.16	33	28	89	67
06.05.16	34	29	79	55
07.05.16	34	29	79	59
08.05.16	34	28	89	59
09.05.16	33	29	89	67
10.05.16	33	29	87	65
11.05.16	34	24	85	63
12.05.16	32	28	84	59
13.05.16	32	26	86	50
14.05.16	39	28	84	54
15.05.16	31	27	83	50
16.05.16	33	26	86	57
17.05.16	32	27	88	54
Average	33.5	27.7	84.13	56.13

APPENDIX – II

Abbreviations used

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

26.	Mt	Metric tonnes
27.	Mt/ha	Metric tonnes per hectare
28.	m ha	Million hectare
29.	mg	Mili gram
30.	mg/g^{-1}	Milligram per gram
31.	mg/l^{-1}	Milligram per liter
32.	ml/l	Milliliter per liter
33.	$ml\ l^{-1}$	Milliliter per liter
34.	NS	Non-significant
35.	O_2	Oxygen
36.	PLW	Physiological loss in weight
37.	ppm	Part per million
38.	RH	Relative humidity
39.	S.Em.	Standard error of mean
40.	TSS	Total soluble solids
41.	TA	Tritratable acidity
42.	Var.	Variety
43.	*viz.*,	Videlicet (Namely)

VITAE

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A candidate for the degree of

M.Sc. (Post Harvest Management)

Title of thesis Effect of post harvest treatment of chitosan on storage behaviour of mango (*Mangiferaindica* L.) Cv. Alphonso

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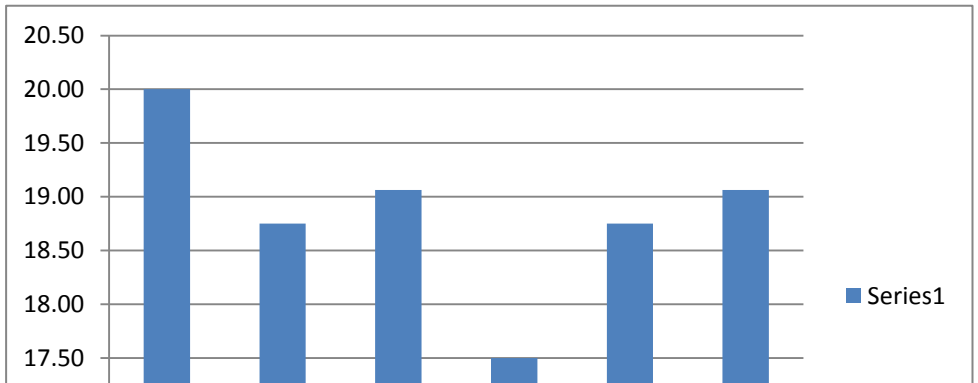
pulp recovery percentage

		R1	R2	R3	R4	Sum	Mean
T1		7.50	7.50	7.63	7.82	30.44	7.61
T2		7.37	7.13	7.38	7.25	29.12	7.28
T3		7.25	7.00	7.00	7.13	28.38	7.09
T4		6.87	6.87	6.75	6.88	27.37	6.84
T5		7.25	7.00	6.50	6.50	27.25	6.81
T6		7.13	6.75	7.00	7.00	27.88	6.97
		43.37	42.25	42.25	42.57	170.43	
Sig							
S.Em ±				0.10			
C.D.				0.28			

r =	4	Tss =	2.50	SE (m)=	0.10

T1	19.03
T2	18.20
T3	17.73
T4	17.10
T5	17.03
T6	17.42



t =	6			SE (d) =	0.14
GM =	7.10	**Tr ss =**	1.84	**CD =**	0.28
CF =	1210.20	**Ess =**	0.66	**CV =**	2.69

ANOVA TABLE						
SOV	**DF**	**SS**	**MSS**	**Cal F**	**TAB F**	**Result**
Treat	5	1.837	0.367	10.043	2.773	Sig
Error	18	0.659	0.037			
Total	23	2.496				

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rs

47	1.06383
42	1.190476
34.5	1.449275
37	1.351351
43	1.162791
32	1.5625
39	1.282051

ts

67	3.731343
62	4.032258
54	4.62963
49	5.102041
57	4.385965
45	5.555556
45.5	5.494505

40	1.25	44.5	5.617978
39.5	1.265823	47.5	5.263158
26	1.923077	49.4	5.060729
44	1.136364	48	5.208333
34	1.470588	50	5
47	1.06383	72	3.472222
37	1.351351	65	3.846154
43	1.162791	49	5.102041
40	1.25	42	5.952381
36	1.388889	63.7	3.924647
39.5	1.265823	55	4.545455
	#DIV/0!		#DIV/0!
	#DIV/0!		#DIV/0!
			#DIV/0!

	Peel colour	Pulp colour	Flavour	Texture	Overall acceptabitlity
T1	7.13	8	7.75	7.63	7.61
T2	6.25	7.5	7.75	7.63	7.28
T3	6.13	7.63	7.5	7.25	7.09
T4	6.5	7	7.25	6.88	6.84
T5	6.5	7.5	7	6	6.81
T6	6.13	7.63	7.13	7	6.97
mean	6.44	7.54	7.4	7.07	7.1