"Studies on various packaging materials on fruit quality and shelf life of Kinnow"

THESIS
Submitted to

LOVELY PROFESSIONAL UNIVERSITY
PHAGWARA (PUNJAB), INDIA

In partial fulfillment of the requirements for the award of degree of

MASTER OF SCIENCE
in
(Fruit Science)

BY

Rupinder Singh

Registration Number: 11510881

Under the guidance of
Dr. S. Senthilkumar
(Assistant Professor)
School of Agriculture

DEPARTMENT OF HORTICULTURE
SCHOOL OF AGRICULTURE
LOVELY PROFESSINAL UNIVERSITY
PUNJAB 144401

June 2017

LOVELY PROFESSIONAL UNIVERSITY

Transforming Education Transforming India

CERTIFICATE- I

This is to certify that thesis titled **"Studies on various packaging materials on fruit quality and shelf life of Kinnow"** submitted in partial fulfillment of the requirement for the award of degree of **Master of Science in Fruit Science** under the discipline of horticulture, is a bonafide research work carried out by **Mr. Rupinder Singh (Registration No. 11510881)** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

(Signature of Supervisor)

Dr. S. Senthilkumar

Assistant Professor

School of Agriculture,

Lovely Professional University

Phagwara, Punjab.

CERTIFICATE - II

This is to certify that the thesis entitled **"Studies on various packaging materials on fruit quality and shelf life of Kinnow"** submitted by Rupinder Singh to Lovely Professional University, Phagwara in partial fulfillment of the requirements for the degree of Master of Science (Fruit Science) in the discipline of Horticulture has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

(Dr. S. Senthilkumar)
Chairperson
Advisory Committee

( )
External Examiner

(Dr. Shailesh Kumar Singh)
Member

(Head of the Department)

Dean (School of Agriculture)

DECLARATION

I hereby declare that the thesis entitled **"Studies on various packaging materials on fruit quality and shelf life of Kinnow"** is an authentic record of my work carried out at Lovely Professional University as requirement for the degree of **Master of Science (Fruit Science)** in the discipline of **Horticulture,** under the guidance of Dr.S.Senthilkumar, Assistant Professor, School of Agriculture and no part of this thesis has been submitted for any other degree and diploma.

Rupinder Singh

(Registration No. 11510881)

ACKNOWLEDGEMENT

Pride, praise and perfection belong to Almighty alone. So, first of all, I would like to offer my heartfelt salvation at the lotus feet of the supreme being for unbroken health and vigour, bestowed upon me and in whose faith, I was able to complete this task. I am grateful to our Lovely Professional University for providing me with an opportunity to undertake this project in the university and providing us with all the facilities. I am really thankful from my heart to Dr. S. Senthilkumar, who allowed me to do this project under his guidance. I am highly thankful to my co advisor Dr. Shailesh Kumar Singh, my family and friends for their active support, valuable time and advice, whole-hearted guidance, sincere cooperation and pains taking involvement during this study.

Lastly, I am thankful to my friends and Former COD of Horticulture, Dr. Madhu Sharma, who has been theoretically and instrumental in creating proper, healthy and conductive environment and including new and fresh innovative ideas during the project. Without their help, it would have been extremely difficult for me to prepare the project in a time bound framework.

Yours faithfully

Rupinder Singh

Registration no. 11510881

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	:	percent
&	:	and
/	:	per
@	:	at the rate of
A.O.A.C	:	Association of Official Agricultural Chemists
CAP	:	Controlled Atmospheric Packaging
CD (0.05%)	:	Critical difference at 0.05% level
CFB	:	Corrugated fiber box
cm	:	Centimeter
CO2	:	Carbon dioxide
cv.	:	Cultivar
DAS	:	Days After Storage
DCPIP	:	2,6 dichlorophenol indophenols
et. al.	:	and Co-workers
CRD	:	Complete Randomized Design
Fig.	:	Figure
FSI	:	Fruit Shape Index
g	:	Gram
HDPE	:	High density polyethylene film
i.e.,	:	that is
IHD	:	Indian Horticulture Database
kg	:	Kilogram
LDPE	:	Low density polyethylene film
LLDPE	:	Linear low density polyethylene
LPU	:	Lovely Professional University
MA	:	Modified atmosphere
MAP	:	Modified Atmosphere Packaging
mg	:	milligram
Mg/100 ml	:	Milligram per 100 milliliter
mm	:	millimeter
NS	:	Non-Significant
nm	:	nanometer
no.	:	Number
O_2	:	Oxygen
°B	:	Degree Brix
°C	:	Degree Centigrade
°F	:	Degree Fahrenheit
PE	:	Poly ethylene
PF	:	Poly film
pH	:	puissance de hydrogen
PLW	:	Physiological loss in weight
PP	:	Polypropylene
ppm	:	Parts per million
PVC	:	Polyvinyl chloride
RH	:	Relative humidity
RS	:	Reducing sugar
S.Ed	:	Standard error deviation
S.Em	:	Standard error of mean
TA	:	Titrable acidity
TSS	:	Total soluble solids
Vit. C	:	Vitamin C
Viz.,	:	*N*amely
W	:	Weight
µ	:	Micro
µm	:	Micrometer

ABSTRACT

An investigation was conducted at post harvest laboratory, Department of Horticulture, Lovely Professional University, Punjab during the academic year 2016-17 to study the effect of various packaging materials on fruit quality and shelf life of Kinnow. The packaging films include LDPE (25 micron), HDPE (15 micron), Polypropylene (25 micron), Shrink film (15 micron) and Cling film (15 micron) were used for experimentation. Liquid paraffin wax (10%) was used as a coating material. For various packaging treatments, the fruits under the treatments T_2, T_5, T_6, T_8, T_9 and T_{11} retained maximum 'Fruit length' which were on par with each other including T_4 at 5 days after storage. Observations at 25 days after storage revealed that the fruits under treatment T_6 (Cling film at 15 micron) expressed better value for 'Fruit length' and 'Fruit girth'. Packaging and post harvest treatments significantly influenced certain other physical traits *viz.*, 'Fruit shape index' and 'Fruit specific gravity', In both the cases, the fruits under treatment T_3 (HDPE at 15 micron) registered maximum value at 25^{th} day after storage.

Regarding the status for spoilage percentage, the minimum 'Spoilage percentage' was recorded in T_6 (Cling film at 15 micron) which was found to be on par with T_{11} (Cling film at 15 micron + wax at 10%) at 25^{th} day after storage. The packaging and post harvest treatments exhibited the minimum value for 'Physiological loss in weight' in the treatment T_{11} (Cling film at 15 micron + wax at 10%) at 25^{th} day after storage. In case of quality related traits, the fruits under treatment T_{11} (Cling film at 15 micron + wax at 10%) recorded the maximum value for 'TSS' when compared with other packaging treatments including control at 25^{th} day after storage.

With regard to remaining quality related traits, the fruits under treatment T_{11} (Cling film at 15 micron + wax at 10%) expressed the maximum value for 'TSS: acid ratio', 'Total sugars', 'Non-reducing sugars' and 'Sugar: acid ratio' at 25^{th} day after storage.

Chapter I

INTRODUCTION

Citrus fruits are grown commercially in tropics and subtropic regions of the world. Kinnow, a mandarin hybrid (King x Willow leaf) occupies the prime position amongst the citrus fruits grown in India. In subtropical regions of Punjab, it occupies around 50% area of fruit growing regions. It is precocious, prolific bearer and has excellent fruit quality with high juice content (Jawandha, 2015). Kinnow fruits are deep orange yellow in colour and very juicy (Gangwar *et al.*, 2005) and have lot of market potential, which help in increasing the farm income. Due to these quality traits, kinnow is in high demand not only in Indian markets, but also in other countries *viz.*, Sri Lanka, Thailand, Bahrain, Kuwait and Saudi Arabia (Dhatt and Mahajan, 2011).

In Kinnow, improper post-harvest handling practices lead to quality deterioration and fetch poor market price. In mandarin, loss of 20-25% has been estimated due with transportation of fruits from field to market (PHLRD, 2005). Qualitative losses, in sense of caloric and nutritive value, non acceptability by consumers, and poor edibility are more difficult to measure than quantitative losses of fresh fruits (Kader, 2005).

Post harvest treatments play a significant role in extending shelf life of the fruits (Deka *et. al.*, 2006). In harvested fruits, loss in water vapour, results in peel shrinkage, reduction of turgidity and decrease in resistance to gas diffusion, results in negative consequences on the flavour and taste (D’Aquino *et al.*, 2001). Many facts have been studied in order to overcome these problems and extend the shelf life of fresh produce. According to Panhwar (2006), worldwide post-harvest losses in fruits are as high as 30-40 percent and it seems to be more in some developing countries. Reducing post harvest losses ensures food safety, both in quantity as well as quality, that prefers to every inhabitant in our planet. In developed countries like, Japan, Korea and Taiwan, it has been reported that the post-harvest losses for fruits to be 10 percent (FAO, 2010). India is the world’s second largest producer of fruits stands next to China and has good potential of being the biggest among others. In total, 60 to 70 percent of fruits produced in India are consumed domestically and 2% of fruits are being processed. Out of the total production, only 1% is being exported. Among for stored fruits, post-harvest losses account to 20-30%. In post harvest losses, qualitative losses rather than quantitative losses are more difficult to measure (Kader, 2005).

In most of the storability studies for fruits, it is found to be observed that the levels of CO_2 and O_2 inside package altered due to fruit respiration and permeability of the film, resulted in recommendation of modified atmosphere packaging (MAP) for fresh fruit storage (Geeson *et al.*, 1981). Impart of reduced O_2 and increased CO_2 levels on fruit varies with gas concentration, exposure time and varietal character, generally lowering respiration rate and results in softening of fruits. Apart, any fungal infection on fruit gets retarded inhibit ethylene expression, results in quality deterioration (Thompson, 1995). MAP also tends to cause saturated atmosphere around the fruit, that reduces water loss and shrinkage. When the rate of oxygen and carbon dioxide transmission through the package equal the product's respiration rate then desirable equilibrium modified atmosphere gets created in the package film at right permeability. (Day, 1993).

Edible coatings have long been used for quality retention and shelf life extension of several fresh fruits *viz.*, apple, citrus (Baldwin *et al.*, 1996; Li and Barth, 1998). They have been applied directly on fruit surface with several mode of application *viz.*, dipping, spraying or brushing to create a modified atmosphere (McHugh and Senesi, 2000). Use of edible coating provides a barrier against external elements and hence it increases shelf life by reducing gas exchange, water loss, aroma, flavours, and soluble migration towards the cuticle (Guilbert et al., 1996). In general any type of material used for coating or wrapping various fruits tends to extend storability that may be eaten together with or without further removal is considered as an edible film or coating (Pavlath and Orts, 2009). In kinnow, the impact of coating on fruits depends mainly on temperature, alkalinity, thickness and type of coating, varietal nature and condition of fruit (Park *et al.*, 1994). Basically the usage of food grade wax coatings on fresh fruits and vegetables have been approved by the Government of India (FSSA, 2006) and with implementation of this technology on with several wax formulations are now-a-days being supplied by suppliers in market. So, the impact of these wax coating plays a vital role in monitoring the storability of fresh fruits, especially kinnow. However, the role of these waxes alone or in combination with packaging needed much focus on correlating the positive mode of applicability to kinnow.

Hence, the present investigation was performed to study the effects of various packaging materials had undertaken following objectives:-

- To assess the effect of different packaging materials on quality and storability of kinnow fruits,
- To evaluate the influence of fruits quality parameters with various packaging materials, and
- To standardize a suitable packaging material for kinnow fruits for better marketability.

Chapter II

REVIEW OF LITERATURE

Effect of packaging on physical parameters of fruits

Farooqi *et al*., (1988) made a study on effect of wax emulsions Fruitex, Britex-561 and SB65 on oranges, Kinnow, lemons and grape fruits. It was found to be observed that wax coating improved external appearance of fruits and reduced weight loss, retained fruit firmer, and fresh look.

Dhatt *et al*., (1991) reported that in the treatment of kinnow fruits wrapped with shrink wrap films with 25 micron thickness registered lesser weight loss (2%) and fruits also tasted better.

Dhatt and Randhawa (1991) observed the average weight loss was minimum (6.1%) in the treatment with polymeric wrapped film and maximum (23.4%) in unwrapped. It was also observed, in individually wrapped kinnow fruits with high density polyethylene (HDPE) film, storability extended for about 8 weeks at ambient condition.

According to Dhatt *et al*., (1995) the maximum weight loss of 25.57 and 45.31 percent was observed in unwrapped fruits after 30 and 60 days. But in other packaging treatments, the weight loss in individually wrapped fruit was 1.54 (Imazalil 500ppm), 3.85 (Imazalil 1000 ppm) and 6.33 per cent (2,4-D 200 ppm) after 30, 60 and 90 days.

Ladaniya *et al*. (1997) reported that the minimum weight loss in fruits of Nagpur mandarin observed in the treatment of fruits wrapped with heat shrinkable film individually. In vice versa, the weight loss in fruits increased with extended storage period.

According to Sonkar and Ladaniya (1998) the technique of tray-over wrapping of Nagpur mandarin with linear low density polyethylene (LLDPE) stretch cling film extended the shelf life upto 2 months. The individual film wrapping of Nagpur mandarin fruit using stretch cling film after carbendazim treatment extended the storability to 60 days under refrigerated condition and possessed minimum weight loss.

Randhawa *et al.*, (1999) reported that, the wrapping of Nagpur mandarin fruits reduced water loss drastically (1-2%) as compared with non-wrapped fruits (13.29%) after 60 days of storage under refrigerated condition.

Perez-Guzman (1999) studied the effect of individual seal packaging of 'Dancy' mandarin (*Citrus reticulata*) with polyolefin (0.019 mm) and PVC (0.025 mm) and reported that the minimum weight loss was observed under refrigeration storage.

Deshmukh *et al.*, (1999) observed the effect of film wrapping and low temperature (5-6^{0}C) on storage quality of sweet orange cv. Mosambi and reported that, both the treatments were found to be positive with the parameters viz., minimized weight loss and fruit diameter.

Ladaniya (2003) reported that packing of 'Mosambi' orange with stretchable cling with shrinkable cryovac and shrinkable LDPE registered minimum weight loss and spoilage upto 40 days, under 20 to 25° C storage.

In an investigation made by Hussain *et al.*, (2004) on citrus by using Uni-Packaging with polyethylene, it was found to be observed that the treatments tends to have significant effect in prolonging the shelf life and maintenance of external appearance, taste, and texture.

Ramin and Khoshbakhat (2008) accesed the impact of packaging with high density polyethylene (HDPE) bags of thickness 30µm on acid lime. The film found to have microperforations and the storage of fruits @ 20°C and 10°C minimized the weight loss of acid lime fruits.

Jadhao *et al.*, (2008) observed that storage of kagzi lime in 200 gauge perforated polypropylene bags registered the minimum in physiological loss in weight and diameter at the end of 70 days of cold storage.

Nasciment *et al*., (2011) evaluated the effect of cold storage of Murcott mandarins subjected to treatment with modified atmosphere and observed that the fruits treated with wax and/or packed in flexible packaging material extended shelf life for 30 days. Observations on physico-chemical traits and disease incidence on fruits revealed that observation of fruits at thirty days of storage at 10±1°C, retained greater intensity of skin colour than that of control. The fruits (with or without wax) packed in flexible bags showed lower weight loss (<10%) and extended shelf life up to sixty days at 10±1°C followed by seven days at 25°C.

Hassan *et. al*., (2013) accessed the impact of wax coating on fruit quality of tangerine citrus (*Citrus reticulata*). Fruits were coated with 3 different concentrations of wax emulsion (10, 12 and 15%) and gets stored at two temperature levels (5 and 25°C) with 85-90% RH. The results revealed that the combination of 12% wax coating and storage at 5°C was found to be most effective.

Mahajan *et al.,* (2013) investigated the effect of surface coating on fruit quality of kinnow. The fruits coated with 'Nipro Fresh SS 40T and SS 50' formulations, air dried, and packed in CFB boxes, showed significant effect in delaying weight loss.

Dhillon *et. al*., (2016) reported that the fruits of Daisy mandarin were packed in paper moulded trays followed by wrapping with different packaging films, *viz*., heat shrinkable film (15 μ), cling (15 μ) and low density polyethylene (25 μ LDPE) film. The results revealed that, shrink film helped in reducing the loss in weight (1.12%) and decay incidence (0%), for 15 days under storage.

Effect of packaging on physiological parameters of fruits

According to Raghav and Gupta (2003), the individually wrapped fruits could be stored for 84 days with acceptable eating quality and less PLW (4.0%). It was found to be at nominal level upto 40 days in unwrapped control (37.0%) of fruits at ambient condition. Apart, the waxing treatments were quite effective in extending the shelf life and diminishing PLW even after 21 days of storage.

Upadhayaya and Sanghavi (2006) made a study with different treatment of kinnow mandarin as 4 %$CaCl_2$ and packed the fruits in perforated (0.2%) polythene bags. The results revealed that the treatments tends to reduce the physiological weight loss of fruits during storage and extended the storability upto 42 days under ambient condition.

Sharma et al. (2007) reported that kinnow mandarins with 150 gauge polythene bag package with bael leaf extract, exhibited the maximum reduction in PLW as compared to untreated control.

Reddy *et al*., (2008) evaluated the role of several packing materials on shelf life and quality of acid lime. The results showed that the packing of fruits with LDPE treatment found to be most effective in preventing the physiological loss in weight of acid lime.

According to Sonkar *et al.,* (2009) kinnow fruits packed with cling film, registered better performance in respect of PLW under ambient conditions.

Jawandha *et al.,* (2012) examined the impact of low density polyethylene packaging and several chemicals on ambient storage of kinnow. The results revealed that the kinnow fruit treated with boric acid @3 % + LDPE packaging without perforation recorded minimum physiological loss in weight.

Mandal (2015) studied the role of lac-wax, citrashine and shrink wrapping of fruits on storability of kinnow. The fruits treated with waxes and individually shrink wrapped in LDPE (19µ) and packed in 4 kg CFB boxes and stored under ambient condition. The results revealed that the maximum PLW was observed in control, whereas, shrink wrapped and lac-wax treated fruits effectively reduced PLW.

Effect of packaging on quality parameters of fruits

Ahmad *et al*., (1979) examined the impact of waxing and lining material on storability of kinnow and observed the treatment recorded better impact with quality traits. The results revealed ascorbic acid and citric acid content tend to decreased in vice versa sugars and sugar/acid ratio increased under storage.

According to Albert (1983), the major change in internal quality observed for oranges and grapefruit due to the reduction in acidity level with consequent increase in brix: acid ratio under storage.

Farooqi *et al*., (1988) analyzed the impact of wax emulsions of fruitex, Britex-561 and SB65 coating over oranges, kinnow, lemons and grape fruits. No significant changes found to be observed with acidity, and sugar contents in all the examined fruits.

Singh *et al.,* (1988) reported that maximum TSS (11.6%) was observed in non-sealed fruits after four week of storage. However, it was reversed after eight weeks of storage, when higher TSS observed in all type of wrapped fruits.

According to Dhatt *et al.,* (1991), the kinnow fruits which were under storage showed slow increase in sugars with to individual shrink wrapped fruits than that of unwrapped control.

Kaushal and Thakur (1996) reported that the fruits under sealed packaging treatment registered the decreased level of titrable acidity under cool chamber storage. The fruits treated with 1% bavistin and packed in polyethylene bags exposed decreased ascorbic acid under storage. However, the fruits in sealed packaging exhibited gradual increase in sugar content than that of those fruits in untreated control.

According to Raghav and Gupta (2000) the individual shrink wrapped kinnow fruits showed lower sugar content than unwrapped kinnow fruit, with film thickness of 25 micron. Fruits maintained better flavour and quality (TSS, Acidity, Ascorbic acid, Sugars) upto 8 weeks than that of the unwrapped fruits found to get stored at ambient conditions.

Thakur *et al*. (2002) reported that the fruits stored after carbendazim treatment and packed with 150 gauge thickness LDPE bags observed to be effective in retaining better fruit quality under storage. In a vice versa, the total sugar content of fruits remained to be increased throughout the period of storage.

Juliana *et. al*., (2004) analyzed the physicochemical and microbiological characteristics of minimally processed 'Champagne' oranges (*Citrus reticulata*× *Citrus sinensis*) under various packaging treatments. The minimally processed fruit packed in lidded polystyrene containers and polyethylene and PVC films retained superiority in overall fresh visual appearance with a few physicochemical and microbiological changes up to storability for 8 days.

Hussain *et al*., (2004) studied the effects of Uni-Packaging with polyethylene on citrus fruits. The result showed uni-packaging had no significant effect on the pH of citrus fruit. T.S.S observed to be increased during storage but individual packaging had non-significant effect on the T.S.S. In vice versa, ascorbic acid decreased from 1.59-0.63% under storage condition.

Kaur *et al.,* (2004) studied the effectiveness of wax in combination with fungicides on the storage behaviour of seal packaged kinnow mandarins. The observations on physico-chemical characteristics of the fruits recorded after 30 and 60 days of ambient storage, expressed that the treatment of fruits to Imazalil 1000 ppm with HDPE film wrapping registered better fruit appearance, quality and low rate of pathological rotting.

Ladaniya *et al.,* (2005) conducted an experiment to study the effect of sub-optimum low temperature storage of 'Nagpur' mandarin along with wax coating and intermittent warming. The results of the study revealed, the intermittent warming and wax coating are useful for extending the storability of 'Nagpur' mandarin up to 75 days.

Reddy *et al*., (2008) analyzed the impact of various packing materials on shelf life and quality of acid lime. The packing of fruits with LDPE found to be most effective in minimizing the pH, ascorbic acid, increase in TSS, and acidity.

Jadhao *et al*., (2008) observed that the kagzi lime stored with 200 gauge perforated polypropylene bags recorded the minimum loss in TSS, TSS/acid ratio and the maximum content of acidity and ascorbic acid at the end of 70 days under cold storage.

Shein *et. al*., (2008) examined the influence of wax coating over post harvest quality of 'Sai Nam Peung' mandarin orange. The fruits were coated with teva wax (18% food grade shellac, polyethylene) and placed under cold storage for 1 month. In the study, it was observed that there was no significant difference in T.S.S/ T.A ratio during storage.

Randhawa *et al*., (2009) accessed impact of high density polyethylene packaging along with edible oil and wax coating on storage quality of kinnow. The results of the study exposed the highest palatability rating after 45 days of ambient storage was recorded in HDPE packed. The fruits coated with neem oil with HDPE packaging recorded highest juice content and minimum spoilage during storage. However, the maximum value for TSS and PLW registered with untreated control.

According to Sumanjit Kaur *et al.*, (2010), the kagzi lime fruits wrapped with polyethylene films of high density polyethylene and low density of various thickness retained better quality traits for 3 weeks at room temperature.

Sahid and Abbasi (2011) analyzed the influence of wax coating on sweet orange cv. Blood Red. The results of the study revealed that wax treatment (5%) maintained positiveness in terms of pH, TSS, titartable acidity, TSS/acid ratio, sugars (total, reducing, and non-reducing) and ascorbic acid of fruits.

According to Mahajan *et al.,* (2013) the kinnow fruits coated with 'Nipro Fresh SS 40T or SS 50' showed significant delay in the change of TSS, titratable acidity and vitamin-C content of kinnow fruits, under storage

Jawandha *et al*., (2014) assessed the response of Baramasi lemon under modified atmosphere packaging on storage. The healthy fruits after disinfestation with 0.1% bavistin solution for 2 minutes and wax coating were packed (four fruits in each pack) in high density polyethylene (HDPE) and low density polyethylene (LDPE) bags. The results of the study revealed that fruits treated with bavistin @ 0.1% and packed in LDPE bags registered betterness in quality with regard to juice content, and acidity during 50 days of ambient storage.

Mahajan and Singh (2014) noticed the shrink film packaging of kinnow fruits improved the storage life and better quality retention for 20 days as against 10 days in unpacked control.

Jhalegar *et al*., (2015) accessed the role of surface coating with lac based wax, Citrashine, P-104 and Niprofresh on quality of kinnow. The results indicated the surface coatings extended storability and quality of kinnow fruits even upto 60 days.

Mandal (2013) assessed the impact of waxing and shrink wrapping on kinnow fruits. The study revealed that individually shrink wrapped, lac-wax and citrashine coated fruits expressed better quality traits even under the storability of fruits for 21 days in ambient conditions.

According to Singh and Yadav (2015) packaging of kinnow fruits with 100 gauge LDPE bag packaging combined with evaporative cool chamber plus rice husk ash (RHA) maintained superiority in terms of highest overall acceptability.

Chaudhary *et al*., (2015) reported that 'Star Ruby' grapefruits (*Citrus paradisi*, Macf.) stored upto 16 weeks at 10 °C in micro or macro perforated bags did not had negative value in terms of ascorbic acid, acidity, and TSS content.

Mandal (2015) made a study on role of lac-wax, citrashine and shrink wrapping of fruits on storability of kinnow. The results indicated that individually shrink wrapped, lac-wax and citrashine coated fruits extended the storability upto 21 days of storage in ambient conditions without altering quality.

Dhillon *et al*., (2016) observed the significance of different packaging films on shelf-life and quality of Daisy mandarin under ambient conditions. The fruits were exposed to various packaging treatments *viz*., heat shrinkable film (15 μ), cling (15 μ) and low density polyethylene (25 μ LDPE) film. The results of the study revealed that shrink film proved to be effective in extending the storability and quality retention upto 15 days as compared to that of control (5 days).

Chapter III

MATERIALS AND METHODS

The present investigation entitled "Studies on various packaging materials on fruit quality and shelf life of Kinnow" was conducted at post harvest laboratory, Department of Horticulture, Lovely Professional University, Punjab during the academic year 2016-17.

The details of materials used during experimentation and methodologies followed are furnished as below:

3.1. MATERIALS

3.1.1. Selection and harvest of fruits

The fresh kinnow fruits of uniform size and well matured ones were selected. Apart, other traits of healthiness for fruits free from that of disease and bruising on skin were also taken in consideration for selection of fruits for harvest. The selected fruits were randomly picked from entire direction of the plant with the help of secateurs. The act of fruit harvest commenced during the month of February, collected and brought to Horticulture laboratory.

3.1.2. Preparation of fruits

Before incorporation of treatments, the fruits were dipped in chlorine solution and then washed thoroughly with normal water to remove contaminants. Later, the fruits were allowed to dry under electric fan, after spreading over the table.

3.1.3. Packaging and coating materials for fruits

The packaging films used in this experimentation were purchased from Jalandhar commercial market area. The materials include LDPE (25 micron), HDPE (15 micron), Polypropylene (25 micron), Shrink film (15 micron) and Cling film (15 micron). Liquid paraffin wax (10%) was used as a coating material.

3.2. DETAILS OF EXPERIMENT

The investigation was conducted from February, 2017 to April, 2017 and was laid out in Completely Randomized Design (CRD). A total of 6 fruits were utilized and observed in each replication under each treatment for collection of data. Details of the experiment are given as follows,

Treatments	Treatment Details
T1	Control (Room temperature)
T2	LDPE (25 micron)
T3	HDPE (15 micron)
T4	Polypropylene (25 micron)
T5	Shrink film (15 micron)
T6	Cling film (15 micron)
T7	LDPE (25 micron) + wax (10%)
T8	HDPE (15 micron) + wax (10%)
T9	Polypropylene (25 micron) + wax (10%)
T10	Shrink film (15 micron) + wax (10%)
T11	Cling film (15 micron) + wax (10%)

A total of 27 fruits per treatment were divided into equal lots for all 3 replications and each of lot under every replication found to be accumulated with 9 fruits. The treated fruits were kept for storage and observed at 5 days interval upto 25 days.

OBSERVATIONS RECORDED

3.3. Fruit physical parameters

3.3.1. Fruit length

Randomly selected fruits under each replication of every treatment were utilized for the measurement of fruit length by using vernier caliper and expressed in centimeter.

3.3.2. Fruit girth

Randomly selected fruits under each replication of every treatment were utilized for the measurement of fruit girth by using vernier caliper and expressed in centimeter.

3.3.3. Fruit shape index

Fruit shape index was calculated by dividing fruit length by fruit girth.

3.3.4. Fruit weight

Randomly selected fruits under each replication of every treatment were utilized for the measurement of fruit weight by using sensitive electronic balance and expressed in grams.

3.3.5. Fruit spoilage percent

The spoilage percent of fruits under each treatment was calculated by comparing the total number of fruits spoiled divided by total number of fruits in the pack and converted to percentage value.

3.3.6. Fruit specific gravity

Randomly selected fruits under each replication of every treatment were observed for specific gravity. It was obtained by water displacement method by comparing the weight in air divided by the weight in water.

3.4. Physiological Parameters

3.4.1. Physiological loss in weight (%)

The per cent loss in weight after each storage interval was calculated by subtracting final weight from initial weight of the fruits and then converted into percentage value. The cumulative loss in weight was calculated on fresh weight basis.

Physiological loss in weight (PLW %) = (Initial fruit wt. - Final fruit wt.) / Initial fruit wt. X 100

3.5. Quality Parameters

Randomly selected fruits in each treatment of the experimentation were used for assessing the quality parameters.

3.5.1. Total soluble solids

Total Soluble Solids of the juice after squeezing from the fruit were determined by using Carl-Zeiss hand refractometer and expressed as degree Brix at 21°C.

3.5.2. Titrable acidity

Titrable acidity was estimated by adopting the standard method formulated through A.O.A.C (Association of Official Analytical Chemists) (1975) by titrating against 0.1 N NaOH using phenolphthalein indicator and expressed in terms of percentage tartaric acid equivalent.

3.5.3. Ascorbic acid

Ascorbic acid content was estimated by using 2,6-dichlorophenol indo phenol dye and then expressed in terms of milligrams of ascorbic acid per 100 g of fruit (Freed, 1966).

3.5.4. pH

The pH of each fruit sample was determined with the help of digital pH meter (HANA 8520, Japan). Kinnow juice of optimal quantity (50mL) was taken in 100mL beaker and pH meter was utilized to record the pH value according to standard methodology expressed under official methods of analysis.

3.5.5. TSS: acid ratio

TSS: acid ratio was calculated by dividing TSS (°Brix) by acidity (%).

3.5.6. Estimation of Sugars

The total, reducing and non-reducing sugars were estimated as per the method suggested by Somogyi (1952) in randomly selected fruits under each treatment. The value was expressed in terms of percentage.

3.5.7. Sugar-acid ratio

The sugar-acid ratio was calculated by dividing total sugar content with acidity.

3.5.8. Statistical Analysis

The data were subjected to statistical analysis as outlined by Panse and Sukhatme (1985). The various comparisons were made after working out the standard errors and critical difference at 5 per cent level of significance.

Chapter IV

EXPERIMENTAL RESULTS

The results of the present study entitled ‘Studies on various packaging materials on fruit quality and shelf life of Kinnow’ are presented in this chapter.

4.1. Effect of various packaging materials on physical parameters of Kinnow

The treatments with regard to various packaging films *viz.,* LDPE (25 micron), HDPE (15 micron), polypropylene (25 micron), shrink film (15 micron) and cling film (15 micron) including liquid paraffin wax (10%), as a coating material were utilized as per the technical programme.

Observations on ‘physical, physiological and quality traits *viz.,* Fruit length, Fruit girth, Fruit shape index, Fruit weight, Fruit spoilage percent and Fruit specific gravity, Physiological loss in weight, Total soluble solids, Titrable acidity, Ascorbic acid, pH, TSS: acid ratio, total, reducing, non-reducing sugars and Sugar-acid ratio were recorded. The observations were statistically analyzed and are presented below.

4.1.1. Fruit length

Observations recorded on ‘Fruit length’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 1).

Among the packaging treatments, the fruits under the treatments T_2, T_5, T_6, T_8, T_9 and T_{11} retained maximum ‘Fruit length’ (5.10 cm), which were on par with each other including T_4 (5.0 cm) at 5 days after storage. The minimum ‘Fruit length’ was recorded in control (4.70 cm). It was found to be on par with T_3, T_7 and T_{10} (4.90 cm).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_6 retained maximum ‘Fruit length’ (4.25 cm). The minimum ‘Fruit length’ was recorded in T_3 (3.90 cm). In rest of the treatments, except $T_{11,}$ no fruits were found to be retained for observation.

Table 1. Effect of different packaging materials on 'Fruit Length (cm)' in Kinnow

Treatments	'Fruit Length (cm)'				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	4.70	4.10	3.10	0.00	0.00
T2	5.10	5.00	4.85	4.55	0.00
T3	4.90	4.70	4.45	4.15	3.90
T4	5.00	4.85	4.55	4.10	0.00
T5	5.10	4.90	4.60	4.10	0.00
T6	5.10	5.00	4.85	4.60	4.25
T7	4.90	4.80	4.70	4.40	0.00
T8	5.10	5.00	4.80	4.30	0.00
T9	5.10	5.00	4.70	4.20	0.00
T10	4.90	4.75	4.60	4.30	0.00
T11	5.10	5.00	4.75	4.40	4.10
SEd	0.10	0.10	0.09	0.08	0.04
CD (0.05%)	0.21	0.21	0.20	0.17	0.08

Treatment details

T1 : Control (Room temperature)

T2 : LDPE (25 micron)

T3 : HDPE (15 micron)

T4 : Polypropylene (25 micron)

T5 : Shrink film (15 micron)

T6 : Cling film (15 micron)

T7 : LDPE (25 micron) + wax (10%)

T8 : HDPE (15 micron) + wax (10%)

T9 : Polypropylene (25 micron) + wax (10%)

T10 : Shrink film (15 micron) + wax (10%)

T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

4.1.2. Fruit Girth

Observations recorded on ‘Fruit girth’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 2).

Among the packaging treatments, the fruits under the treatments T_6 retained maximum ‘Fruit girth’ (6.00 cm), which was on par with each other including T_2 (5.90 cm), T_8 (5.95 cm), T_9 (5.85 cm) at 5 days after storage. The minimum ‘Fruit girth’ was recorded in control (5.10 cm).

At 25 days of storage, the observations among various packaging treatments revealed that, the fruits under treatment T_6 retained maximum ‘Fruit girth’ (5.20 cm). The minimum ‘Fruit girth’ was recorded in T_3 (4.50 cm). In rest of the treatments, except T_{11}, no fruits were found to be retained for observation.

4.1.3. Fruit Shape Index

Observations recorded on ‘Fruit shape index’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 3).

Among the packaging treatments, the fruits under the treatments T_1 retained maximum ‘Fruit shape index’ (0.921), which was on par with each other including T_4 (0.909) at 5 days after storage. The minimum ‘Fruit shape index’ was recorded in T_6 (0.850). It was found to be on par with T_7 (0.852), T_8 (0.857) and T_{10} (0.859).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_3 retained maximum ‘Fruit shape index’ (0.866). The minimum ‘Fruit shape index’ was recorded in T_6 (0.817). It was found to be on par with T_{11}. In rest of the treatments, no fruits were found to be retained for observation.

4.1.4. Fruit Specific Gravity

Observations recorded on ‘Fruit specific gravity’ exhibited significant differences among the treatments in 10, 15, 20 and 25 days after storage of Kinnow fruits. No significant difference was observed among the treatments in 5 days after storage (Table 4).

Among the packaging treatments, the fruits under the treatments T_{10} retained maximum ‘Fruit specific gravity’ (0.938), which was on par with each other including T_3

Table 2. Effect of different packaging materials on 'Fruit Girth (cm)' in Kinnow

Treatments	**'Fruit Girth (cm)'**				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	5.10	4.50	3.40	0.00	0.00
T2	5.90	5.80	5.50	5.00	0.00
T3	5.70	5.50	5.25	4.85	4.50
T4	5.50	5.30	5.00	4.60	0.00
T5	5.80	5.60	5.30	5.00	0.00
T6	6.00	5.90	5.80	5.60	5.20
T7	5.75	5.65	5.45	5.10	0.00
T8	5.95	5.85	5.70	4.70	0.00
T9	5.85	5.70	5.40	4.80	0.00
T10	5.70	5.60	5.40	5.00	0.00
T11	5.80	5.70	5.55	5.30	5.00
SEd	0.12	0.12	0.11	0.10	0.05
CD (0.05%)	0.25	0.24	0.23	0.20	0.10

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 3. Effect of different packaging materials on 'Fruit Shape Index' in Kinnow

Treatments	'Fruit Shape Index'				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	0.921	0.911	0.911	0.000	0.000
T2	0.864	0.862	0.881	0.910	0.000
T3	0.859	0.854	0.847	0.855	0.866
T4	0.909	0.915	0.910	0.891	0.000
T5	0.879	0.875	0.867	0.820	0.000
T6	0.850	0.847	0.836	0.821	0.817
T7	0.852	0.849	0.862	0.862	0.000
T8	0.857	0.850	0.842	0.912	0.000
T9	0.871	0.877	0.870	0.875	0.000
T10	0.859	0.848	0.851	0.860	0.000
T11	0.879	0.877	0.855	0.830	0.820
SEd	0.018	0.018	0.018	0.017	0.008
CD (0.05%)	0.038	0.037	0.037	0.036	0.017

Treatment details

T1 : Control (Room temperature)

T2 : LDPE (25 micron)

T3 : HDPE (15 micron)

T4 : Polypropylene (25 micron)

T5 : Shrink film (15 micron)

T6 : Cling film (15 micron)

T7 : LDPE (25 micron) + wax (10%)

T8 : HDPE (15 micron) + wax (10%)

T9 : Polypropylene (25 micron) + wax (10%)

T10 : Shrink film (15 micron) + wax (10%)

T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 4. Effect of different packaging materials on 'Fruit Specific Gravity' in Kinnow

Treatments	'Fruit Specific Gravity'				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	0.870	0.847	0.826	0.000	0.000
T2	0.922	0.917	0.906	0.882	0.000
T3	0.926	0.918	0.902	0.876	0.851
T4	0.911	0.904	0.875	0.860	0.000
T5	0.912	0.895	0.897	0.874	0.000
T6	0.924	0.905	0.883	0.851	0.803
T7	0.920	0.911	0.894	0.868	0.000
T8	0.928	0.913	0.886	0.871	0.000
T9	0.917	0.877	0.884	0.820	0.000
T10	0.926	0.938	0.928	0.824	0.000
T11	0.944	0.846	0.850	0.817	0.796
SEd	0.019	0.018	0.019	0.017	0.008
CD (0.05%)	NS	0.038	0.038	0.035	0.016

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

NS : Non Significant

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

(0.918) and T_2 (0.917) at 10 days after storage. The minimum 'Fruit specific gravity' was recorded in T_{11} (0.846). It was found to be on par with control (0.847).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_3 retained maximum 'Fruit specific gravity' (0.851). The minimum 'Fruit specific gravity' was recorded in T_{11} (0.796), which is found to be on par with T_6 (0.803). In rest of the treatments, no fruits were found to be retained for observation.

4.1.5. Spoilage Percentage

Observations recorded on 'Spoilage percentage' exhibited significant differences among the treatments in 10, 15, 20 and 25 days after storage of Kinnow fruits. No significant difference was observed among the treatments in 5 days after storage (Table 5).

Among the packaging treatments, the fruits under the treatment T_1 recorded maximum 'Spoilage percentage' (7.40%) at 5 days after storage. In rest of the treatments, no spoilage was found to be observed.

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_1 retained maximum 'Spoilage percentage' (100%). The minimum 'Spoilage percentage' was recorded in T_6 (44.42%), which is found to be on par with T_{11} (48.11%), T_7 (48.12%), T_2 (48.14%), T_3 (48.14%). In rest of the treatments, no fruits were found to be retained for observation.

4.2. Effect of various packaging materials on physiological parameters of Kinnow

In the treatments with regard to various packaging films, observations on Physiological loss in weight was recorded and analyzed statistically. The results are presented as below.

4.2.1. Physiological loss in weight

Observations recorded on 'Physiological loss in weight' exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 6).

Table 5. Effect of different packaging materials on 'Spoilage Percentage' in Kinnow

Treatments	'Spoilage Percentage'				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	7.40	18.51	37.03	70.37	100.00
T2	0.00	3.70	14.81	29.62	48.14
T3	0.00	3.70	11.11	29.62	48.14
T4	0.00	7.40	22.22	40.73	59.24
T5	0.00	11.11	22.22	37.02	55.53
T6	0.00	3.70	11.11	25.91	44.42
T7	0.00	3.70	18.50	37.01	48.12
T8	0.00	7.40	14.80	33.31	55.53
T9	0.00	11.11	22.22	37.02	62.94
T10	0.00	11.11	22.22	37.02	55.53
T11	0.00	7.40	14.80	29.60	48.11
SEd	0.05	0.20	0.44	0.82	1.06
CD (0.05%)	0.10	0.41	0.90	1.71	2.19

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 6. Effect of different packaging materials on 'PLW (%)' in Kinnow

Treatments	PLW (%)				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	8.16	14.21	22.90	0.00	0.00
T2	0.66	1.16	2.21	3.62	0.00
T3	0.66	1.46	2.39	3.23	4.55
T4	1.19	2.09	3.25	4.81	0.00
T5	0.96	1.17	2.53	3.85	0.00
T6	0.72	1.02	2.32	3.28	4.42
T7	0.61	1.31	2.54	3.45	0.00
T8	0.89	1.68	2.42	3.33	0.00
T9	0.85	1.87	2.67	3.98	0.00
T10	0.67	2.05	2.15	3.83	0.00
T11	0.51	1.29	2.47	3.72	4.13
SEd	0.05	0.10	0.16	0.07	0.04
CD (0.05%)	0.11	0.20	0.33	0.15	0.09

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Among the packaging treatments, the fruits under the treatment T_1 retained maximum ‘Physiological loss in weight’ (8.16%), at 5 days after storage. The minimum ‘Physiological loss in weight’ was recorded in T_{11} (0.51%). It was found to be on par with T_7 (0.61%), T_2 (0.66%), T_3 (0.66%) and T_{10} (0.67%).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_3 retained maximum ‘Physiological loss in weight’ (4.55%). The minimum ‘Physiological loss in weight’ was recorded in T_{11} (4.13%). In rest of the treatments, except T_6, no fruits were found to be retained for observation.

4.3. Effect of various packaging materials on quality parameters of Kinnow

In the treatments with regard to various packaging films, observations on Total soluble solids (TSS), Titrable acidity, Ascorbic acid, pH, TSS: acid ratio, total, reducing, non-reducing sugars and Sugar-acid ratio were recorded and analyzed statistically. The results are presented as below.

4.3.1. Total Soluble Solids

Observations recorded on ‘TSS’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow (Table 7).

Among the packaging treatments, the fruits under the treatment T_1 retained maximum ‘TSS’ (11.56˚B), which were on par with each other including T_3 (11.10˚B) at 5 days after storage. The minimum ‘TSS’ was recorded in T_7 (10.20˚B). It was found to be on par with T_9 (10.50˚B) and T_{10} (10.60˚B).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_{11} retained maximum ‘TSS’ (12.20˚B). The minimum ‘TSS’ was recorded in T_6 (11.95˚B), which was on par with T_3 (12.00˚B). In rest of the treatments, no fruits were found to be retained for observation.

4.3.2. Titrable acidity

Observations recorded on ‘Titrable acidity’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 8).

Table 7. Effect of different packaging materials on 'TSS (ºB)' in Kinnow

Treatments	TSS (ºB)				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	11.56	12.57	14.13	0.00	0.00
T2	10.85	11.20	11.50	12.30	0.00
T3	11.10	11.40	11.65	12.25	12.00
T4	10.67	10.82	11.05	11.26	0.00
T5	10.70	10.95	11.35	11.55	0.00
T6	10.80	11.20	11.39	11.61	11.95
T7	10.20	10.60	11.26	11.50	0.00
T8	10.80	11.70	11.90	12.30	0.00
T9	10.50	10.70	11.10	12.00	0.00
T10	10.60	10.81	11.40	11.80	0.00
T11	10.90	11.35	11.50	11.90	12.20
SEd	0.22	0.23	0.24	0.24	0.12
CD (0.05%)	0.47	0.48	0.50	0.49	0.24

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage
SEd: Standard error deviation
CD (0.05%): Critical difference @ 0.05% level

Table 8. Effect of different packaging materials on 'Titrable Acidity (%)' in Kinnow

Treatments	Titrable Acidity (%)				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	1.33	1.19	0.93	0.00	0.00
T2	1.29	1.14	0.98	0.96	0.00
T3	1.21	1.15	1.03	0.95	0.78
T4	1.32	1.16	1.05	0.98	0.00
T5	1.25	1.10	0.99	0.91	0.00
T6	1.22	1.13	1.04	0.97	0.81
T7	1.17	1.12	1.03	0.96	0.00
T8	1.24	1.17	1.09	0.98	0.00
T9	1.22	1.06	0.94	0.91	0.00
T10	1.26	1.11	1.01	0.95	0.00
T11	1.23	1.09	0.99	0.92	0.76
SEd	0.03	0.02	0.02	0.02	0.01
CD (0.05%)	0.06	0.05	0.04	0.04	0.02

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Among the packaging treatments, the fruits under the treatment T_1 retained maximum 'Titrable acidity' (1.33%), which were on par with each other including T_4 (1.32%) and T_2 (1.29%) at 5 days after storage. The minimum 'Titrable acidity' was recorded in T_7 (1.17%). It was found to be on par with T_3 (1.21%), T_6 (1.22%), T_9 (1.22%) and T_{11} (1.23%).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_6 retained maximum 'Titrable acidity' (0.81%). The minimum 'Titrable acidity' was recorded in T_{11} (0.76%). In rest of the treatments, except T_3, no fruits were found to be retained for observation.

4.3.3. Ascorbic Acid

Observations recorded on 'Ascorbic acid' exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 9).

Among the packaging treatments, the fruits under the treatment T_5 retained maximum 'Ascorbic acid' (25.58 mg/100ml), which were on par with each other including T_2 (25.24 mg/100 ml) and T_{11} (25.16 mg/100ml) at 5 days after storage. The minimum 'Ascorbic acid' was recorded in T_1 (21.33 mg/100ml).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_6 retained maximum 'Ascorbic acid' (16.04 mg/100ml). The minimum 'ascorbic acid' was recorded in T_{11} (15.51 mg/100ml). In rest of the treatments, except T_3, no fruits were found to be retained for observation.

4.3.4. pH

Observations recorded on 'pH' exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 10).

Among the packaging treatments, the fruits under the treatment T_1 retained maximum 'pH' (3.90), which were on par with each other including T_9 (3.72) and T_7 (3.70) at 5 days after storage. The minimum 'pH' was recorded in T_5 (3.42), which was on par with T_2 (3.46) and T_{11} (3.47).

Table 9. Effect of different packaging materials on 'Ascorbic Acid (mg/100ml)' in Kinnow

Treatments	**Ascorbic Acid (mg/100ml)**				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	21.33	17.52	12.49	0.00	0.00
T2	25.24	22.17	19.02	17.36	0.00
T3	23.74	21.87	19.62	17.42	15.75
T4	23.85	21.9	19.48	17.74	0.00
T5	25.58	22.24	19.2	17.86	0.00
T6	24.37	21.71	19.89	18.11	16.04
T7	23.33	21.2	18.43	17.13	0.00
T8	24.51	22.08	18.77	17.83	0.00
T9	23.15	21.43	18.17	16.82	0.00
T10	24.83	22.39	19.25	17.08	0.00
T11	25.16	22.89	19.41	17.24	15.51
SEd	0.50	0.45	0.38	0.34	0.15
CD (0.05%)	1.04	0.93	0.80	0.71	0.31

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 10. Effect of different packaging materials on 'pH' in Kinnow

Treatments	pH				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	3.90	4.10	4.30	0.00	0.00
T2	3.46	3.76	3.87	4.00	0.00
T3	3.67	3.86	3.83	3.98	4.13
T4	3.65	3.81	3.91	3.97	0.00
T5	3.42	3.72	3.97	4.03	0.00
T6	3.58	3.80	3.86	3.94	4.06
T7	3.70	3.88	4.00	4.10	0.00
T8	3.56	3.78	3.96	4.02	0.00
T9	3.72	3.87	3.98	4.10	0.00
T10	3.54	3.73	3.90	4.12	0.00
T11	3.47	3.69	3.91	4.08	4.17
SEd	0.08	0.08	0.08	0.08	0.04
CD (0.05%)	0.16	0.17	0.17	0.16	0.08

Treatment details

T1 : Control (Room temperature)

T2 : LDPE (25 micron)

T3 : HDPE (15 micron)

T4 : Polypropylene (25 micron)

T5 : Shrink film (15 micron)

T6 : Cling film (15 micron)

T7 : LDPE (25 micron) + wax (10%)

T8 : HDPE (15 micron) + wax (10%)

T9 : Polypropylene (25 micron) + wax (10%)

T10 : Shrink film (15 micron) + wax (10%)

T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_{11} retained maximum pH (4.17). The minimum 'pH' was recorded in T_6 (4.06). In rest of the treatments, except T_3, no fruits were found to be retained for observation.

4.3.5. TSS: Acid ratio

Observations recorded on 'TSS: Acid ratio' exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 11).

Among the packaging treatments, the fruits under the treatment T_3 retained maximum 'TSS: Acid ratio' (9.17), which were on par with each other including T_6 (8.85) and T_{11} (8.86) at 5 days after storage. The minimum 'TSS: Acid ratio' was recorded in T_4 (8.08). It was found to be on par with T_2 and T_{10} (8.41).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_{11} retained maximum 'TSS: Acid ratio' (16.05). The minimum 'TSS: Acid ratio' was recorded in T_6 (14.75). In rest of the treatments, except T_3, no fruits were found to be retained for observation.

4.3.6. Total Sugars

Observations recorded on 'Total sugars' exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 12).

Among the packaging treatments, the fruits under the treatment T_1 retained maximum 'Total sugars' (5.82%) at 5 days after storage. The minimum 'Total sugars' was recorded in T_7 (5.25%). It was found to be on par with T_4 (5.35%) and T_9 (5.36%).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_{11} retained maximum 'Total sugars' (6.12%). The minimum 'Total sugars' was recorded in T_6 (5.88%). In rest of the treatments, except T_3, no fruits were found to be retained for observation.

4.3.7. Reducing Sugars

Observations recorded on 'Reducing sugars' exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 13).

Table 11. Effect of different packaging materials on 'TSS: Acid ratio' in Kinnow

Treatments	TSS: Acid ratio				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	8.69	10.56	15.19	0.00	0.00
T2	8.41	9.82	11.73	12.81	0.00
T3	9.17	9.91	11.31	12.89	15.38
T4	8.08	9.32	10.52	11.48	0.00
T5	8.56	9.95	11.46	12.69	0.00
T6	8.85	9.91	10.95	11.96	14.75
T7	8.71	9.46	10.93	11.97	0.00
T8	8.70	10	10.91	12.55	0.00
T9	8.60	10.09	11.80	13.18	0.00
T10	8.41	9.73	11.28	12.42	0.00
T11	8.86	10.41	11.61	12.93	16.05
SEd	0.18	0.21	0.24	0.25	0.15
CD (0.05%)	0.37	0.43	0.51	0.51	0.31

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 12. Effect of different packaging materials on 'Total Sugars (%)' in Kinnow

Treatments	Total Sugars (%)				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	5.82	5.92	6.37	0.00	0.00
T2	5.39	5.48	5.62	6.25	0.00
T3	5.51	5.58	5.64	6.19	5.95
T4	5.35	5.43	5.60	5.71	0.00
T5	5.37	5.53	5.50	5.69	0.00
T6	5.40	5.61	5.67	5.78	5.88
T7	5.25	5.45	5.73	5.75	0.00
T8	5.41	5.54	5.70	6.21	0.00
T9	5.36	5.44	5.57	5.90	0.00
T10	5.43	5.49	5.81	5.92	0.00
T11	5.40	5.50	5.78	5.85	6.12
SEd	0.11	0.12	0.12	0.12	0.06
CD (0.05%)	0.23	0.24	0.25	0.25	0.12

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 13. Effect of different packaging materials on 'Reducing Sugars (%)' in Kinnow

Treatments	Reducing Sugars (%)				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	2.93	3.21	3.78	0.00	0.00
T2	3.31	3.37	3.57	4.09	0.00
T3	3.20	3.26	3.80	4.27	3.14
T4	3.27	3.22	3.75	3.80	0.00
T5	3.41	3.42	3.47	3.61	0.00
T6	3.35	3.51	3.93	3.10	3.83
T7	3.51	4.01	3.91	3.80	0.00
T8	3.19	3.37	3.81	3.54	0.00
T9	3.25	4.11	3.78	4.11	0.00
T10	3.11	3.19	3.62	3.70	0.00
T11	3.35	3.46	4.16	2.93	3.26
SEd	0.07	0.07	0.08	0.07	0.03
CD (0.05%)	0.14	0.15	0.16	0.15	0.06

Treatment details

T1 : Control (Room temperature)
T2 : LDPE (25 micron)
T3 : HDPE (15 micron)
T4 : Polypropylene (25 micron)
T5 : Shrink film (15 micron)
T6 : Cling film (15 micron)
T7 : LDPE (25 micron) + wax (10%)
T8 : HDPE (15 micron) + wax (10%)
T9 : Polypropylene (25 micron) + wax (10%)
T10 : Shrink film (15 micron) + wax (10%)
T11 : Cling film (15 micron) + wax (10%)

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Among the packaging treatments, the fruits under the treatment T_7 retained maximum ‘Reducing sugars’ (3.51%), which was on par with each other including T_5 (3.41%), T_6 (3.35%) and T_{11} (3.35%) at 5 days after storage. The minimum ‘Reducing sugars’ was recorded in T_1 (2.93%). It was found to be on par with T_{10} (3.11%).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_6 retained maximum ‘Reducing sugars’ (3.83%). The minimum ‘Reducing sugars’ was recorded in T_3 (3.14%). In rest of the treatments, except $T_{11,}$ no fruits were found to be retained for observation.

4.3.8. Non-reducing Sugars

Observations recorded on ‘Non-reducing sugars’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 14).

Among the packaging treatments, the fruits under the treatment T_1 retained maximum ‘Non-reducing sugars’ (2.89%) at 5 days after storage. The minimum ‘Non-reducing sugars’ was recorded in T_7 (1.74%). It was found to be on par with T_5 (1.96%).

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_{11} retained maximum ‘Non-reducing sugars’ (2.86%), which was on par with each other including T_3 (2.81%). The minimum ‘Non-reducing sugars’ was recorded in T_6 (2.05%). In rest of the treatments, no fruits were found to be retained for observation.

4.3.9. Sugar: Acid ratio

Observations recorded on ‘Sugar: Acid ratio’ exhibited significant differences among the treatments in 5, 10, 15, 20 and 25 days after storage of Kinnow fruits (Table 15).

Among the packaging treatments, the fruits under the treatment T_3 retained maximum ‘Sugar: Acid ratio’ (4.55), which were on par with each other including T_7 (4.48) and T_6 (4.42) at 5 days after storage. The minimum ‘Sugar: Acid ratio’ was recorded in T_4 (4.05). It was found to be on par with T_2 (4.17).

Table 14. Effect of different packaging materials on 'Non-Reducing Sugars (%)' in Kinnow

Treatments	Non-Reducing Sugars (%)				
	5 DAS	10 DAS	15 DAS	20 DAS	25 DAS
T1	2.89	2.71	2.59	0.00	0.00
T2	2.08	2.11	2.05	2.16	0.00
T3	2.31	2.32	1.84	1.92	2.81
T4	2.08	2.21	1.85	1.91	0.00
T5	1.96	2.11	2.03	2.08	0.00
T6	2.05	2.10	1.74	2.68	2.05
T7	1.74	1.44	2.02	1.95	0.00
T8	2.22	2.17	1.89	2.67	0.00
T9	2.11	1.33	1.79	1.79	0.00
T10	2.32	2.30	2.19	2.22	0.00
T11	2.05	2.04	1.62	2.92	2.86
SEd	0.04	0.04	0.04	0.04	0.03
CD (0.05%)	0.09	0.09	0.09	0.09	0.06

Treatment details

T1	:	Control (Room temperature)	T7	:	LDPE (25 micron) + wax (10%)
T2	:	LDPE (25 micron)	T8	:	HDPE (15 micron) + wax (10%)
T3	:	HDPE (15 micron)	T9	:	Polypropylene (25 micron) + wax (10%)
T4	:	Polypropylene (25 micron)	T10	:	Shrink film (15 micron) + wax (10%)
T5	:	Shrink film (15 micron)	T11	:	Cling film (15 micron) + wax (10%)
T6	:	Cling film (15 micron)			

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

Table 15. Effect of different packaging materials on 'Sugar: Acid ratio' in Kinnow

Treatments	Sugar: Acid ratio				
	5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**
T1	4.37	4.97	6.84	0.00	0.00
T2	4.17	4.80	5.73	6.51	0.00
T3	4.55	4.85	5.47	6.51	7.62
T4	4.05	4.68	5.33	5.82	0.00
T5	4.29	5.02	5.55	6.25	0.00
T6	4.42	4.96	5.45	5.95	7.25
T7	4.48	4.86	5.56	5.98	0.00
T8	4.36	4.73	5.22	6.33	0.00
T9	4.39	5.13	5.92	6.48	0.00
T10	4.30	4.94	5.75	6.23	0.00
T11	4.39	5.04	5.83	6.35	8.05
SEd	0.09	0.10	0.12	0.12	0.07
CD (0.05%)	0.19	0.21	0.25	0.26	0.15

Treatment details

T1	:	Control (Room temperature)	T7	:	LDPE (25 micron) + wax (10%)
T2	:	LDPE (25 micron)	T8	:	HDPE (15 micron) + wax (10%)
T3	:	HDPE (15 micron)	T9	:	Polypropylene (25 micron) + wax (10%)
T4	:	Polypropylene (25 micron)	T10	:	Shrink film (15 micron) + wax (10%)
T5	:	Shrink film (15 micron)	T11	:	Cling film (15 micron) + wax (10%)
T6	:	Cling film (15 micron)			

DAS: Days after storage

SEd: Standard error deviation

CD (0.05%): Critical difference @ 0.05% level

At 25 days after storage, the observations among various packaging treatments revealed that the fruits under treatment T_{11} retained maximum 'Sugar-Acid ratio' (8.05). The minimum 'Sugar-Acid ratio' was recorded in T_6 (7.25). In rest of the treatments, except T_3, no fruits were found to be retained for observation.

DISCUSSION

Kinnow is one among a popular fruit in citrus group having notable delicacy for its sweetness and juice, turgid tender skinned, delicious and tasty fruits. It is the first generation hybrid having the parentage of ‘King’ and ‘Willow leaf’ evolved at Regional fruit station, USA, University of California by H.B. Frost.

Though as a non-climacteric fruit, Kinnow shows no respiratory peak and little ethylene production in normal conditions after harvest. However, the demand picks up for kinnow with advent of summer, normally it cannot be stored in proper condition for longer time under ambient conditions. By promoting proper storability condition for fruits, availability of kinnow can be extended in market.

In citrus fruits, the post-harvest handling losses are estimated to be 5-10 per cent in most developed countries, but in developing countries they are over 25-30 per cent (Coursey and Booth, 1971). The losses in case of kinnow tends to be ranged from 11.09 to 24.63 per cent which might be due to faulty storage techniques, condensation of moisture and heat under high temperature condition which permit slow gas exchange leading to spoilage (Verma and Tikoo, 2004).

Nowadays, usage of different packaging material for fresh fruit marketing widely a common practice that helps in extending storability by reducing shrinkage, weight loss and occurrence of various blemishes. The films used are partially permeable to gases and water vapour and can also intended to modify fruit’s micro atmospheric condition and hence, delayed the deterioration at room temperature.

Kinnow generally have relatively a short post harvest life. The film wrapping of fruits under ambient condition with certain packaging material along with suitable post harvest treatment would have positive fact in reducing the rate of respiration which resulted in extended storability. Plastic film tends to be observed as one of the most economic and powerful one in minimizing fruit weight loss (Kawada and Kitagawa, 1988).

By the considering the above facts, the present experimentation was made to standardize a appropriate packaging material and post harvest treatment for enhancement of shelf life and quality of kinnow. The results obtained are discussed as below.

5.1. Effect of various packaging materials on physical parameters of Kinnow

In the present study, the impact of various packaging and post harvest treatment were significantly influenced with physical parameters like 'Fruit length', 'Fruit girth', 'Fruit shape index', 'Fruit specific gravity' and 'Spoilage percentage' and the results were critically discussed as below,

Among different packaging and post harvest treatments, the fruits under the treatment T_6 (Cling film at 15 micron) retained maximum value for 'Fruit length' and 'Fruit girth' at 25 days after storage (Fig 1 and 2). Kinnow under other treatments were not retained for longer time. This might be due to the fact that in ambient condition during storage, the moisture loss through respiration and transpiration affects the fruit shape and fruit weight eventually fruit becomes unsalable as a result of shrinking (Salunkhe and Desai, 1984). Hence, an increase in fruit shrink for all other treatments including control during storage could be attributed to the loss of moisture from the fruits through respiration and transpiration processes. The results are in line with Banik *et al.* (1988) in ber fruits.

Water loss can also be one of the major cause for deterioration, since it not only results in indirect quantative losses, but also results losses in appearance (due to wilting and shriveling) and nutritional quality. Water stress caused by prolonged storage can resulted in an increase and early ethylene production, which in turn may enhance ripening processes (Joyce and Shorter, 1992).

Similarly in other case, the fruits under the treatment T_3 (HDPE at 15 micron) retained maximum value for 'Fruit Shape Index' and 'Fruit Specific Gravity' at 25 days after storage. The changes are due to shrinkage of fruits over a period of time under extended storage period. The results are in line with Ben Yehoshua *et al*. (2001) on mandarins; Abdel Aziz-Atiat *et al.* (2002) on Ponkan tangarine; Henriod (2006) on navel orange; and Nasciment *et al*. (2011) on Murcott mandarins. Egwim *et al.* (2013) revealed that the density of fruits decreases with storability. Decrease in specific gravity with increase in storage period was due to degradation of structural polysaccharides which resulted in decrease of pulp concentration.

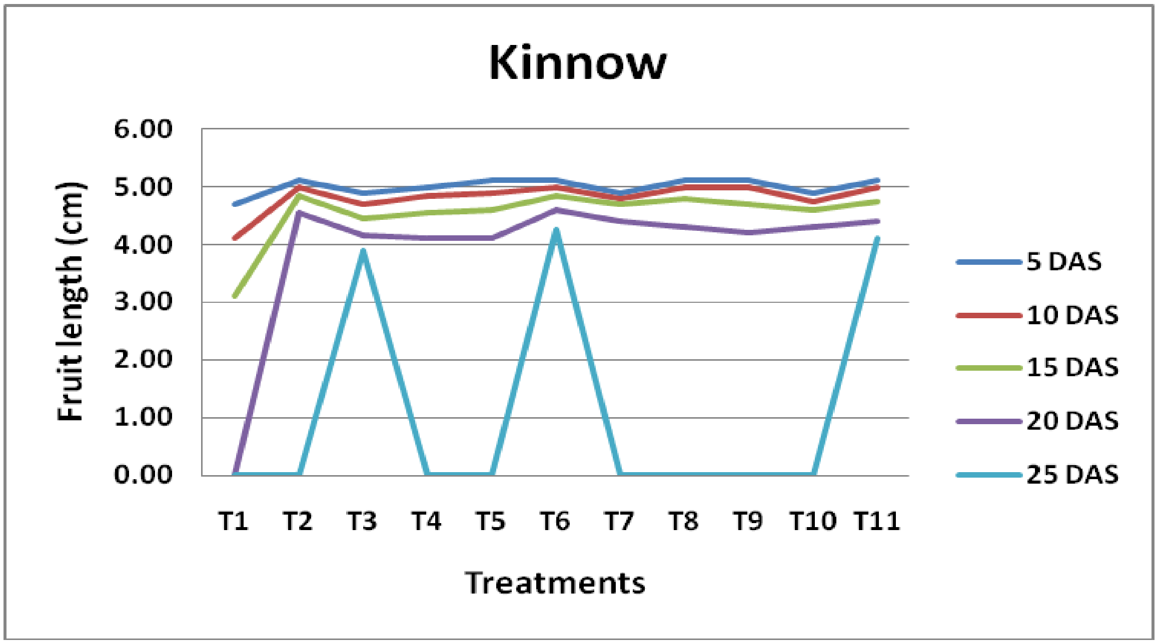

Fig.1. Effect of different packaging materials on 'Fruit Length (cm)' in Kinnow

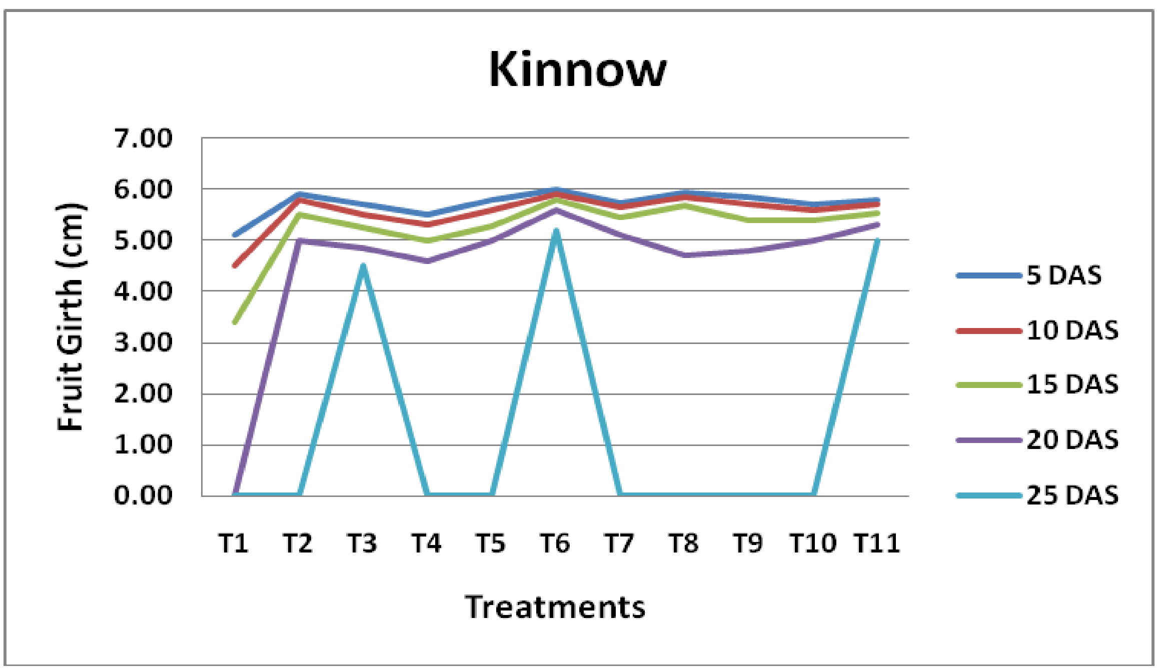

Fig.2. Effect of different packaging materials on 'Fruit Girth (cm)' in Kinnow

For spoilage percentage, the fruits under the treatment T_6 (Cling film at 15 micron) retained minimum value (Fig 3). Higher the spoilage in control might be due to weakening of the defense system against fungal attack with the passage of time and due to higher rates of respiration that leads to shriveling and wrinkling. Storage in polythene bag delayed rotting of fruits and decreased the percentage of rotted fruits compared to control. The fruits stored in Cling film at 15 micron polythene bags recorded the minimum spoilage might be due to reduced attack of microorganisms on the fruit surface and there by maintaining the fruit quality without significant loss. This was in line with the findings of Ismail and Menshway (1997) in lemon and Bhullar *et al.*, (1985) in mandarin.

5.2. Effect of various packaging materials on physiological parameters of Kinnow

In the treatments with regard to various packaging films, observations on Physiological loss in weight (%) was recorded and analyzed statistically. The discussion is presented as below.

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) retained minimum value for 'Physiological loss in weight' at 25 days after storage (Fig 4). In other treatments, except T_3 and T_6, the physiological loss in weight (PLW) of fruits gradually increased till the end of shelf life. An increase in PLW of fruits in all treatments with increasing period of storability was due to moisture loss by evapo-transpiration and loss of reserved food material by respiration. During respiration process, various reserved food materials present in fruits are used. Secondly, the process of transpiration from fruit surface also continues even after harvest. Hence, due to the respiration and evapo-transpiration, the physiological loss in weight of fruits increased with increasing period of storage. The results are in conformity with the results of Aworth *et al.* (1991) in citrus, Kumar *et al.* (2000) in kinnow and Pandey *et al.* (2006) in apple.

In other hand, Haard and Salunkhe (1975) reported that PLW is mainly due to the evaporation of water from the fruits, respiration and various degradation processes occurring during storage. This might be due to the restriction on diffusion of gasses and feedback mechanism resulting into slow rate of evapo-transpiration and respiration. These results are in agreement with those observed by Joshua and Sathiamoorthy (1993) in sapota and Venkatesha and Reddy (1994) in guava.

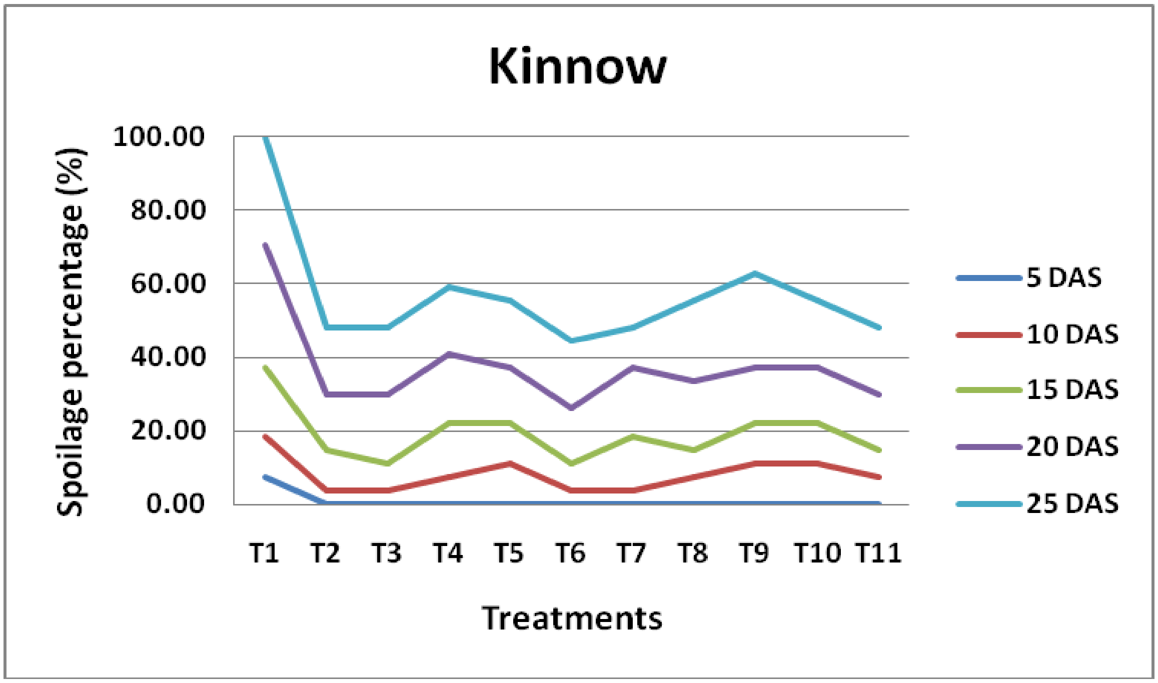

Fig.3. Effect of different packaging materials on 'Spoilage Percentage' in Kinnow

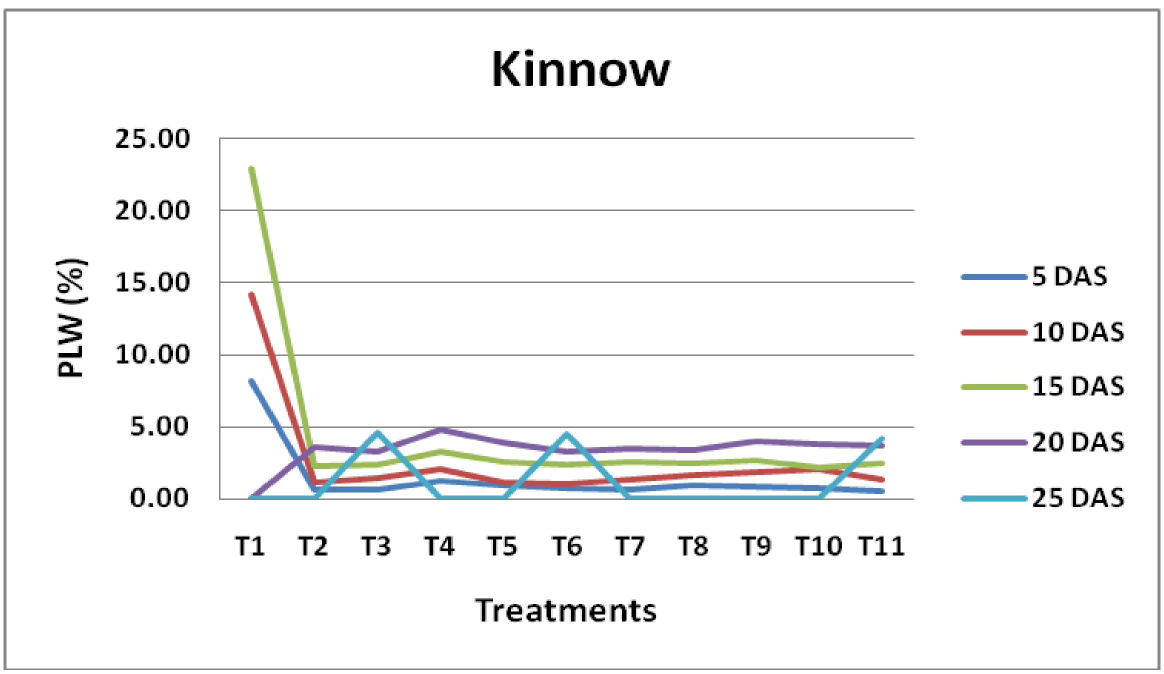

Fig.4. Effect of different packaging materials on 'PLW (%)' in Kinnow

5.3. Effect of various packaging materials on quality parameters of Kinnow

In the treatments with regard to various packaging films, observations on Total soluble solids, Titrable acidity, Ascorbic acid, pH, TSS: acid ratio, total, reducing, non-reducing sugars and Sugar-acid ratio were recorded and analyzed statistically. The discussion is presented as below.

5.3.1. Total Soluble Solids

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) retained maximum value for 'Total soluble solids' at 25 days after storage (Fig 5). The retention of better TSS value of with the increasing storability could be due to the degradation of complex insoluble compounds, like starch, to simple soluble compounds, like sugars, which acts as the major TSS components. These results are in line with the findings of Efiuvwere and Oyelade (1991) on orange; Kumar *et al.* (1991) on Kinnow mandarin; Kaushal and Thakur (1996) on Kinnow mandarin; Ismail and El-Menshawy 1997 on lemon; D'Aquino *et al*. (1998) on Minneola tangelo; Abdel Aziz-Atiat *et al*. (2002) on ponkan tangerine.

In addition, the retention of higher the value for TSS might be due lowering of water loss by transpiration during the storage period (Hussein *et al*. 1998). According to Artes-Hernandez *et al*. (2004), higher the TSS values in fruits may be due to retarding the respiration rate, water losses and conversions of polysaccharides into disaccharides and monosaccharides (Munoz *et al*., 2006).

5.3.2. Titrable Acidity

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) retained minimum value for 'Titrable Acidity (%)' at 25 days after storage (Fig 6). The gradual decline in acidity content was observed in fruits stored in packaging materials during storage in citrus fruits (Hussain *et al.*, 2004). The decline in acidity might be due to conversion of acids into sugars and its utility in respiration process. Results are in line with the results of Sonkar and Ladaniya (1999) in Nagpur mandarin and Mahajan *et al*. (2005) in kinnow.

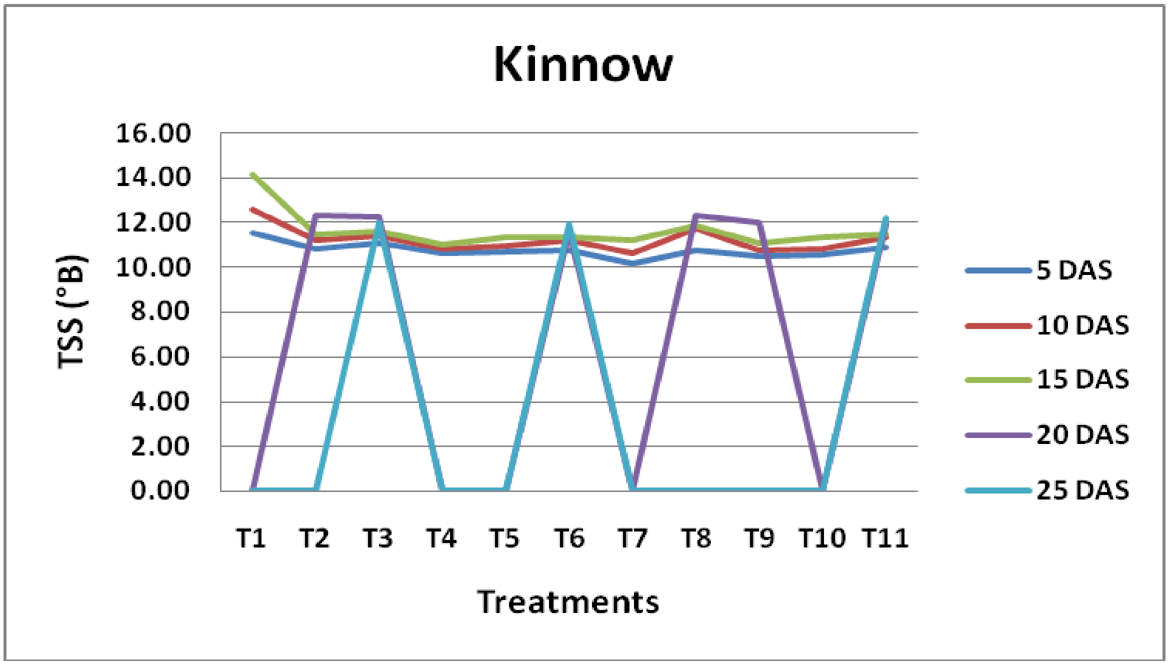

Fig.5. Effect of different packaging materials on 'TSS (°B)' in Kinnow

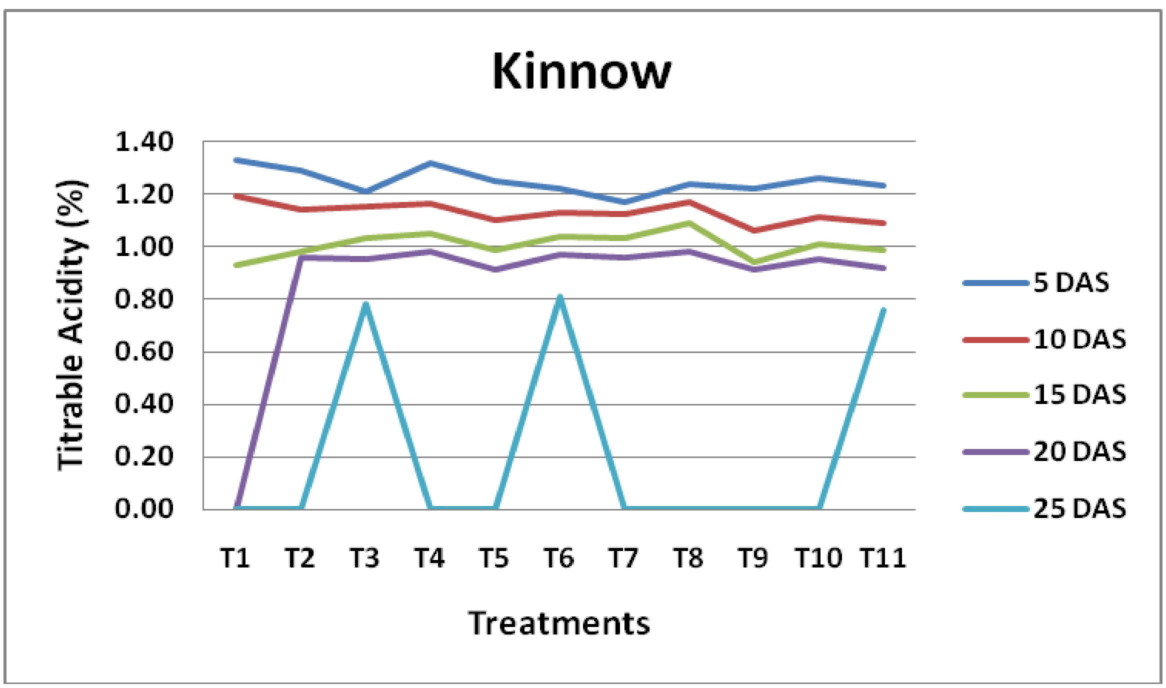

Fig.6. Effect of different packaging materials on 'Titrable Acidity (%)' in Kinnow

Titrable acidity gradually decreased with the advancement in storage interval. The decrease of acid percentage during storage period could be due to the destruction of organic acids through oxidation and consumption of these acids, as an organic substrate in the respiration processes of the fruit tissues. The progress of storage period was found to raise the respiration rate of the fresh fruits (Hussien *et al*. 1998). The reduction in the titrable acid content of Kinnow fruit juice during storage has also been noticed by Kausal and Thakur (1996) and reported that that wax coating and film wrapping preserve the acid content during prolonged storage.

5.3.3. Ascorbic Acid

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) retained minimum value for 'Ascorbic acid' at 25 days after storage. Ascorbic acid content decreases with the increment in shelf life period and retained significantly higher values with packaging treatments. These findings were in line with Kumar *et al.* (1991) on Kinnow mandarin; Amarjit and Rajinder (1996) on mandarin; Kaushal and Thakur (1996) on mandarin; Singh and Singh (1996) on Kinnow mandarin.

Ascorbic acid content in fruits is known to decrease during storage possibly due to utilization of organic acids during respiration or their conversion to sugars (Kader, 2002). The trend in case of other treatments might be due to the fact that ascorbic acid is very susceptible to oxidative deterioration (Piga *et al*., 2003), occurred at accelerated rate due to the presence of higher concentrations of O_2 as compared to polyethylene packages. The results of this study are in line with Kohli and Bhambota (1966), who reported that ascorbic acid of acid lime and Kinnow decreased respectively with the increase of storage period because of oxidation of ascorbic acid.

In addition, ascorbic acid content in citrus fruits generally declines with enhanced storability due to increase in the activity of oxidizing enzymes like ascorbic acid oxidase, peroxidase and catalase which might have into dehydro ascorbic acid as reported by Mapson (1970); Ladaniya and Shyam Singh (1998). The results are in line with Banik *et al*. (1988) in litchi; Kumar and Chauhan (1990) in mandarin.

5.3.4. pH

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) registered maximum value for 'pH' at 25 days after storage. The juice pH value was gradually increased with the advance in storage period. All treatments recorded lower values compared with the control in all stages of observation during storage. These results are in line with the findings of El-Hefnawi (2002) in mango; El-Hefnawi *et al*. (2008) in guava; Artés-Hernández *et al.*(2004, 2006) in grapes.

5.3.5. TSS:Acid ratio

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) registered maximum value for 'TSS:Acid ratio' at 25 days after storage (Fig 7). The higher change in TSS:Acid ratio is straightly related to hydrolytic changes in the starch concentration (conversion of starch to sugars). With the passage of time degradation of ascorbic acid results to more TSS as structural formula of ascorbic acid is similar to glucose therefore decrease in ascorbic acid correlated to increase in TSS:Acid ratio (Carrillo *et al.*, 1995; Kays, 1997). Manazano and Diaz (2003) reported that 'Valencia' oranges fruits harvested, sorted, graded and treated with a wax coating found that TSS:Acid ratio was increased with the passage of time.

5.3.6. Sugars

Among different packaging and post harvest treatments, the fruits under the treatment T_{11} (Cling film at 15 micron + wax at 10%) registered positive value for 'Total, non-reducing and Sugar:Acid ratio' at 25 days after storage (Fig 8). The maximum value for sugars might be due to conversion of polysaccharides into soluble sugars, dehydration and transformation of certain cell wall materials like hemicelluloses and pectins and also due to decrease in ascorbic acid content. The results are in line with the findings of Kumar and Chauhan (1990) in mandarin; Haikerwal (2001) in Jaffa sweet orange. The lowest percent of sugars in some treatments might be due to delayed transpiration, respiration and ripening processes and also delayed activity in the conversion of polysaccharides into soluble sugars and ascorbic acid into dehydro ascorbic acid in the fruits. The results are in agreement with the findings of Das and Dash (1967) in sweet orange.

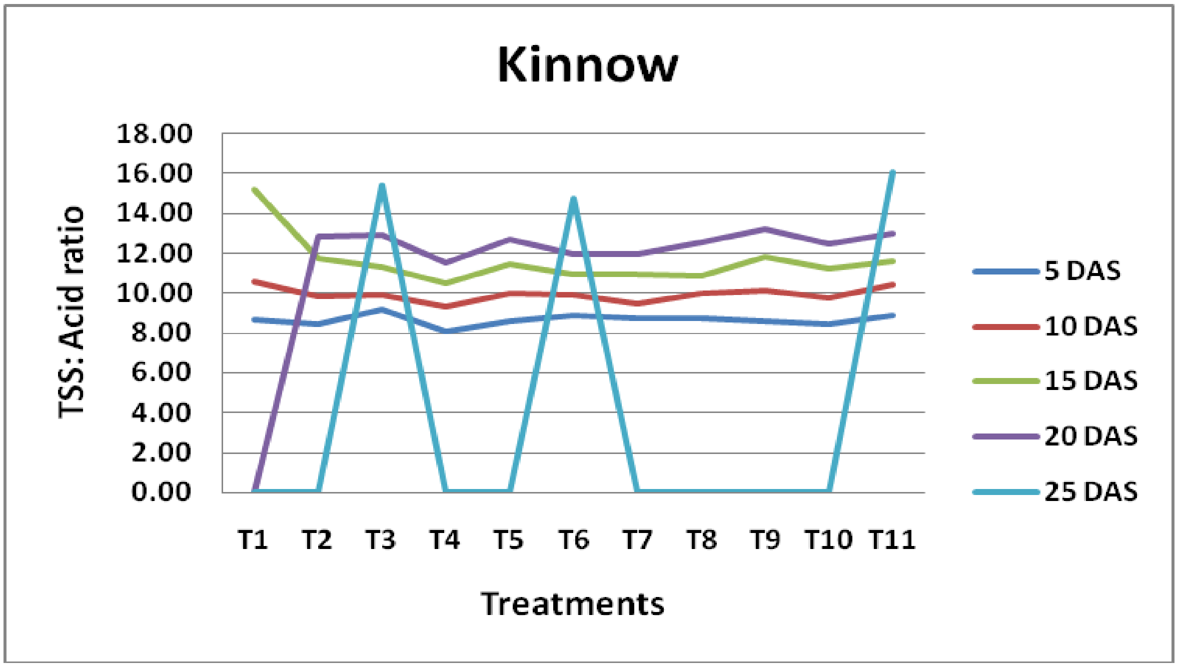

Fig.7. Effect of different packaging materials on 'TSS: Acid ratio' in Kinnow

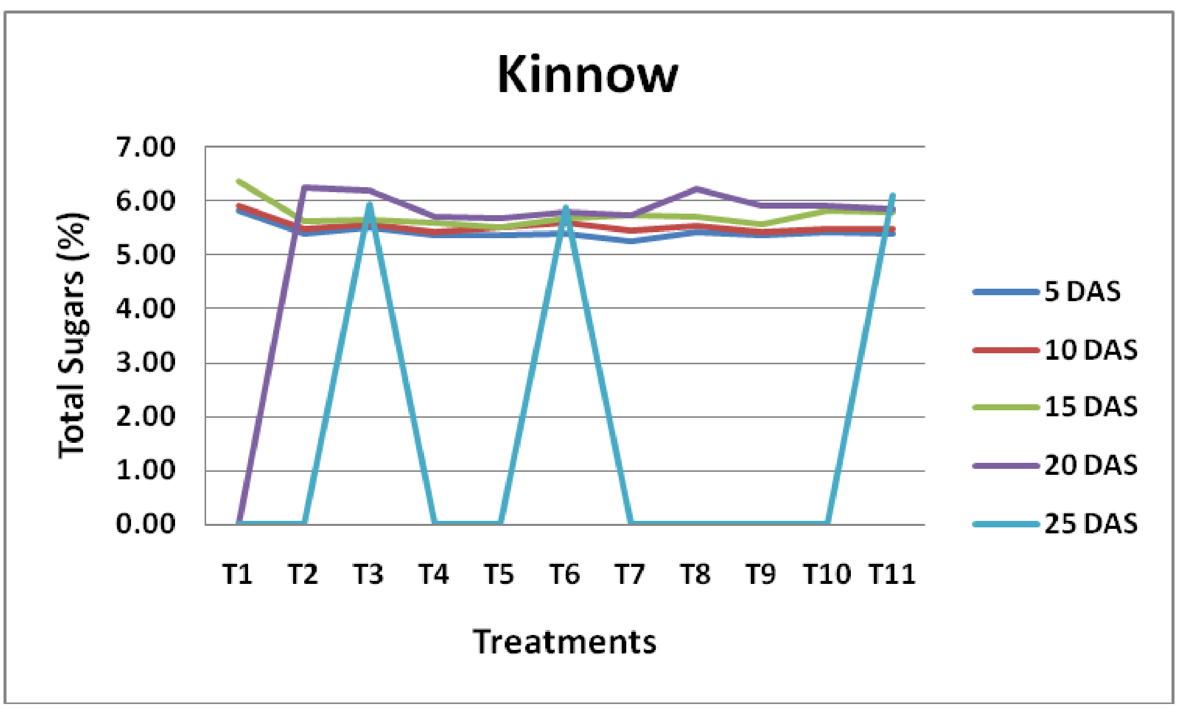

Fig.8. Effect of different packaging materials on 'Total Sugars (%)' in Kinnow

Due to packaging and waxing treatments, it was observed that there was a gradual increase in sugar content with advancement of storage period (Stahl and Camp, 1971). This trend could be due to the hydrolysis of starch during ripening resulting in an accumulation of sugars (Laxminarayana and Bazquezalinas, 1978).

In other aspect, due to the enhancement of storability, several internal fruit physiological activities like respiration, transpiration and other metabolic processes enhanced. So, starch gets converted to sugars and reducing sugar quantity increased. The results are in line with findings of Gul *et al.*, (1990) who observed that the effect of Fruitex (wax emulsion) on blood red oranges during room storage found that non-reducing sugars increased during storage. This was in agreement with the findings of Ahmad *et al.*, (1986) who reported waxing influences increment in non-reducing sugars during storage with enzyme activity.

Chapter V

SUMMARY AND CONCLUSION

An experimentation on 'Studies on various packaging materials on fruit quality and shelf life of Kinnow' was performed to study the impact of various packaging materials on physical, physiological and quality traits of Kinnow. The salient research outcomes of the present experiment are summarized as below.

- For various packaging treatments, the fruits under the treatments T_2, T_5, T_6, T_8, T_9 and T_{11} retained maximum 'Fruit length' which were on par with each other including T_4 at 5 days after storage. Observations at 25 days after storage revealed that the fruits under treatment T_6 (Cling film at 15 micron) expressed better value for 'Fruit length'.

- The results of the experiment conducted with packaging and post harvest treatment in Kinnow revealed that the fruits under the treatments T_6 (Cling film at 15 micron) retained maximum 'Fruit girth' which was on par with each other including $T_{2,}$ T_8 and T_9 at 5 days after storage. Observations on 25 day after storage revealed the fruits under treatment T_6 again retained superiority over other treatments.

- Packaging and post harvest treatments significantly influenced certain other physical traits *viz.*, 'Fruit shape index' and 'Fruit specific gravity', In both the cases, the fruits under treatment T_3 (HDPE at 15 micron) registered maximum value at 25th day after storage.

- With regard to spoilage percentage, the minimum 'Spoilage percentage' was recorded in T_6 (Cling film at 15 micron) which was found to be on par with T_{11} (Cling film at 15 micron + wax at 10%) at 25th day after storage.

- The packaging and post harvest treatments exhibited the minimum value for 'Physiological loss in weight' in the treatment T_{11} (Cling film at 15 micron + wax at 10%) at 25th day after storage.

- In case of quality related traits, the fruits under treatment T_{11} (Cling film at 15 micron + wax at 10%) recorded the maximum value for 'TSS' when compared with other packaging treatments including control at 25th day after storage.

- With regard to remaining quality related traits, the fruits under treatment T_{11} (Cling film at 15 micron + wax at 10%) expressed the maximum value for 'TSS: acid ratio', 'Total sugars', 'Non-reducing sugars' and 'Sugar: acid ratio' at 25th day after storage.

From the above research findings, it was concluded that packaging of kinnow with the Cling film at 15 micron + wax at 10% combination found to be beneficial on majority of physical, physiological and most of quality related traits upto 25 days of storage. Therefore, packaging of kinnow fruits with Cling film at 15 micron + wax at 10% combination found to be recommended.

REFERENCES

Abdel Aziz- Attiat S., S.M. El-Hefnawi and S.I. Habashy. 2002. Effect of some post-harvest treatments and packaging types on Ponkan tangerine fruit quality during and after cold storage. ***Zagazig J. Agric. Res.,*** **29(3)**:845-875.

Ahmad, M., M. A. Chaudry and I. Khan. 1986. Some post harvest shelf life extension studies on citrus fruits. NIFA Annual Report. pp. 55-71.

Amarjit, S. and S. Rajinder. 1996. Quality of Kinnow mandarin as affected by modified atmosphere storage. ***J. of Food Sci. and Technol.,*** **33(6)**: 483-487.

AOAC. 1975. Association of Official Agricultural Chemists, Official methods of Analysis, AOAC, Washington DC.

Artes-Hernandez, F., E. Aguayo and F. Artes. 2004. Alternative atmosphere treatments for keeping quality of 'Autumn Seedless' table grapes during long- term cold storage. ***Post-harvest Biology and Technology,*** **31**:59-67.

Artes-Hernandez, F., F.A Tomas-Barberan and F. Artes. 2006. Modified atmosphere packaging preserves quality of SO2 - free 'Superior seedless' table grapes. ***Postharvest Biology and Technology,*** **39(2)**: 146-154.

Baldwin, E.A., M.O. Nisperos, , X. Chen, R.D. Hagenmaier. 1996. Improving storage life of cut apple and potato with edible coating. ***Postharvest Biology and Technology,*** **9(2)**: 151-163.

Banik, D, J.K. Hore and S.K. Sen. 1988. Studies on extension of storage life of litchi (*Litchi chinensis* Sonn). ***Indian Agriculture,*** **31**: 159-164.

Banik, D, J.K. Hore, and S.K. Sen. 1988. Studies on storage life of ber (*Ziziphus maritiana* Lamk). ***Haryana Journal of Horticultural Sciences,*** **17**: 49-44.

Ben -Yehoshua, S., J. Pereiz; R. Moran; B. Lavie and J. J. Kim. 2001. Reducing the incidence of superficial flavedo necrosis (noxan) of 'Shamouti' oranges. ***Postharvest Biology and Technology,*** **22(1)**: 19-27.

Bhullar, J.S., B.S. Dhillon and J.S. Randhawa. 1985. Effect of wrappers on the storage of Kinnow mandarin. ***J. Res. Punjab Agric. Univ.,*** **22(4)**: 663-666.

Carrillo, L.A., J.B. Valdez, R. Rojas, E.M. Yahia and J.A. Gomas. 1995. Ripening and quality of mangoes affected bycoating with "Samper Fresh". Int'l Symp. on Tropical Fruits. ***Acta Hort.,*** **370**: 203-216.

Chaudhary, P. R., G. K. Jayaprakasha, R. Porat, & B. S. Patil. 2015. Influence of modified atmosphere packaging on 'star ruby'grapefruit phytochemicals. ***Journal of agricultural and food chemistry***, ***63*****(3)**: 1020-1028.

Coursey, D.G. and R.H. Booth. 1971. Post-harvest loses in perishable tropical produce. *Proc.6th Br.* ***Insect.Fung. Conf.,*****3**: 673.1

D'Aquino, S., A. Piga; M. Agabbio and T.G. McCollum. 1998. Film wrapping delays aging of Minneola tangelos under shelf- life conditions. ***Postharvest Biol. and Technol.,*** **14 (1)**: 107-116.

D'Aquino, S., M.G. Molinu, A. Piga, and M. Agabbio. 2001. Influence of film wrapping on quality maintenance of "Salustiana" oranges under shelf-life conditions. ***Italian Journal of Food Science,*** **1(13)**: 87-100.

Das, R.C. and Dash, J. 1967. The effect of wax emulsion, 2, 4-D and 2, 4, 5-T on the storage behaviour of mosambi (*Citrus sinensis* Osbeck). ***Proceedings of the International Symposium on Subtropical and Tropical Horticulture***, held at New Delhi. pp. 104-107.

Day, B.P.F. 1993. **In**: Principles and Application of Modified Atmosphere Packaging of Food. (R. Parry. Ed.) Blackie. ***Academic and Professional***. UK. London. pp: 114-133.

Deka, B.C., S. Sharma, and S.C. Borah. 2006. Postharvest Management Practices for Shelf Life Extension of Khasi Mandarin. ***Indian Journal of Horticulture***, **63:** 251-255.

Deshmukh, V.U., K.D. Kulkarni, and D.N. Kulkarni. 1999. Effect of packaging and low temperature on storage quality of sweet orange (*Citrus sinensis* cv. Mosambi) ***Int. Symp. Citri.,*** pp 186: p4 (Abstr.). 23-27 Nov.N.R.C. for Citrus, Nagpur.

Dhatt A S, J.S. Randhawa, and S.N. Singh. 1991. Effect of individual seal packaging in high density polyethylene (HDPE) film on storage life and quality of kinnow. ***Journal Plant Sci. Res.,* 7:** 84-85.

Dhatt, A. S., Randhawa, J. S., Kaur, H., Singh, G., & Sharma, R. (1995). Seal packaged storage of Kinnow fruits under ambient conditions. In ***Proceedings of National Seminar on Physiology of fruits, August*** (pp. 7-9).

Dhatt, A.S. and B.V.C. Mahajan,. 2011. Postharvest management of citrus fruits: Prospects and problems of citrus in Punjab, PS Aulakh PS and others (eds), Punjab Agricultural University, Ludhiana, Punjab, pp 98-105.

Dhatt, A.S. and J.S. Randhawa. 1991. Effect of individual seal packaging in high-density polyethylene film on storage life and quality of Kinnow. ***J. Pl. Sci. Res.*, 7**:84-85.

Dhillon, W. S., B. V. C. Mahajan, T. S. Chahal, , M. Kumar, M. K. Sidhu, & S. P. Singh. 2016. Effect of different packaging films on shelf-life and quality of Daisy mandarin under ambient conditions. ***The Horticultural Society of India (Regd.), 73*(2)**, 262-266.

Efiuvwere, B.J.O. and J.A. Oyelade. 1991. Biodeteriorative and physicochemical changes in modified atmosphere packaged oranges and the microbial quality of the preserved and unpreserved juice. ***Tropical Science,* 31(4)**: 325-333.

Egwim, E. C., A.C. Ogudoro, & G. Folashade. 2013. The effect of pectinase on the yield and organoleptic evaluation of juice and wine from banana and paw-paw. ***Ann. Food Sci. Technol., 14*(2)**:206-211.

El-Hefnawi, S.M. 2002. Effect of some post-harvest treatments and type of bagging on some quality parameters of Awais mango fruits during and after cold storage. ***Zagazig J. Agric. Res.,* 29(3)**: 709-726.

El-Hefnawi, S.M., Safaa, A. Nomier, A.S.A. Hassan and M.M. Gad. 2008. Effect of packaging during cold storage period on guava fruits cv. El-Mamoura. ***Egypt. J. of Appl. Sci.,* 23(3)**:186-212.

FAO–World Bank. 2010. Reducing post-harvest losses in grain supply chains in Africa. Workshop held from 18–19th March, 2010 in Rome, Italy. 120p

Farooqi, W. A., & M. S. Ahmad. 1988. Effect of wax-coating on the physiological and bio-chemical aspects of" kinnow" fruit. ***Pakistan Journal of Scientific and Industrial Research (Pakistan)*, 31**:142-145

Freed M. 1966. Methods of Vitamin Assay, Interscience, New York, p. 287.

FSSA. 2006. Food Safety and Standard Act 2006 with Food Safety and Standard Regulation 2010, chapter 7 regulation 7.3.6 p 513 (www.fssai.gov.in)

Gangwar, L. S., S. M. Ilyas, D. Singh, and S. Kumar. 2005. An economic evaluation of kinnow mandarin cultivation in Punjab. ***Agricultural Economics Research Review*, 18(1)**: 71-80.

Geeson, J.D., K. Maddison and K.M. Browne .1981. Modified Atmosphere Packaging of Tomatoes. **In**: Packaging of Horticultures Produce. AAB/NCAE Residential Meeting. London. p:8-15.

Guilbert, S., N. Gontard, and L.G.M. Gorris. 1996. Prolongation of the shelf life of perishable food products using biodegradable films and coatings. ***Food Science Technology*, 29: 10–17.**

Gul, S., M. Ishtiaq and S.H. Shah. 1990. Studies on the effect of storage on the quality of sweet orange. ***Sarhad J. Aric.*, 6(5)**: 433-436.

Haard, N. F. and D.K. Salunkhe. 1975. Symposium on pest biology and handling of fruits and vegetables. The AVI Publishing Co.

Haikerwal, S. 2001. Effect of protective coating and individual seal packing on the storage life of Jaffa sweet orange, M.Sc. Thesis, PAU, Ludhiana.

Hassan, Z. H., S. Lesmayati, R. Qomariah, & A. Hasbianto. 2013. Effects of wax coating applications and storage temperatures on the quality of tangerine citrus (*Citrus reticulata*) var. Siam Banjar. ***International Food Research Journal, 21*(2).**

Henriod, R.E. 2006. Postharvest characteristics of Navel oranges following high humidity and low temperature storage and transport. ***Postharvest Biology and Technology*, 42 (1)**: 57-64.

Hussain, M.A, M.K. Ahmed, and I. Shakir. 2004. Effect of uni-packing on the post-harvest behaviour of citrus fruits in N.W.F.P. ***Pakistan Journal of Nutrition,*** **3**: 336-339.

Hussein, A.M.; M.B. El-Sabrout and A.E. Zaghloul. 1998. Postharvest physical and biochemical changes of common and late types of seedy guava fruits during storage. ***Alex. J. Agric. Res.,*** **43(3)**: 187-204.

Ismail, H.A. and E.A. El-Menshawy. 1997. Effect of polyethylene seal packaging on storage quality of lemon and grapefruit. ***Annals of Agric. Sci. Moshtohor,*** **35(1)**: 511-519.

Ismail, M.A. and D.L. Menshamy. 1997.Effect of polyethylene seal packaging on storage quality of lemon and Grapefruit. ***J. Ann. Agri. Sci. Mastohor,*** **35**:511-519.

Jadhao, S. D., P.A. Borkar, S.L. Borkar, P.H. Bakane, & R.P. Murumkar. 2008. Effect of different treatments and packaging materials on biochemical changes during storage of kagzi lime. ***Asian Journal of Bio Science, 3*****(2)**, 247-250.

Jawandha, S. K., H. Singh, A. Arora, & J. Singh. (2014). Effect of modified atmosphere packaging on storage of Baramasi lemon (Citrus limon (L.) Burm). ***International Journal of Agriculture, Environment and Biotechnology, 7*****(3)**, 635.

Jawandha, S. K., M.S. Gill, N.P. Singh, & Anil Sangwan. 2015. Study of fruit quality attributes of kinnow mandarin in relation to fruit size. ***International Journal of Science and Nature.,*** **6(1)**:103-104.

Jawandha, S. K., P.S. Tiwan, & J.S. Randhawa. 2012. Effect of low density polyethylene (LDPE) packaging and chemicals on ambient storage of kinnow. ***HortFlora Research Spectrum, 1*****(1)**, 55-59.

Jhalegar, J., R.R. Sharma, & S.K. Singh. 2015. Effect of surface coatings on postharvest quality of Kinnow mandarin. ***Indian Journal of Horticulture, 72*****(2)**, 267-272.

Joushua, P. and S. Sathiyamoorthy. 1993. Storage of sapota fruits in polythene bags. ***South Indian Horticulture,*** **41(6)**: 368-369.

Joyce, D.C. and A.J. Shorter. 1992. Modified atmosphere packaging to extend avocado green life: preliminary investigation. **In**: Proc. Conf. '92 Management into the Future'. Australian avocado Growers Federation Inc.

Juliana. D. S. A, S.D.P.Q. Scalon, K.E.D. Silva, F.F.D. Lima, A.P.E. Gomes, & M.M. Leite. 2004. Physicochemical and microbiological characteristics of minimally processed'Champagne'oranges (*Citrus reticulata*× *Citrus sinensis*) in different packgings. ***Food Science and Technology (Campinas),*** **33(1)**, 84-92.

Kader, A.A. 2002. Recommendations for maintaining postharvest quality. Post harvest Technology Research Information Center. Dept of Pomology. Univ. of California. One Shield Ave., Davis, CA., 95616-8683.

Kader, A.A. 2005. Increasing Food Availability and Reducing Postharvest Losses of fresh Produce. Proceedings of the ***5th International Postharvest Symposium***, Verona, **6(11)**, 2169-2175.

Kaur, H., J.S. Randhawa, & A.S. Dhatt. 2004. Effectivity of wax and fungicides on the storage behaviour of seal packaged kinnow mandarins. ***Journal of Research, 41*****(1)**, 47-52.

Kaushal, B.B.L. and K.S. Thakur. 1996. Influences of ambient and evaporative cool chamber storage conditions on the quality of polyethylene-packed Kinnow fruits. ***Advances in Horticultural Science,*** **10(4)**:179-184.

Kawada, K. and H. Kitagawa. 1988. Plastic-film packaged storage of citrus and some other fruits in Japan. ***Proc. 6th Int. Citrus Cong.,*** **3**:1555-65, Tel Aviv, Israel.

Kays, S.J. 1997. Post Harvest Physiology of Perishable Plant Products. Vas Nostrand Rein Hold Book, AVI Publish. Co. pp. 147-316.

Kohli, R.R. and J.R. Bhambota. 1966. Storage of lime (*Citrus aurantifolia* Swingle). ***Indian Journal of Horticulture,*** **23(3/4)**: 240-246.

Kumar, J., R.K. Sharma and R. Singh. 1991. Effect of modified atmospheric storage on shelf life of Kinnow mandarin. ***Haryana Journal of Horticultural Science,*** **20(3/4)**: 156-160.

Kumar, J., R.K. Sharma and R. Singh. 1991. Effect of modified atmospheric storage on shelf life of Kinnow mandarin. ***Haryana Journal of Horticultural Science,*** **20(3/4)**: 156-160.

Kumar, J., R.K. Sharma and R. Singh. 2000. The effect of different methods of packing on the shelf life of kinnow. ***Haryana J. Hort. Sci.,*** **29 (3-4)**: 202-203.

Kumar, S. and K.S Chauhan. 1990. Effect of fungicides and calcium compounds on shelf life of kinnow mandarin. ***Haryana Journal of Horticultural Sciences,*** **19**: 102-121.

Ladabiya M.S, S. Singh and A.K. Wadhawan. 2003. Response of 'Nagpur Mandarin', 'Mosambi' sweet orange and 'Kagzi' acid lime to gamma radiation. ***Radiation Physics and Chemistry, 67*****(5)**, 665-675.

Ladaniya, M. S., S. Singh, & B. Mahalle. 2005. Sub-optimum low temperature storage of 'Nagpur'mandarin as influenced by wax coating and intermittent warming. ***Indian Journal of Horticulture, 62*****(1)**, 1-7.

Ladaniya, M.S. 2001. Response of Mosambi sweet orange to degreening, mechanical waxing, packaging and ambient storage conditions. ***Indian Journal Agri. Sci.,*** **71**: 234-39.

Ladaniya, M.S. and Shyam Singh. 1998. Post harvest technology of Nagpur mandarin (*Citrus reticulata* Blanco). NRCC, Nagpur, Technical Bulletin-2, pp 44.

Ladaniya, M.S., Sonkar, R.K. and Das, H.C. 1997. Evaluation of heat shrinkable film wrapping of Nagpur mandarin (*C. reticulata* Blanco) for storage. ***J. Food. Sci. Tech.,*** **34(4)**:324-327.

Laximinarayana, S. and Bazquezalinas, C. 1978. Changes in chemical constituents of mango fruits during ripening as influenced by storage temperature. Abstracts of papers. Amer. Chem.soc. 176, AGFD 50, ***Food Science and Technology.***

Li, P., and M.M. Barth. 1998. Impact of edible coatings on nutritional and physiological changes in lightly processed carrots. ***Postharvest Biology and Technology,*** **14**: 51-60.

Mahajan, B. V. C., & R. Singh. 2014. Effect of packaging films on shelf life and quality of kinnow fruits packed in consumer packages. ***International Journal of Farm Sciences, 4*****(1)**, 92-98.

Mahajan, B. V. C., W.S. Dhillon, & M. Kumar. 2013. Effect of surface coatings on the shelf life and quality of kinnow fruits during storage. ***Journal of Postharvest Technology, 1*****(1)**:008-015.

Mahajan, B.V.C, A.S. Dhatt, and K.S. Sandhu. 2005. Effect of different post harvest treatments on the storage life of kinnow mandarin. ***Journal of Food Science and Technology,*** **42(4)**:296-299.

Mandal, G. 2015. Effect of lac-wax, citrashine and individual shrink wrapping of fruits on storage life of late harvested kinnow under ambient conditions. ***Int. J. Bio-res. Env. Agril. Sci.,*** **1(3)**:84-89.

Manzano, J.E. and A. Diaz. 2001. Effect of storage time, temperature and wax coating on the quality of fruits of 'Valencia' orange (*Citrus sinensis* L.). Proc. Int'l. Soc. ***Tropical Hort.,*** **44**: 24-29.

Mapson, C.W. 1970. Vitamins in fruits. **In**: ***Biochemistry of fruits ad their products***. Vol 1. Hulme AC (ed.) Academic Press, New York.

McHugh, T.H., and E. Senesi. 2000. Apple wraps: A novel method to improve the quality and extend the shelf life of fresh-cut apples. ***Journal of Food Science, 65(3)***: 480-485.

Munoz, P.H., E. Almenar, M. Ocio and R. Gavara. 2006. Effect of calcium dips and chitosan coating on post harvest life of strawberries (*Fragaria ananassa*). ***J. Postharvest Biol. Tec.,*** **39**:247-253.

Nasciment, L.M., M.C. Arruda, I.H. Fischer, L.P. Ferraz, and M.B. Fonseca. 2011. Storage potential of Murcott mandarin: refrigerated storage x modified atmosphere. ***Citrus Research and Technology,*** **32 (3)**: 167-172.

Pandey G, M.K. Verma, A.N. Tripathi. 2006. Studies on storage behaviour of apple cultivars. ***Indian J Hort.,*** **63**:368–371.

Panhwar, F., 2006. *Post Harvest Technology of Fruits and Vegetables* –http://www.eco-web.com

Panse, V.G. and Sukhtme, P.V. 1985. Statistical methods for Agricultural workers. Indian Council of Agricultural Research, New Delhi.

Park, H.J., M.S. Chinnan, and R. Shewfelt. 1994. Edible corn-zein film coatings to extend storage life of tomatoes. ***Journal of Food Processing and Preservation*, 18**: 317-331.

Pavlath, A. E., & W. Orts.2009. Edible films and coatings: why, what, and how?. In ***Edible films and coatings for food applications*** (pp. 1-23). Springer New York.

Perez-Guzman A E, C. Saucedo-Veloz and Arana-Errasquin. 1999. Effect of individual seal packaging in plastic films on quality of Dancy mandarin stored under refrigeration. ***Food Sci Tech International,* 5(3)**:215-222.

PHLRD, 2005. Food Loss Status in Nepal. Progress Report. Postharvest Loss Reduction Division, Postharvest Management Directorate, Kathmandu, Nepal, 3.

Piga, A., S. D`Aquino; M. Agabbio and L. Piergiovanni. 2003. Polyethylene film packaging affects quality of Lisbon lemons during long-term storage. ***Italian J. of Food Sci.,* 9(1)**:25-35.

Raghav P K and A.K. Gupta. 2000. Quality and shelf life of individually shrink wrapped kinnow fruits**.** ***Journal Food Science Technology,* 37**: 613-16.

Raghav, P. K., & A.K. Gupta. 2003. Simulated transportation of individually shrink wrapped kinnow fruits. ***Journal of food science and technology, 40*(4)**, 389-397.

Ramin A A and D. Khoshbakhat. 2008. Effects of microperforated polyethylene bags and temperatures on the storage quality of acid lime fruits. ***American-Eurasian Journal Agric & Environ Sci.,* 3(4)**: 590-94.

Randhawa, J. S., S.K. Jawandha, & P.P.S. Gill. 2009. Effect of high density polyethylene packaging with edible oil and wax coating on storage quality of 'Kinnow'mandarin. ***Journal of Food Science and Technology, 46*(2)**: 169.

Randhawa, J.S, A.S. Dhatt, H. Kaur and G.S. Dhillon. 1999. Studies on prolongation of storage life of kinnow fruits with individual seal packaging. ***In: Proceedings of International Symposium on Citriculture***, held at NRC for Citrus, Nagpur on Nov 23-27:461-465.

Randhwa, J.S., A.S. Dhatt and H.S. Rattanpal. 1999. Effect of HDPE packaging on shelf life of citrus fruits. ***Int. Symp. Citri.*** pp 181: 07 (Abstr). N.R.C. for Citrus, Nagpur.

Reddy V B, G.B. Madhavi, D.V. Reddy, V.C. Reddy, B. Srinu. 2008. Effect of different packaging materials on the shelf life and quality of acid lime at room temperature. ***Journal Dairying, Foods & H.S.,*** **27(3/4)**: 216-220.

Salunkhe, D.K. and B.S. Desai. 1984. Post harvest biology of fruits vol. II. CRC press INC Bora Raton Florida.

Shahid, M. N., & N.A. Abbasi. 2011. Effect of bee wax coatings on physiological changes in fruits of sweet orange CV."blood red". ***Sarhad Journal of Agriculture, 27*****(3)**: 385-394.

Sharma, S., Singh, B., Rani, G., Zaidi, A. A., Hallan, V., Nagpal, A. and Virk, G. S. 2007. Production of Indian citrus ring spot virus free plants of kinnow employing chemotherapy coupled with shoot tip grafting. ***Journal of Central European Agriculture,*** **8(1)**: 1-8.

Shein, N. N., T. Jaroenkit, S. Ussahatanonta & N. Jarassamrit. 2008. Effect of wax coating on the postharvest quality of 'Sai Nam Peung'mandarin orange (*Citrus reticulata* Blanco). ***Agricultural Science Journal, 39*****(3):** 13-16.

Singh, A. and R. Singh. 1996. Quality of Kinnow mandarins as affected by modified atmosphere storage. ***Journal of food science and technology,*** **33(6)**: 483-487.

Singh, Y., & Y.K. Yadav. 2015. Effect of different storage environment on quality characteristics of tomato and kinnow fruits. ***Agricultural Engineering International: CIGR Journal, 17*****(1)**:238-44.

Somogyi, M. (1952). Notes on sugar determination. *Journal of biological chemistry, 195*, 19-23.

Sonkar R K and M.S. Ladaniya. 1998. Effect of tray over wrapping by heat shrinkable and stretchable films on Nagpur mandarin fruits. ***Indian Food Packer, 52 (5)***: 22-26.

Sonkar R K, D.A. Sarnaik, S.N. Dikhshit and R.R. Saxena. 2009. Individually stretch cling film wrapped kinnow mandarin under ambient storage. ***Indian J Hort,* 66**: 22-27.

Sonkar, R.K. and M.S. Ladaniya. 1999. Unipacking of nagpur mandarin fruits with heat shrinkable and stretch cling polyethylene film. In: ***Proceedings of International Symposium on Citriculture***, held at NRC for Citrus, Nagpur. Pp- 465-468.

Stahl, A.L. and A.F. Camp. 1971. Citrus fruits in the biochemistry of fruits and their products (Edition) hulme A.C.Vol. 2 pp. 107-109.

Sumanjit, R. K., & S.R. Mahajan. 2010. Adsorptive removal of five acid dyes using various unconventional adsorbents. ***Journal of Surface Science and Technology, 26*(1-2)**, 77-93.

Thakur, K. S., B.B. Lal Kaushal, & R.M. Sharma. 2002. Effect of different post-harvest treatments and storage conditions on the fruit quality of Kinnow. ***Journal of food science and technology, 39*(6)**, 609-618.

Thompson, A.K. 1995. Postharvest Technology of Fruit and Vegetables. Logmans. London.

Upadhayaya, A.K. and K.U. Sanghavi. 2006. Effect of different chemicals and packaging materials on the shelf life of kinnow mandarin. ***Environment and Ecology,* 24(1)**: 213-216.

Venkatesha, M. and T. Venkatesh Reddy. 1994. Use of polyethylene bag to extend the shelf life of guava (*Psidium guajava* L.) fruits. Indian Fd. Packer 48:5-10.

Verma, V.S. and M.L. Tikoo. 2004. Packing systems and pattern of physical damage in post-harvest citrus fruit decay in Jammu market. ***Indian Phyto.,* 57 (3)**:267-271.

Plate 1. Collection of freshly harvested Kinnow

Plate 2. Preparation of Kinnow for packaging

Fruit dipping in chlorine solution **Washing of Kinnow with normal water** **Shade drying of Kinnow**

Plate 3. Various packaging materials used under experimentation of Kinnow

LDPE (25 μ)

HDPE (15 μ)

Polypropylene (25 μ)

Shrink film (15 μ)

Cling film (15 μ)

Liquid paraffin wax (10%)

Plate 4. View of Kinnow in control condition

Plate 5. View of spoilage fruits in Kinnow