Effect of different packaging films on shelf life and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa* L.).

THESIS

Submitted to the

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

MASTER OF SCIENCE
IN
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BY
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Registration Number: 11308149

Under the supervision of
Dr. MADHU SHARMA

Transforming Education Transforming India

Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, India
June, 2015

CERTIFICATE- I

This is to certify that thesis titled **"Effect of different packaging films on shelf life and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa* L.)"** submitted in partial fulfilment of the requirement for the award of degree of **Master of Science** in the discipline of **Horticulture** is a bonafide research work carried out by **Mr. Satpal singh (Registration No. 11308149)** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

(Signature of Supervisor)
Dr. Madhu Sharma
Assistant Professor
School of Agriculture
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CERTIFICATE- II

This is to certify that the thesis entitled **"Effect of different packaging films on shelf life and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa* L.)"** submitted by **Satpal Singh** to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of **Master of 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.

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DECLARATION

I hereby declare that the thesis entitled **"Effect of different packaging films on shelf life and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa* L.)"** is an authentic record of my work carried out at Lovely Professional University as requirement for the degree of **Master of Science** in the discipline of **Horticulture**, under the guidance of Dr. Madhu Sharma, Assistant Professor, School of Agriculture and no part of this thesis has been submitted for any other degree and diploma.

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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. Madhu Sharma,** who allowed me to do this project under her guidance. I am highly thankful to my family and friends for their active support, valuable time and advice, whole-hearted guidance, sincere cooperation and pains-taking involvement during this study.*

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(Satpal Singh)

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LIST OF ABBREVIATIONS

/	per
%	Percent
@	At the rate of
µ	Micro
^0C	Degree Celsius
^{0}Brix	Degree brix
AR	Analytical Reagent
$C_2K_2O_4$	Potassium oxalate
CO_2	Carbon dioxide
CRD	Completely randomized design
cv.	Cultivar
DCPIP	2,6 dichlorophenol indophenols
et. al.,	et alii (and others)
g	Gram
GA_3	Gibberellic acid
hac.	Hectare
HCl	Hydrochloric acid
HDPE	High density polyethylene film
i.e.	That is
LDPE	Low density polyethylene film
LDPP	Low density polypropylene
LPU	Lovely Professional University
MA	Modified atmosphere
MAP	Modified atmosphere packaging
mg	Milligram
mg/100ml	Milligram per 100 milliliter
MHPT	Mild heat pre-treatments
ml	Millilitre

mm	Millimeter
NaOH	Sodium hydroxide
O_2	Oxygen
OTRs	Oxygen Transmission Rate
PE	Polyethylene films
PET	Potential evapotranspiration
PLW	Physiological loss in weight
PP	Polypropylene film
PPF	Polyolephynic film
ppm	Part per million
PVC	Polyvinyl chloride
RH	Relative humidity
SD	Standard deviation
SE	Standard error
SPE	Sucrose polyester
TSS	Total soluble solids
Vitamin A	Retinol
Vitamin C	Ascorbic Acid
viz.	Videlicet
wt.	Weight
µm	Micrometer

Effect of different packaging films on shelf life and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa* L.).

ABSTRACT

The present investigation entitled, “Effect of different packaging film on shelf life and quality of Kinnow” was conducted in the Postgraduate Horticulture laboratory, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2014-15. The plants of uniform size and spread were selected in an orchard of progressive farmer at Phuglana, Dist. Hoshiarpur for carrying out this study. The experiment was laid out in a completely randomized design (CRD) with three replications. There were six treatments *viz.*, T_1 [Shrink film (125 micron)], T_2 [shrink film (25 micron)], T_3 [cling film (10 micron)], T_4 [cellophane (30 micron)], T_5 [LDPE (25micron)] and T_6 [control]. After packaging, consumer packs were stored at ambient conditions (21-22^o C and 45-48 % RH). The results of experiment revealed that T_1 [Shrink film (125 micron)] proved quite effective in reducing firmness loss, spoilage and maintained the various quality attributes like total soluble solids, acidity and vitamin C content of the fruit during shelf life period followed by T_2 [shrink film (25 micron)]. It was concluded that shrink film improved the shelf life and maintained the quality of kinnow fruits up to twenty days under ambient conditions as compared to unpacked or control fruits.

Key words: Kinnow, Shrink film, Cling film, Cellophane, Quality

CHAPTER I

INTRODUCTION

The Kinnow mandarin, a hybrid of King and Willow leaf (*Citrus nobilis x Citrus deliciosa*), occupies the prime position amongst the citrus fruits grown in India. Kinnow cultivation in Punjab is gaining momentum because of its adaptability, high yield and more economic return. Kinnow is commercially grown in Ferozpur, Faridkot, Muktsar, Bathinda, Mansa, Hoshiarpur, Ropar and Gurdaspur. India is next to Mexico in production of citrus fruits with an area of 763 lakh hectares and production of 599 lakh tons annually (Anonymous, 2014). In India, it occupies third rank in production after banana and mango crop. Furthermore, citrus ranks first in area (46,000 ha) and production (988,000 tonnes) in the Punjab, occupying 64.20% of the total fruit area (Anonymous, 2014). It is a predominant fruit commercially grown in the arid, irrigated and sub-mountainous zones of Punjab. It is famous for its attractive colour, high juice content and pleasant taste.

Citrus fruits are known for their high ascorbic acid content. Compared to other vitamins, minerals, biochemical compounds and antioxidants, ascorbic acid is the most susceptible to significant losses during post harvest handling and storage (Wilhelmina, 2005). Ascorbic acid content of harvested fruits is the major criteria used for monitoring freshness. As per Sanusi *et. al*., (2008) fruit spoilage is associated with loss of functional compounds such as phenolics and ascorbic acid. Kinnow is a good source of vitamin C, vitamin A and limonin content. The peels of this fruit act as a good source of pectin and essential oils. Due to these quality traits kinnow is greatly demanded not only in Indian market but also in Sri Lanka, Thailand and some Middle-East countries like Kuwait and Saudi Arabia (Dhatt and Mahajan, 2011). The Kinnow fruit matures during December to February for commercial harvesting. Generally, in India, fruits and vegetables are sold at the prevailing ambient condition which leads to huge qualitative and quantitative losses. Internationally, several postharvest technologies have been introduced to control fruit disorders, maintain optimum quality, freshness and minimize the losses (Krochta, 1997; Hagenimaier, 2002; Bajwa and Anjum, 2007). The role of packaging is very important in postharvest operations of horticultural crops but its role is still underestimated in our country. Use of polymeric films is very pronounced in packaging of fruits with a purpose to extend their storage life.

Polyethylene film creates water saturation atmosphere around fruits which decreases water loss and respiration from the fruits, and can interplay with physiological processes of commodity resulting in decreasing rate of respiration, transpiration, other metabolic processes of fruits (Lange, 2000), thereby, allowing lower physiological weight loss, reducing decay incidence and maintaining retention of colour and texture of fruits during extended shelf life (Sharma *et. al.,* 2010). Individual film wrapping of fresh fruits and vegetables will greatly reduce weight loss by reducing the transpiration rate and maintain fruit firmness.

There are many methods and techniques to enhance the shelf life of fruit available over the decades. Applied techniques made it possible to reduce the distances between the production and marketing areas. It has been observed that after harvesting, 25-80% fruit and vegetables are spoiled every year due to inappropriate handling and storage conditions. The shelf life extension and quality retention after harvesting can be possible with the application of skin coating materials, controlled atmosphere storage and modified atmosphere packaging. In India the concept of super market is coming up and many companies like Walmart, Reliance, Mother Dairy, Namdhari fresh etc. have opened up there retail outlets in big cities and are in demand of good quality fruits for sale in their outlets.

The incidence of microbial fruit rot of fungal and bacterial origin is a common problem in storage, which markedly deteriorates the keeping quality of the fruit. The species of *Penicillium, Alternaria, Aspergillus, Botrydiploidia* and *Geotrichum* etc. are particularly responsible for causing heavy losses. The main factors governing storage life of citrus fruit are weight loss and decay. Individual sealed packaging could significantly reduce weight loss and shrivelling, but the potential decay problem of sealed fruit needs to be resolved through perforation. The post harvest losses can be minimized by extension of shelf life through checking the rate of transpiration and respiration, microbial infection and protecting membranes from disorganization (Bisen and Pandey, 2008).

Fresh-cut processing affects quality factors such as appearance, flavour, colour and is accompanied with rapid product deterioration. Modified atmosphere packaging (MAP) is effective in extending the shelf-life of horticultural commodities by lowering oxygen (O_2) and increasing carbon dioxide (CO_2) concentrations in the package atmosphere, achieved via the interaction between respiratory O_2 uptake and CO_2 evolution of packaged produce, and gas transfer from the package films (Jacxsens *et. al.*, 1999; Makino, 2001; Schlimme and Rooney, 1994). In general, major factors which affect the equilibrium between gas concentrations of packaged produce include weight of packaged product and its respiration rate, package film oxygen/carbon dioxide transmission rate and the respiring surface area (Bell, 1996), and above all storage temperature. However, for packaged fresh-cut vegetables in the retail market, package surface area and product fill weight are often pre-determined to certain degree to achieve a market appeal. The respiration rate is also influenced by numerous factors, including storage temperature, cut size and vegetables types etc. Therefore, selecting package films with suitable OTRs (Oxygen Transmission Rate) plays an important role in developing MA (Modified atmosphere) packages for extended shelf-life and quality of fresh-cut produce.

Modified atmosphere packaging (MAP) is an effective tool used in the fresh-cut industry to extend shelf life by altering the gases in the package to produce a composition different from that of air (Al-Ati and Joseph, 2002). Depleted O_2 and/or enriched CO_2 levels reduce respiration, decrease ethylene production, delay enzymatic reactions, alleviate physiological disorders and preserve the product from quality losses and growth of microorganisms (Day, 1994). The equilibrium gas concentration thus developed within the package may extend the product shelf life (McDonald *et. al.*, 1990; Omary *et. al.*1993).

Research on edible coatings and films has been intense in recent years. Attempts to diminish crop losses and maintain the quality of fresh fruit for a longer period is a priority for all the producers (Ribeiro *et. al.,* 2007). Modified atmosphere packaging of fruits can result in reduction of respiratory activity, delay in softening, ripening and a reduced incidence of various physiological disorders and pathogenic infestations (Artés, 1993). However, when fruit respiration does not correlate to the permeability properties of packaging film, increase in the concentration of carbon dioxide (CO_2) will build up resulting in a state of anaerobic respiration and ethanol accumulation in the fruit (Ait-Oubahou and Yahia 1999). This results in the development of off-flavours and decay of fruit while in the package unit.

Hence, the present investigation was carried out to study the effect of packaging films such as shrink and cling on storage life and quality of kinnow fruits under ambient room temperature conditions, with following objectives.

1. To determine the effect of different packaging films on storage life and quality of kinnow mandarin,
2. To identify the best packaging strategy for enhancing the shelf life of kinnow mandarin.

Chapter II

REVIEW OF LITERATURE

The literature pertaining to the "Effect of different packaging films on shelf life and quality of Kinnow mandarin" has been reviewed under following headings.

2.1 Packaging films

2.1.1 Cling film (10 micron)

2.1.2 Shrink film (125 micron)

2.1.3 Shrink film (25 micron)

2.1.4 Low density polyethylene film (LDPE, 25 micron)

2.1.5 Cellophane (30 micron)

2.2 Physical characters

2.2.1 Fruit firmness

2.2.2 Percent spoilage

2.3 Chemical characters

2.3.1 Total soluble solids

2.3.2 Acidity

2.3.3 Sugars

2.3.3 Vitamin C

2.1.1 Cling film

Yuen *et. al.*, (1993) stated that wrapping of mango fruit of cv. 'Kensington pride' in sealed poly bags or in cling wraps significantly maintained attractive appearance with eating quality up to 10th day of storage. Sonkar and Ladaniya (1998) found that physiological loss in weight was significantly reduced by wrapping the Nagpur mandarin fruits in trays with heat shrinkable and stretch cling polythene films. Nain *et. al.,* (2002) revealed that cling film wrapping on 'Dashehari' mangoes checks the physiological loss in weight (PLW) and decay loss in fruits. Ladaniya (2003) studied the effect of heat shrinkable wrapping and stretchable cling films on ‘Mosambi’ orange fruits, stored at 25 ± 5^0c and 40-45% relative humidity. It was observed that these film wrappings led to reduction in weight loss and control of decay up to 40 days of storage. Ayhan *et. al.,* (2008) investigated the effect of modified atmosphere packaging on the quality and shelf life of minimally processed carrots cv. Nantes during cold storage. The carrots packed with high oxygen and passive MAP retained quality properties better compared to low oxygen. The whiteness index did not significantly changed during the 21 days of storage in all applications, indicating the good retention of orange colour.

2.1.2 Shrink film

McCollum *et. al.,* (1992) revealed that mango fruits packed in shrink wrap (RD 106) had better shelf life than un-wrapped fruits. Rao *et. al.,* (2000) claimed that maximum extension in the shelf life (24 days) was observed in shrink wrapped cucumbers, in addition to reduction in weight loss and maintenance of firmness during storage. The optimum storage temperature for cucumbers shrink wrapped with PE and polyolefin films was found to be 10^0C and 15^0C respectively. Nanda *et. al.,* (2001) studied the effect of shrink film wrapping with two polythene films (BDF-2001 and D-955) and skin coating with a sucrose polyester (SPE) samperfresh on the shelf life and quality of soft seeded ‘Ganesh’ pomegranate (*Punica granatum* L.) stored at 8,15 and 25 ^{o}C. Peel thickness, freshness and firmness of the fruit were retained and weight loss greatly reduced by shrink wrapping. The weight loss in shrink-wrapped fruits was 1.2-1.3% after 12 weeks of storage at 8^0C and 2.2-3.7% after 10 weeks at 15^0C.

Singh and Sudhakar Rao (2005) stated that fresh mature green papaya (*Carica papaya* L.) cv. ‘Solo’ fruits individually shrink wrapped with Cryovac D-955 film, could be kept well for 10 days at ambient temperature that ripened in 5 days with firm texture and good flavour after unwrapping. Sharma *et. al.,* (2010) conducted experiment on apple cv. ‘Royal Delicious’ individually shrink wrapped in three heat shrinkable film viz. Cryovac (9µ), polyolefin (13µ) and LDPE (25µ) in zero energy cool chamber for 60 days. They observed that Cryovac (9µ) films exhibited the least physiological loss in weight (6.7%), decay loss (6.5%), juice recovery (64.8%) and total soluble solids (16.1%).

2.1.4 Low density polyethylene film (LDPE)

Ben-Yehoshua (1978) found that shelf life of citrus fruit could be doubled under ambient conditions by packaging in high density polyethylene films. Rameshwar *et. al.,* (1979) wrapped mango fruits in 200 gauge polyethylene bag with 0.4% ventilation and concluded that the storage life of mangoes could be extended by wrapping in polyethylene film with ethylene absorbent. Adsule and Tandon (1983) stated that the guava fruits stored in low density polyethylene bags (600 gauge) had good organoleptic score and marketability up to 10 days of storage. Smith *et. al.,* (1987) studied the effect of LDPE packs on primary quality attributes *viz.* skin colour, flesh firmness and sensory quality of 'Discovery' apples stored at 20^0 C. They observed marked reduction in softening and yellowing.

Lazan *et. al.,* (1990) reported that the seal packaging of papaya in three layers of LDPE (0.0125mm thick) stored at 24-28^0C for 18 days retarded the peel colour development and fruit softening. Norma Casas *et. al.,* (1990) revealed that the shelf life of tomato and spinach packed in cellophane film and LDPE film could be increased up to 35 days at 25^0 C and 85-90% RH in case of tomato and 25 days in case of spinach at 2^0 C and 85-90% RH, accounting for at least 200% increase in shelf life. Cohen *et. al.,* (1990) observed significant reduction in weight loss up to 6 months at 2^0C with negligible chilling injury as well as higher retention of better quality attributes in lemon fruits packed in HDPE (10μ) and stored at varying temperatures of 2, 8 and 13^0C.

Dhatt *et. al.,* (1991) claimed that Kinnow fruit packed in high density polythene film and tightly sealed with manual electric sealer maintained acceptable firmness and test up to 56 days of storage. Khalon and Bajwa (1991) stated that perforated plastic bags and perforated LDPE bags for litchi effectively increased the shelf life of stored produce. Geeson *et. al.,* (1991) observed that shelf life of pear fruits packed in low density polyethylene (LDPE) bags under ambient conditions extends for four days. Lurie (1993) used low density polyethylene (LDPE) of 40 μ thickness or polyolefin films to seal pack various varieties of peaches and nectarins. Low density polyethylene found beneficial in extending storage life and decreasing internal flesh breakdown and reddening as compared to polyolefin. Noomhorn and Potey (1993) stated that shelf life of packed banana cv. 'Klua Hom Tong' in Low density polyethylene films stored at 23^0 C extended up to 22 days.

Pala *et. al.,* (1994) stated that the packaging of apricot fruits using 50 µ low density polyethylene (LDPE) film helped to preserve the quality of apricots during 6 weeks of storage at 0^oC. Apples cv. "Pilafa Delicious" kept inside cold storage in sealed-packing inside low and medium density polyethylene (PE) film of different thickness showed reduced weight loss, decay and remarkably flesh softening as reported by Lambrinos *et. al.,* (1995). Fruits retain good quality even after a long term storage of 7 months, but intense fermentation, when CO_2 concentrations exceeded certain limits.

Manolopoulou *et. al.,* (1997) used low density polyethylene films to pack 'Hayward kiwifruit' followed by storage at 0^0 C and 90% RH. They found reduced weight loss, decay and flesh softening in kiwi fruits maintaining high dessert quality, preserving texture, taste and flavour. Mango fruits cv. 'Amrapali' packed in perforated polyethylene after calcium treatment showed reduced weight loss, maximum total sugars, β-carotene and minimum acidity after 11 days of storage in the study conducted by Singh *et. al.,* (1998). Kumar *et. al*., (1999) observed increase in the shelf life of tomato fruit up to 25 days when wrapped at turning stage with HDPE (10 µm) film and stored in evaporative cooling brick and sand store. Talhouk *et. al.,* (1999) made an attempt to check the storability of 'Ahmar' loquat in modified atmosphere packaging using LDPE and HDPE and reported that the use of polyethylene wraps delayed shrivelling of fruits and maintain their juiciness.

Kluge *et. al.,* (1999) packed fruits of peaches cv. 'Flordaprince' in different plastic packing including PVC films, HDPE, LDPE films and stored them at 1 ± 1^0 C and 80-85% RH for periods of 14 and 28 days. The use of plastic packing reduced the weight loss during cold storage. Low density polyethylene maintained higher pulp firmness during refrigeration period. Sandhu and Singh (2000) compared individual seal packaging on pear fruit cv, 'Le Conte' with LDPE and HDPE during cold storage and observed that HDPE film resulted in lower weight loss and spoilage as compared to LDPE film. The TSS was found to be more in LDPE seal packed fruits while total acids and starch were higher in fruits seal packed in HDPE film. Chamara *et. al.,* (2000) stated that modified atmosphere packaging with LDPE bags (0.075mm) of ‘Kolikuttu’ bananas extended the storage period up to 24 days at 14^0 C and 94% RH without effecting fruit quality.

Patel and Singh (2001) studied the combined effects of different MAP film types, i.e. polypropylene (PP), high density polythene (HDPE) and low density polythene (LDPE); at different storage temperatures (5, 10 and 15°C) on flower quality and vase life of gerbera flowers. The PP (24 μm) and HDPE (24 μm) films used as MAPs at 5°C were found promising in maintaining flower quality of gerbera during and after storage. Hussain *et. al.*, (2004) performed a 45 days storage experiment to investigate the effect of uni-packaging with polyethylene on citrus and observed significant effect in prolonging the shelf life and maintenance of external appearance, taste and texture. Alsadon *et. al.*, (2004) pack tomato fruits cultivars Red Gold in LDPE film and HDPE film and stated that tomato could be stored for up to 3 weeks at 15^o C without weight loss in case of LDPE.

Neeraj *et. al.*, (2004) estimated the effect of HDPE, LDPP and PVC packaging on aonla fruits cultivar Chakaiya during storage. After 30 days of storage at room temperature, maximum retention of ascorbic acid and minimum spoilage was recorded in HDPE packed fruits whereas minimum ascorbic acid and maximum spoilage was observed in fruits packed in PVC bags.

Ali *et. al.*, (2004) noticed that carambolas packed in LDPE films and held at 10^0 C significantly restricted as well as reduced tissue firmness, development of fruit colour, water loss and suppressed the incidence of chilling injury. Brahmachari and Rani (2005) reported the effect of polyethylene packaging on storage behaviour of guava fruits. Fruits harvested at colour break stage were packed in polyethylene bags and stored at 32 ± 4^0C and 70-85% RH. The shelf life was significantly prolonged up to 9 days, with improvement in overall quality of fruits as indicated by reduced weight loss and decay, as well as retention of TSS, sugars and ascorbic acid content.

Jindal *et. al.*, (2005) conducted an experiment to find the effect of polyethylene packaging on shelf life of sapota fruit cultivar Cricket Ball. They wrapped fruits individually in polyethylene in different thickness, viz. 50,100 and 150 gauge, stored at room temperature of 40^oC for 8 days. Polyethylene packed fruits were found to be better in reducing decay loss. Maximum fruit firmness was retained in fruits packed individually in 100 gauge polyethylene along with maximum acidity and ascorbic acid content. Whereas, maximum TSS was recorded in fruits packed in 150 gauge polyethylene. Kumar *et. al.,* (2005) dipped the fruits of aonla in 2% Bael leaf extract and packed in HDPE and LDPE polyethylene bags for storage at room temperature of 25±5^{0}C. Polyethylene packaging was found to be effective in reducing the physiological loss in weight, with the fruits remaining marketable up to 18 days of storage. The TSS, acidity and ascorbic acid contents of fruits were also found to be desirably maintained in polyethylene packed fruits.

Cia *et. al.,* (2006) stated that packing of 'Fuyu' persimmon fruit in 58 **µ** polyolephynic film and 50 **µ** LDPE film to be most suitable for atmosphere modification for 84 days at 1^0 C plus five days at 25^0 C. Singh and Mandal (2006) studied the effect of different levels of perforation in polyethylene bags on quality and spoilage of peach fruit under cold storage. Fruits of peach cultivar Sharbati were packed in HDPE bags (200 gauge) having ventilation of 0.5, 1, 1.5 and 2%. Minimum spoilage (3.9%) was found in 1% opening level whereas, maximum spoilage (9.6%) was in unventilated bags after 40 days of storage. Fruits registered minimum weight loss in case of unventilated bags having 0.5% opening level. Total soluble solids content of fruit increased significantly with increase in the ventilation level in the bags, thus indicating that 1% perforation in polyethylene bags (200 gauge) is important to retain quality as well as to reduce the spoilage of fruits during storage.

Steiner *et. al.,* (2006) recorded the combined influence of mild heat pre-treatments (MHPT) and two types of modified atmosphere packaging conditions on metabolic response of fresh-cut peach during 8 day long storage under refrigeration (4^{0}C). They reported passive modified atmosphere to be more efficient in preserving the quality attributes of fresh-cut peaches. An *et. al.,* (2007) revealed that MAP treatment inhibit the climacteric peak, avoided the increase in flesh colour, decrease the development of softness and retard the reduction of TSS, titratable acidity and membrane integrity of peach fruits packed in low density polyethylene bags at 2^0 C. Sirichote *et. al.,* (2008) estimated physical, chemical, microbial and sensory properties of the peeled Rambutan samples. They stated that the samples were acceptable for consumption even after 21 days of storage in modified atmosphere packaging using LDPE bags at 4^{0}C.

2.1.5 Cellophane

Hall (1957) reported that the cellophane film is more permeable to water vapours as compared to polyethylene films. Neeraj *et. al.,* (2003) stated that the use of cellophane bags and pliofilm respectively, for extending shelf life of apples and also use moisture proof cellulose sheets to prevent shrivelling of Golden delicious apples in cold storage. Kahlon and Uppal (2005) stated that the shelf life of mango cv. ' Chausa' could be extended up to 15 days at a temperature of 28-33^{0}C and 85-90% RH after treating with GA_3 (2000 ppm) followed by packaging in perforated polythene bags. The TSS and reducing sugars increased up to 15 days and decreased thereafter, while acidity level of fruits decreased throughout the storage period.

Sammi and Masud (2007) noticed that freshly harvested mature green tomatoes cv. 'Rio Grande' packed in polyethylene packaging could be stored up to 96 days as compared to that of control (24 days). Ambros *et. al.,* (2008) stored loquat fruits in modified atmosphere packaging (MAP), using microperforated polypropylene (PP) films for 2, 4 and 6 weeks at 2^{0}C. They reported that weight loss was drastically reduced by MAP conditions. Apart from this, softening, colour evolution, decrease in sugars and organic acids were also delayed.

Chapter III

MATERIALS AND RESEARCH METHODOLOGY

The present investigation entitled, "Effect of different packaging film on shelf life and quality of Kinnow" was conducted in the Postgraduate Horticulture laboratory, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2014-15. The plants of uniform size and spread were selected in an orchard of progressive farmer at Phuglana, Dist. Hoshiarpur for carrying out this study.

3.1 Location and Soil

Lovely Professional University, Phagwara, Punjab, is located at latitude 31.25 and longitude 75.70 as per google map coordinates along with altitude of above 232 m above sea level. The soil of the sub-region are deep to very deep, loamy sand to loam and developed on alluvium. Soil is moderately well drained. Soil is alkaline in reaction with pH ranging from 7.5 to 8.3. Both calcareous as well as non-calcareous soil occur in this sub-region. In general, soil has low to medium organic carbon and low salt content.

3.2 Climate

The sub-region is characterized by hot dry sub-humid to semi-arid transition with dry summers and cool winters. The mean annual air temperature ranges from 24 to 26^0C. The mean maximum summer (May to July) temperature ranges from 35 to 39.4^0C rising to a maximum of 40^0C in May to June. The mean winter (December to February) minimum temperature ranges from 4^0C to 6^0C dropping to a minimum of 3.7 ^{0}C- 4.4 ^{0}C during December and January. The sub-region receives mean annual rainfall ranging between 700-1000 mm covering 52-60 per` cent of mean annual PET (Potential evapotranspiration) ranging between 1300-1500 mm. The monsoon last from June end to September end covering 75-80 per cent of total annual rainfall. As presented in figure 3.1.

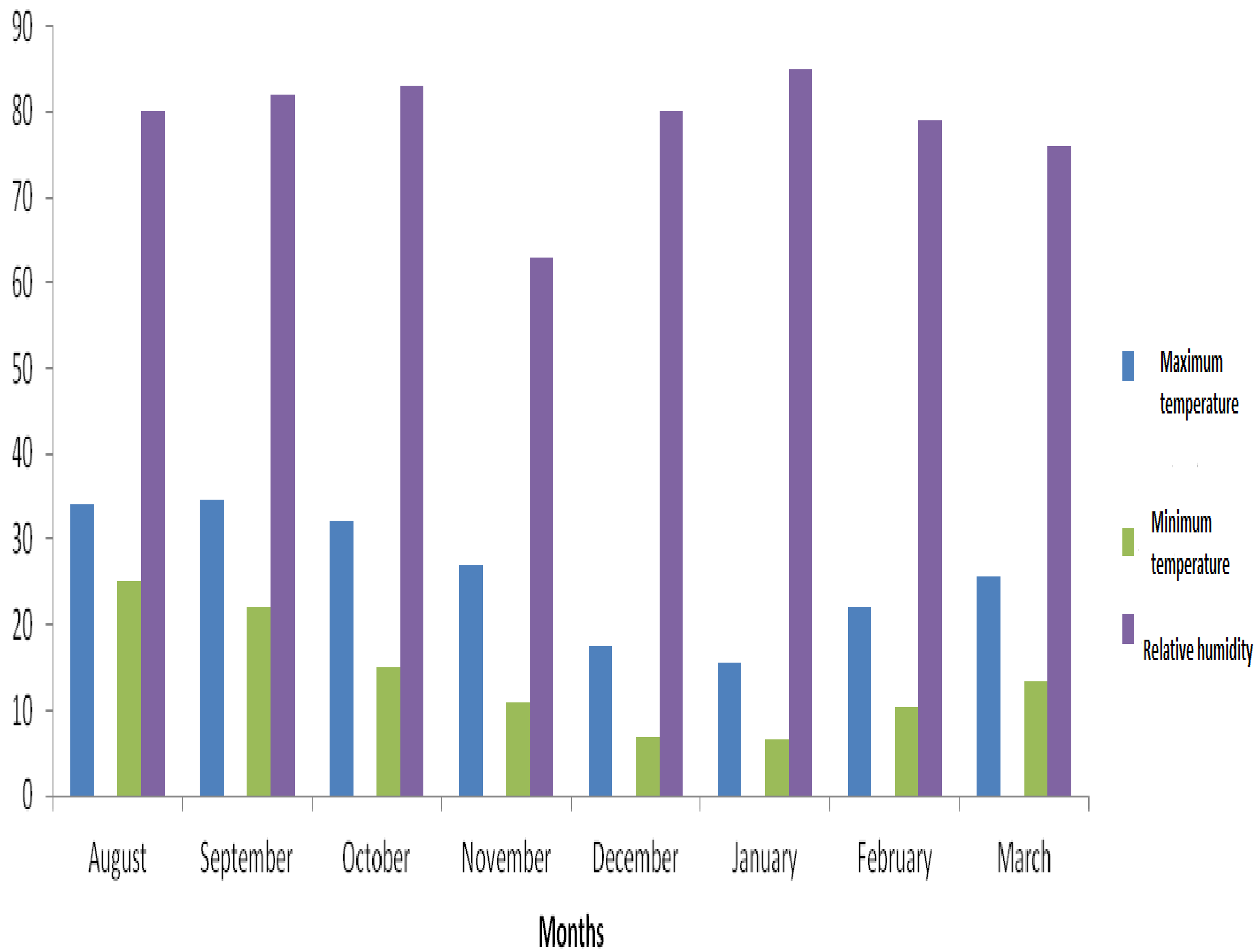

Fig. 3.1: Average monthly meteorological data of year 2014-15.

3.3 Preparation of fruit samples

The Kinnow fruits of uniform size, disease free were picked randomly from all the four directions of the plants with the help of secateurs at physiological maturity. The fruits were collected in plastic crates and shifted to School of Agriculture, Lovely Professional University, Phagwara for further study. In the Postgraduate laboratory of Department of Horticulture, the fruits were sorted, washed and graded. Thereafter, fruits were divided into requisite lot for further handling.

3.4 Packaging films

In the present study, 5 types of packaging films were tried for packing kinnow fruits in corrugated trays. The shrink film and LDPE were procured from Saluja Plastic Industries. The Cling film was procured from M/S Sol pack system Ludhiana, whereas, the Cellophane was obtained from local market of Phagwara.

Table 3.1 Tabular view of packaging films and their thickness

S.No.	Packaging material	Thickness (micron)
1	Cling film	10
2	Shrink film	125
3	Shrink film	25
4	Low Density Polyethylene film	25
5	Cellophane	30

Experimental details:

The effect of different packaging films on shelf life and quality of Kinnow fruits under ambient conditions (21-22^{o} C and 45-48 % RH), was evaluated as under:

Number of treatments : 6
Number of Replications : 3(5 fruits in each replication)
Storage intervals : 5(5, 10, 15, 20, 25 days)
Storage conditions : 21-22^{o} C and 45-48 % RH

T_1	- Shrink film (125 micron)
T_2	- Shrink film (25 micron)
T_3	- Cling film (10 micron)
T_4	- Cellophane (30 micron)
T_5	- Low Density Polyethylene film (25 micron)
T_6	- Control

Storage of fruits

The film wrapped and control fruits in corrugated trays were stored under ambient conditions (21-22^{o} C and 45-48 % RH) in the postgraduate laboratory of School of Agriculture.

Observations recorded

1 Physical parameters

1.1 Fruit firmness

Firmness of randomly selected fruits were measured with the help of a Digital Penetrometer. The fruit was kept on the platform of the instrument and was compressed. The results were expressed as g force of compression.

1.2 Percent spoilage

Percent fruit rot was calculated by counting the total number of fruits that had rotten

$$\text{Percent fruit rot} = \frac{\text{Number of rotten fruits}}{\text{Total no of fruits}} \times 100$$

2. Chemical parameters

2.1 Total soluble solids (%)

Total soluble solids (TSS) were determined from the juice at ambient temperature with the help of hand refractometer and expressed in percent. These reading were corrected with the help of temperature correction chart at 20^0C temperature (AOAC, 1990).

2.2 Titratable acidity (%)

The acidity in Kinnow fruits was determined as citric acid by titrating against 0.1 N NaOH (AOAC, 2000). 10 ml of kinnow fruit juice along with 100 ml water was taken and then titrated with the 0.1 N NaOH using phenolphthalein as an indicator (one-two drops) till light pink end point which persist for 3 sec. The percent acidity was calculated according to the expression given below:

$$\text{Acidity (\%)} = \frac{1/10 \times \text{equivalent weight of acid} \times \text{N(NAOH)} \times \text{Titer}}{\text{Volume of sample}} \times 100$$

2.3 Sugars

Sugars in all products were estimated by Lane and Eynon's method (Ranganna, 1995) as below:

Reagents

Fehling A

Fehling B

Methylene blue

Neutral lead acetate

Dissolved 25 mg of lead acetate in water and make final volume to 500 ml by adding water in the solution (45%).

Potassium oxalate

Dissolved 110 g of potassium oxalate ($C_2K_2O_4$) in water and make final volume of solution (22%) to 500 ml.

Preparation of extract

Weighed sample of 10 g was dissolved in water. The volume was made to 250 ml in a conical flask. Two ml of lead acetate was added in the solution, shaked well, and kept as such for 10 minutes. Necessary amount of potassium oxalate was added to remove the excess of lead and filtered through Whatman filter paper No. 1. The filtrate was used for the estimation of reducing sugars.

2.3.1 Reducing Sugars

In a conical flask, 5 ml each of Fehling's solution A and B were taken. The sugar extract was taken in a beaker and titrated against boiling Fehling's solution by using methylene blue as an indicator. The end point was indicated by the appearance of brick red precipitates (Ranganna, 1995).

$$\text{Reducing sugars (\%)} = \frac{\text{mg of invert sugar X Dilution}}{\text{Titre X wt. of sample (g) X 1000}} \text{ X100}$$

Standard invert sugar solution

Took 9.5 mg sucrose (AR) into a 1.0 L volumetric flask. Added 100 ml of water and 5 ml concentrated HCl in the flask. The content was allowed to stand for 3 days at room temperature for inversion and then made up to mark by adding water. Factor for Fehling's solution was determined by titrating equal amounts of Fehling's A and B with invert sugar by using methylene blue indicator and the end point was indicated by the complete discoloration of the indicator.

$$\text{Factor for Fehling's solution (g of invert sugar)} = \frac{\text{Titre X 2.5}}{1000}$$

mg of invert sugar = g of invert sugar X 1000

2.3.2 Total Sugars

A measured amount (50 ml) of the extract was taken in a 100 ml volumetric flask to which 1.0 ml concentrated HCl was added and kept for hydrolyzation over night at room temperature. Next day, the solution was neutralized with saturated NaOH solution followed by a drop of phenolphthalein, finally the volume was made up to the mark with distilled water. This solution was then titrated against Fehling's A and B as was done previously in case of reducing sugars. Titre was used to calculate the per cent total sugar using the formula (Ranganna, 1995).

$$\text{Total sugars (\%)} = \frac{\text{mg of invert sugar X Dilution}}{\text{Titre (after inversion) X Wt. of Sample (g)}} \text{ X100}$$

2.3.3 Non-reducing Sugars (%)

The non- reducing sugars was calculated by subtracting reducing sugars from total sugars and multiplied by 0.95.

Non- reducing sugars = [Total Sugar (%) - Reducing Sugar (%)] X 0.95

2.4 Vitamin C (mg/100ml of juice)

Ascorbic acid content of the juice was calculated by using the detective dye 2,6 dichlorophenol indophenol (DCPIP) through visual titration method (Ranganna, 1994).

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract} \times \text{Weight of sample taken}} \times 100$$

Standardization of Dye

25mg of the standard ascorbic acid was dissolved in 0.04% 100 ml oxalic acid. This was titrated with the 0.04% DCPIP dye solution to the pink colour, which persisted for 15 seconds. Dye factor is determined by the formula:

$$\text{Dye factor} = \frac{\text{Concentration of ascorbic acid per ml/ Volume of dye used}}{\text{Volume of dye used}}$$

To 10 ml of each sample, 90ml of the acid was added. Out of this prepared sample, 10ml was taken and titrated against the 2, 6-dichlorophenol dye solution till the pink end point was obtained which persisted for at least 15 seconds. The percentage ascorbic acid amount was then estimated.

3.5 Statistical analysis

The data were analyzed according to the procedure for analysis of completely randomized design (C.R.D.) as given by Snedecor and Cochran (1987). The overall significance of differences among the treatments was tested, using critical difference (C.D.) at 5% level of significance. The data were presented by way of tables and graphs.

Chapter IV

RESULTS AND DISCUSSION

The present investigation entitled, "Effect of different packaging film on shelf life and quality of Kinnow" was conducted in the Postgraduate Horticulture laboratory, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2014-15. The results observed from the laboratory studies are presented and discussed in the light of available literature in this chapter.

3.1 Fruit Firmness

The data on the effect of different packaging films on fruit firmness (g compression force) of Kinnow fruits stored at 21-22^{o} C and 45-48 % RH are presented in the Table 4.1 and Figure 4.1. It can be seen from the recorded data that there was a regular decline in fruit firmness with advancement of storage period. The maximum average fruit firmness (1,586.02g compression force) was found in T_1 (shrink 125 micron film) followed by T_2 [shrink 25 micron film (1524.46g compression force)], T_4 [cellophane (1311.64g compression force)], T_3 [cling film (1270.62g compression force)] and T_5 [LDPE film (1230.75g compression force)]. However, minimum average fruit firmness (999.33g compression force) was reported with T_6 (control). During different storage periods from five days to twenty five days, T_1 (shrink 125 micron film) packaging showed minimum loss in firmness (1742.58-1300.92g compression force) while it was maximum in T_6 (control) (1,131.04-587.767g compression force). The interaction between treatment and storage was found to be significant. At zero day, all the treatments are statistically at par with each other, but at five day interval of storage all the treatments are significantly different over control. The highest firmness on fifth day was recorded in T_1 [shrink film 125 micron (1742.58g compression force)] and lowest firmness was recorded in T_6 [control (1131.04g compression force)]. At ten day interval, all the treatments were found to be significantly different over control. The highest firmness was observed in T_1 [shrink film 125 micron (1698.93g compression force)] and lowest firmness was found in T_6 [control (1015.92g compression force)]. At fifteen, twenty and twenty five days of storage all the treatments were found to be significant over T6 (control).

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Table 4.1. Effect of different packaging films on fruit firmness (g compression force) under ambient conditions.

Treatments	Days of storage					
	0	5	10	15	20	25	Mean
T_1 (Shrink film 125 micron)	1821.8[a]	1,742.58[f]	1,698.93[f]	1,524.67[f]	1,427.26[f]	1,300.92[f]	1586.02
T_2 (Shrink film 25 micron)	1821.8[a]	1,686.10[e]	1,572.85[e]	1,427.40[e]	1,364.99[e]	1,273.65[e]	1524.46
T_3 (Cling film)	1821.8[a]	1,591.23[c]	1,252.23[c]	1,188.19[c]	958.33[c]	811.94[c]	1270.62
T_4 (Cellophane)	1821.8[a]	1,650.95[d]	1,361.12[d]	1,223.94[d]	981.55[d]	830.52[d]	1311.64
T_5 (LDPE)	1821.8[a]	1,538.19[b]	1,212.86[b]	1,122.59[b]	901.46[b]	787.59[b]	1230.75
T_6 (Control)	1821.8[a]	1,131.04[a]	1,015.92[a]	815.48[a]	623.98[a]	587.76[a]	999.33
Mean	1821.8	1,556.68	1,352.32	1,217.05	1,042.93	932.07	
SE	0.00	48.79	55.26	55.12	67.00	63.93	
SD	0.00	207.04	234.45	233.86	284.25	271.23	

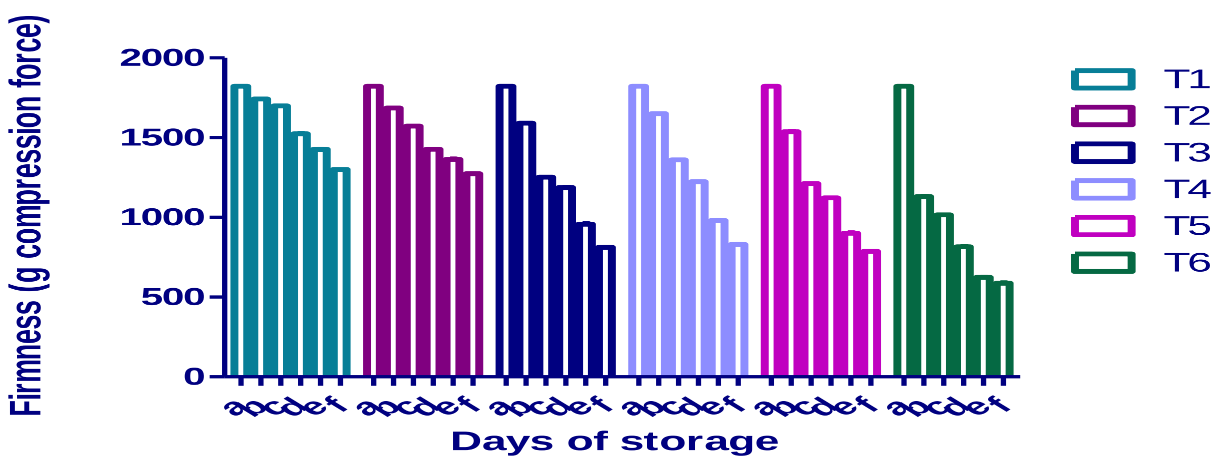

Figure 4.1. Effect of days of storage on fruit firmness (g compression force) under ambient conditions.

[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f= Twenty five day]

The highest firmness was recorded in T_1 [shrink film 125 micron (1300.92g compression force) as compare to T_6 [control (587.76g compression force)] at the end of 25 days. Kinnow fruits maintain desirable firmness at 1000-1100g compression force. Whereas, below this level the fruits become soft, shrivelled and cannot be acceptable for consumption (Lachapella *et. al.,* 2013). The present study proved that shrink film packed fruits maintained acceptable firmness up to twenty five days of storage whereas, cling film, cellophane and LDPE film packed Kinnow fruits possessed acceptable quality till fifteen days under ambient conditions whereas, the unpacked fruits retained desirable firmness up to ten days only. Thereafter, they became unfit for consumption and marketing due to softening and shrivelling.

The loss in firmness of fruits may be because of breakdown of insoluble protopectin into soluble pectin or hydrolysis of starch as confirmed by Mattoo, *et. al*., (1975). The degradation of pectic substances in the middle lamella of the cell wall is the key steps in the ripening process that leads to the loss of cell wall integrity thus cause loss of firmness and induce softening (Solomos and Laties, 1973). Similarly, Ladaniya *et. al.,* (2005), Pongener (2009) and Sharma *et. al.,* (2010) observed that shrink packaging maintained higher firmness in citrus, peach and apple fruits over the unpacked fruits.

3.2 Spoilage

The data on spoilage percentage of Kinnow fruits as affected by different packaging films during storage at 21-22^{o} C and 45-48 % RH are presented in the Table 4.2 and Figure 4.2. Kinnow fruits tray packed in different packaging films showed significantly less spoilage as compared to those in control. There was no spoilage of fruits wrapped with shrink films (shrink 125 micron, 25 micron) up to ten days of storage. The lowest mean spoilage (1.09%) was found in T_1, followed by T_2 (1.59%)]. Kinnow fruits packed in T3, T_4 and T_5 film recorded average spoilage of 3.50%, 3.19% and 4.41%, respectively. In T_6, there was no spoilage for first five days but thereafter 3.81% spoilage was recorded at the end of ten days of storage which immediately rised to 10.63% at the end of fifteen days of storage, averaging 4.69% spoilage at the end of storage. The interaction between treatments and storage intervals was reported significant. At zero day and five days interval, all the treatments are statistically at par with each other. There was no spoilage at the end of zero an five days of storage. After ten days, T_1 and T_2 were statistically at par whereas, other

Table 4.2. Effect of different packaging films on spoilage under ambient conditions.

Treatments	Days of storage						
	0	5	10	15	20	25	Mean
T_1 (Shrink film 125 micron)	0[a]	0[a]	0[a]	0[a]	2.92[a]	3.66[a]	1.09
T_2 (Shrink film 25 micron)	0[a]	0[a]	0[a]	2.13[b]	3.17[b]	4.26[b]	1.59
T_3 (Cling film)	0[a]	0[a]	2.8[c]	4.27[d]	6.67[d]	7.27[d]	3.5
T_4 (Cellophane)	0[a]	0[a]	2.41[b]	3.9[c]	5.95[c]	6.92[c]	3.19
T_5 (LDPE)	0[a]	0[a]	3.54[d]	5.62[e]	7.42[e]	9.9[e]	4.41
T_6 (Control)	0[a]	0[a]	3.81[e]	5.77[f]	7.92[f]	10.63[f]	4.69
Mean	0	0	2.09	3.61	5.68	7.1	
SE	0.00	0.00	0.37	0.49	0.47	0.62	
SD	0.00	0.00	1.59	2.07	2.01	2.66	

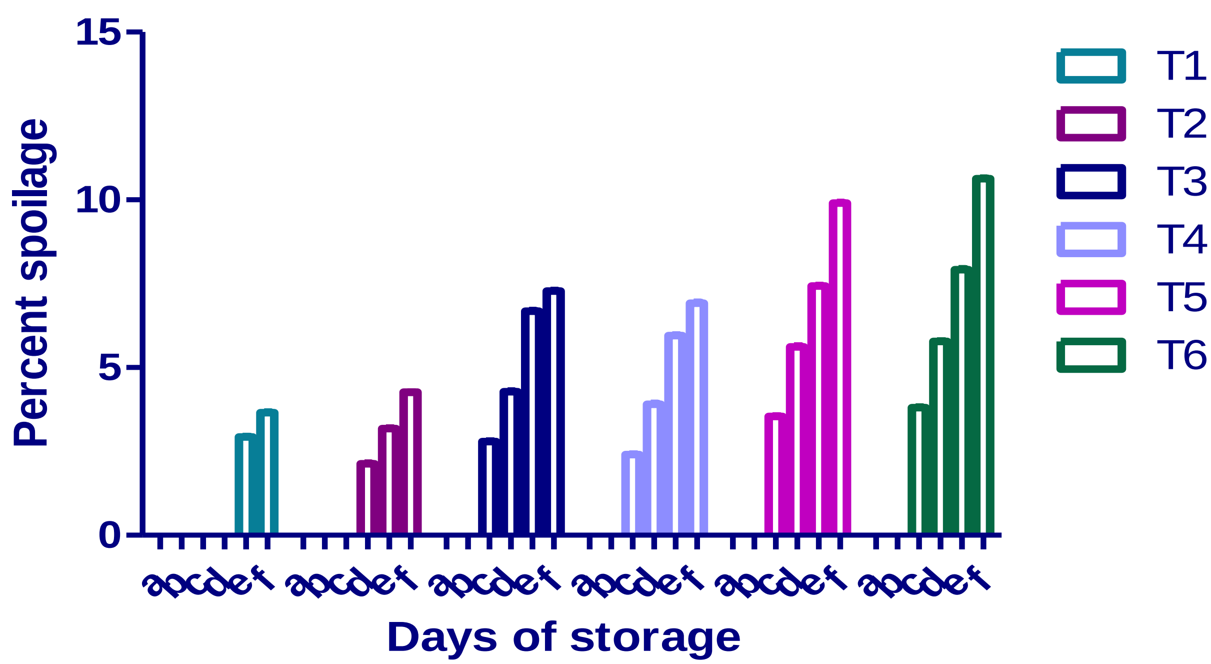

Figure 4.2. Effect of days of storage on spoilage in Kinnow fruits under ambient conditions.
[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f= Twenty five day]

treatments were significant over T_6. At fifteen, twenty and twenty five day interval, all the treatments were found to be significant over control. The lowest spoilage was recorded in T_1 (3.66%) packed fruits while highest spoilage was found in T_6 (10.63%) at the end of 25 day of storage. The positive effect of film packaging and coatings is the maintenance of high relative humidity and reduction of water loss of produce at optimum temperature which are responsible for lowering the spoilage of fruits. This is in conformity with the report of Bishnoi *et. al.,* (2008 and 2009). Yuen *et. al.,* (1993) and McCollum *et. al.,* (1992) also reported least rotting and best appearance of mango fruits in shrink wraps followed by storage at optimum temperature. The reduction in decay of fruits in heat shrinkable films may be due to reduction in vapour condensation in the packs (Ben-Yehoshua *et. al.,*1998).

3.3 Total Soluble Solids

The data on the effect of different packaging films on the TSS content of Kinnow fruits stored at 21-22^o C and 45-48 % RH are presented in the Table 4.3 and Figure 4.3. The perusal of data showed that the TSS content in Kinnow fruits increased slowly and steadily up to twenty days in all treatments after which a decrease in TSS was recorded by the end of twenty five days of storage. The highest mean TSS (10.98%) was observed in Kinnow fruits packed in T1 followed by T2 (10.55%). The treatments T3, T4 and T5 recorded a mean TSS content of 10.38%, 10.49% and 10.25% respectively. On the other hand, T_6 fruits recorded increase in TSS up to fifteen days and then sharp decline afterwards. In T_1, the Kinnow fruits maintained 10.07% of TSS after five days of storage which reached to peak value of 12.61% after twenty days of storage. Whereas, in T_6 the fruits registered 9.32% of TSS after five days of storage which reached to peak value of 10.81% after fifteen days and then declined afterwards. The interaction between treatments and storage intervals was found to be non-significant. At zero day, all the treatments are statistically at par with each other, but at five days interval all the treatments were found to be significant over T_1 but treatments like T_3 (9.20%) and T_5 (9.25%) were statistically at par with each other. T_4, T_5, T_6 and T_2 as well as T_4 and T_6 were statistically at par with each other. After ten days, all the treatments was found to be significant over T_6 but T_3 (10.29%) and T_4 (10.37%) as well as T_4 (10.37%) and T_2 (10.44%) were found statistically at par with each other. On other hand all treatments were significant after fifteen days of storage, however, T_2 (12.12%) and T_4 (12.11%) were found statistically at par with each other after twenty days of storage.

Table 4.3. Effect of different packaging films on total soluble solids (%) in Kinnow under

ambient conditions.

Treatments	**Days of storage**						
	0	**5**	**10**	**15**	**20**	**25**	**Mean**
T_1 (Shrink film 125 micron)	9.2[a]	10.08[e]	11.18[e]	11.02[e]	12.61[e]	11.81[f]	10.98
T_2 (Shrink film 25 micron)	9.2[a]	9.36[d]	10.44[d]	10.81[d]	12.12[d]	11.38[e]	10.55
T_3 (Cling film)	9.2[a]	9.20[a]	10.29[c]	10.60[b]	11.84[c]	11.19[c]	10.38
T_4 (Cellophane)	9.2[a]	9.29[bc]	10.37[cd]	10.70[c]	12.11[d]	11.27[d]	10.49
T_5 (LDPE)	9.2[a]	9.25[ab]	10.18[b]	10.54[a]	11.26[b]	11.06[b]	10.25
T_6 (Control)	9.2[a]	9.32[cd]	9.36[a]	10.82[d]	10.81[a]	9.56[a]	9.84
Mean	9.2	9.42	10.30	10.74	11.79	11.04	
SE	0.00	0.07	0.01	0.037	0.14	0.17	
SD	0.00	0.30	1.59	2.07	0.61	0.72	

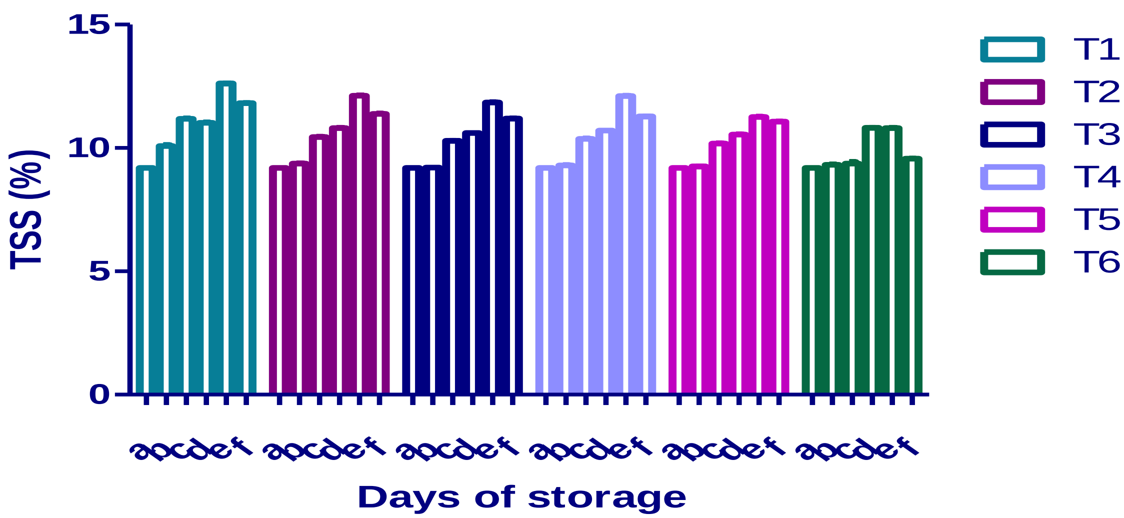

Figure 4.3. Effect of days of storage on total soluble solids (%) in Kinnow fruit under ambient conditions.

[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f= Twenty five day]

All the treatments were significant over T_6 (control) after twenty five days of storage.

The increase in TSS during storage may possibly be due to breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch or pectin into sugars and is in agreement with Wills *et. al.,* (1980) and Wani (1997). The increase in TSS in film wrapped Kinnow fruits might be attributed to delay in ripening and senescence processes which simultaneously delayed the conversion of starch into sugars. Ben-Yehoshua *et. al.,* (1998) also found that positive influence of heat shrinkable films on TSS in citrus fruits.

3.4 Acidity

The perusal of data on the acidity of Kinnow fruits stored at 21-22^{o} C and 45-48 % RH are presented in the Table 4.4 and Figure 4.4. The acidity of kinnow fruit under polyethylene films showed a linear declining trend with advancement of storage period. The packaging films helped in better retention of acidity as compared to control. At the end of storage period, the highest mean acidity (0.55%) was found in the fruits wrapped in T_1, followed by T_2 (0.53%), T_3 (0.53%), T_4 (0.53%) and T_5 (0.52%) while the lowest mean acidity (0.48%) was recorded in T_6 (control). During the storage interval between five to twenty five days, the highest acidity was observed in the T_1 fruits, which ranged between 0.58%-0.49%, followed by T_3 (0.58-0.46%), T_4 (0.57-0.43%) and T_5 (0.55-0.45%). The lowest acidity was recorded in T_6 (control) ranging from 0.52%-0.35%. The interaction between treatments and storage intervals was found to be significant. At zero day, all the treatments were statistically at par with each other, but at five days interval all the treatments were found to be significant over T_6 (control) while T_2 (0.58%), T_3 (0.58%) and T_4 (0.57%) were statistically at par with each other. On other hand, T_4 (0.53%) and T_6 (0.51%) were statistically at par with each other. The treatments like T_2 (0.54%), T_3 (0.54%), T_4 (0.53%) and T_5 (0.54%) were found to be statistically at par with each other. After fifteen days, all the treatments were found to be significant over T_6 (control) but T_2 [shrink film (25 micron)], T_3 (cling film), T_4 (cellophane) and T_5 (LDPE) were found to be statistically at par with each other. The treatments like T_1 (0.54%), T_2 (0.53%) and T_4 (0.52%) were found to be statistically at par with each other as T_6 (control). After twenty days, all the treatments were found to be significant over T_6 (control) but T_2 (0.47%), T_4 (0.51%) and T_5 (0.48%) as well as T_1 (0.51%), T_3 (0.49%) and T_4 (0.51%) were statistically at par with each other.

Table 4.4. Effect of different packaging films on acidity (%) in Kinnow under ambient

conditions.

Treatments	**Days of storage**						
	0	**5**	**10**	**15**	**20**	**25**	**Mean**
T_1 (Shrink film 125 micron)	0.62[a]	0.60[d]	0.56[c]	0.54[c]	0.51[d]	0.49[d]	0.55
T_2 (Shrink film 25 micron)	0.62[a]	0.58[c]	0.54[b]	0.53[bc]	0.47[b]	0.45[c]	0.53
T_3 (Cling film)	0.62[a]	0.58[c]	0.54[b]	0.52[b]	0.49[bc]	0.46[c]	0.53
T_4 (Cellophane)	0.62[a]	0.57[c]	0.53[ab]	0.52[bc]	0.51[d]	0.43[b]	0.53
T_5 (LDPE)	0.62[a]	0.55[b]	0.54[b]	0.52[b]	0.48[b]	0.45[c]	0.52
T_6 (Control)	0.62[a]	0.52[a]	0.51[a]	0.49[a]	0.39[a]	0.35[a]	0.48
Mean	0.62	0.57	0.54	0.52	0.47	0.43	
SE	0.00	0 .006	0.004	0.004	0.010	0.010	
SD	0.00	0.02	0.01	0.02	0.04	0.04	

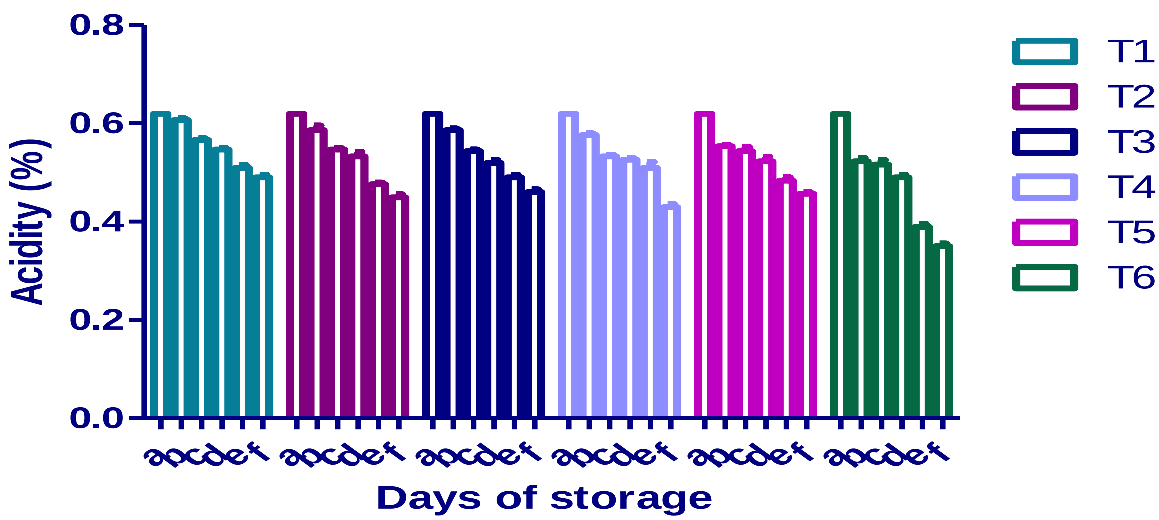

Figure 4.4. Effect of days of storage on acidity (%) in Kinnow fruit under ambient conditions.
[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f= Twenty five day]

At the end of twenty five days of storage all the treatments were found to be significant over T_6

(control) but T_2 (0.45%), T_3 (0.46%) and T_5 (0.45%) were statistically at par with each other.

The decrease in titrable acids during storage may be attributed to utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits and is in conformity with Rhodes *et. al.*, (1968) and Pool *et. al.*, (1972). When the fruits were wrapped in films and coated, the lowering of acidity was delayed, which might be due to the effect of packaging films and coatings in delaying the respiratory and ripening process. However, McCollum *et. al.*, (1992) reported higher acidity content in individual shrink wrapped mangoes. The reduction in the titrable acidity during storage has been also noticed by Kaushal and Thakur (1996).

3.5 Sugars

3.5.1 Reducing Sugars

The data on the effect of different packaging films on the reducing sugars of Kinnow fruits stored at ambient conditions are presented in the Table 4.5 and Figure 4.5. A perusal of the data indicates an increase in the reducing sugars content of Kinnow fruit with advancement of storage period. The highest mean reducing sugars was recorded in T_1 (shrink film 125 micron) packed fruits (3.43%), followed by fruits packed in T_2 [shrink film 25 micron (3.29%)], T_4 [cellophane (3.27%)], T_3 [cling film (3.32%)] and T_5 [LDPE (3.19%)]. From the starting value of 2.9% at harvest, the reducing sugars increased with time and reached a peak value of 3.88% after twenty days in T_1 film wrapped fruits. The T_6 (control) fruits also showed increasing trend of reducing sugars content but attained maximum value 3.48% after ten days. In both, the film packed fruits as well as in unpacked fruits (control), there was a sharp decline in reducing sugars, after a certain maxima. The interaction between treatment and storage was found to be significant. At zero and five day, all the treatments were statistically at par with each other. After ten days, all the treatments was found to be significant over control, but T_3 (3.15%) and T_5 (3.12%) as well as T_2 (3.25%) and T_4 (3.23%) were statistically at par with each other. The treatments like T_1 (3.42%) and T_6 (3.48%) were significant to other treatments at storage. The treatments like T_1 (3.60%) and T_6 (3.35%) found to be significant but other treatments like T_3 (3.31%) and T_5 (3.28%) was recorded statistically at par with each other as well as T_2 (3.43%) and T_4 (3.42%) also found statistically at par with each other.

Table 4.5. Effect of different packaging films on reducing sugars (%) in Kinnow under

ambient conditions.

Treatments	Days of storage					
	0	**5**	**10**	**15**	**20**	**25**	**Mean**
T_1 (Shrink film 125 micron)	2.9^a	3.16^a	3.42^c	3.60^d	3.88^d	3.62^f	3.43
T_2 (Shrink film 25 micron)	2.9^a	3.02^a	3.25^b	3.43^c	3.7^c	3.48^e	3.29
T_3 (Cling film)	2.9^a	2.96^a	3.15^a	3.31^a	3.63^b	3.35^c	3.21
T_4 (Cellophane)	2.9^a	3.02^a	3.23^b	3.42^c	3.67^c	3.41^d	3.27
T_5 (LDPE)	2.9^a	2.95^a	3.12^a	3.28^a	3.61^b	3.30^b	3.19
T_6 (Control)	2.9^a	3.04^a	3.48^d	3.35^b	3.27^a	3.12^a	3.19
Mean	2.9	3.02	3.27	3.40	3.62	3.38	
SE	0.00	0.38	0.032	0.025	0.043	0.037	
SD	0.00	1.6	0.13	0.10	0.18	0.15	

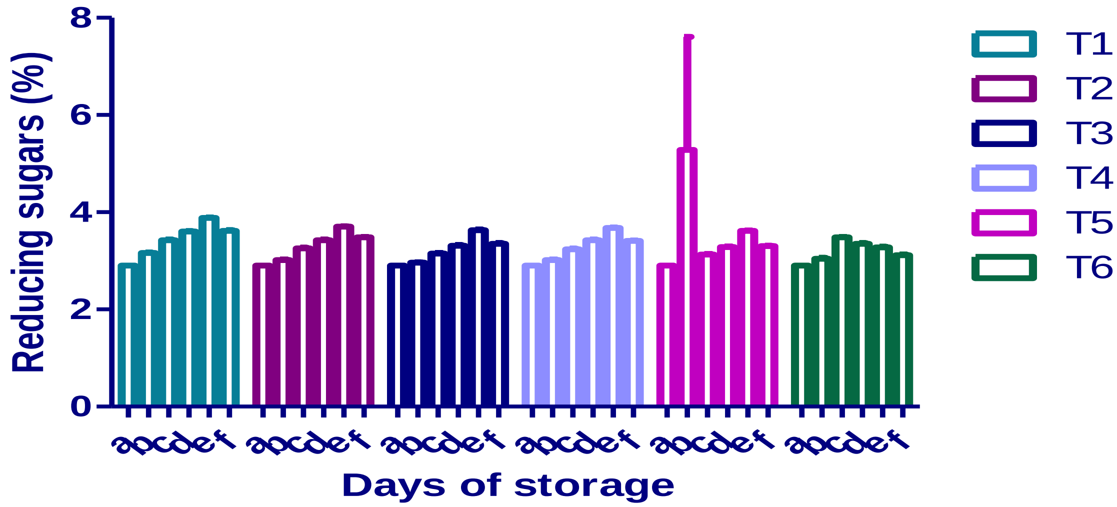

Figure 4.5. Effect of days of storage on reducing sugars (%) in Kinnow fruit under ambient conditions.

[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f=Twenty five day]

After twenty days, all the treatments were found to be significant over T_6 (control) but T_3 (3.63%)

and T_5 (3.61%) as well as T_2 (3.7%) and T_4 (3.67%) were statistically at par with each other. On other hand, T_1 (3.88%) was found significant over all the treatments. At the end of twenty five days of storage all the treatments were found to be significant over T_6 (control).

3.5.2 Non- reducing Sugars

The data on the effect of different packaging films on the non-reducing sugars of Kinnow fruits stored at 21-22^o C and 45-48 % RH are presented in the Table 4.6 and Figure 4.6. An examination of the data revealed an increasing trend in the content of non- reducing sugars with the advancement of storage interval. The highest mean non- reducing was recorded in fruits packed in T_1 [shrink 125 micron film (2.96%)], followed by T_2 [shrink 25 micron film (2.84%)], T_3 [cling film (2.83%)], T_4 [cellophane (2.83%)] and T_5 [LDPE (2.82%)], whereas, the lowest mean value was recorded in T_6 [control (2.73%)]. In T_1 wrapped fruits the non-reducing sugars gradually increased from an initial value of 2.28% to 3.49% up to 20 days and thereafter, declined to 3.2% at the end of twenty five days. The remaining films also showed a similar trend but with lower non-reducing sugars at each storage interval. The fruits kept in T_6 (control), on other hand, showed increase in non-reducing sugars up to ten days, attaining a maximum of 3.10%, after which a decreasing trend was recorded until the end of storage period. The interaction between storage and treatment was found to be significant. At zero day, all the treatments were statistically at par with each other, but at five days interval all the treatments were found to be significant over T_6 (control) while T_1 (2.56%) and T_2 (2.55%) found to be statistically at par with each other. After ten days, all the treatments were found to be statistically at par except T_1 and T_6. After fifteen days, all the treatments were found to be significant over T_1 (3.21%), but T_2 (3.02%), T_3 (3.04%), T_4 (3.02%), T_5 (3.03%) and T_6 (2.97%) were statistically at par with each other. After twenty days, all the treatments were found to be significant over T_6 (2.72%) and T1 (3.49%) but other treatments like T_2 (3.34%), T_3 (3.32%), T_4 (3.35%) and T_5 (3.3%) were statistically at par with each other. On the other hand, all the treatments were found to be significant over T_6 [control (2.62%)] and T_1 [shrink film 125 micron (3.2%)] but treatments like T_2 [shrink film 25 micron (3.05%)] and T_4 [cellophane (3.07%)] as well as T_3 [cling film (3.12%)] and T_5 [LDPE (3.11%)] were statistically at par with each other at the end of twenty five days of storage.

Table 4.6. Effect of different packaging films on non-reducing sugars (%) in Kinnow under

ambient conditions.

Treatments	Days of storage						
	0	5	10	15	20	25	Mean
T_1 (Shrink film 125 micron)	2.28[a]	2.56[c]	3.04[b]	3.21[c]	3.49[c]	3.2[d]	2.96
T_2 (Shrink film 25 micron)	2.28[a]	2.55[c]	2.84[a]	3.02[ab]	3.34[b]	3.05[b]	2.84
T_3 (Cling film)	2.28[a]	2.41[e]	2.84[a]	3.04[b]	3.32[b]	3.12[c]	2.83
T_4 (Cellophane)	2.28[a]	2.42[b]	2.82[a]	3.02[ab]	3.35[b]	3.07[b]	2.83
T_5 (LDPE)	2.28[a]	2.37[a]	2.83[a]	3.03[b]	3.3[b]	3.11[c]	2.82
T_6 (Control)	2.28[a]	2.67[d]	3.10[c]	2.97[a]	2.72[a]	2.62[a]	2.73
Mean	2.28	2.50	2.91	3.05	3.25	3.03	
SE	0.00	0.052	0.028	0.018	0.06	.046	
SD	0.00	0.22	0.11	0.07	0.25	0.19	

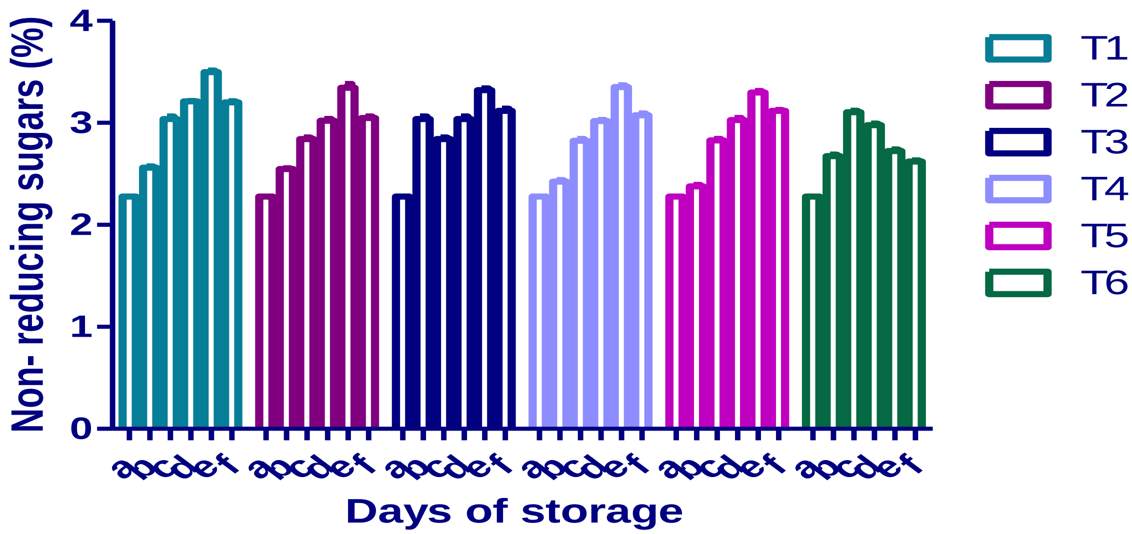

Figure 4.6. Effect of days of storage on non-reducing sugars (%) in Kinnow fruit under ambient conditions.

[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f=Twenty five day]

3.5.3 Total Sugars

The data on the effect of different packaging films on the total sugars of Kinnow fruits stored at 21-22^{o} C and 45-48 % RH are presented in the Table 4.7 and Figure 4.7. The total sugars showed a progressive trend up to twenty days in storage in the fruits packed in different packaging films and up to ten days in control fruits. Thereafter, a decline in total sugars was recorded. In the first ten days of storage, the total sugars content was low in the film wrapped fruits as compared to fruits in control, but afterwards, the sugar content increase steadily up to twenty days in film wrapped fruits and recorded the highest values compared to T_6 (control), and thereafter, declined gradually. The highest mean total sugar was recorded in the fruits packed in T_1 (6.39%), followed by T_2 (6.14%), T_4 (6.10%), T_3 (6.05%) and T_5 (6.01%). Whereas, the lowest mean total sugars (5.92%) was recorded in T_6 (control) fruits. The interaction between treatment and storage was found to be significant. At zero day, all the treatments were statistically at par with each other, but at five days interval T_2 (5.72%) and T_6 (5.72%) were statistically at par with each other but other whereas, all treatments like T_2 (5.57%), T_3 (5.37%), T_4 (5.44%) and T_5 (5.32%) were found to be significant. At ten days interval all the treatments were found to be significant over T_6 (6.58%) and T_2 (6.46%) but T_3 (5.99%) and T_5 (5.95%) as T_3 (5.99%) and T_4 (6.06%) and T_4 (6.06%) and T_2 (6.1%) were statistically at par with each other. After fifteen days, all the treatments were found to be significant over T_1 (6.81%), but other treatments like T_3 (6.35%), T_5 (6.31%) and T_6 (6.33%) as well as T_2 (6.44%) and T_4 (6.44%) were found statistically at par with each other. At twenty days interval all the treatments were found to be significant over T_6 (6%) and T_1 (7.37%) but the treatments like T_3 (6.95%) and T_5 (6.91%) as well as T_2 (7.04%) and T_4 (7.03%) were found statistically at par with each other. On other hand all the treatments were found to be significant overT_6 (5.74%) and T_1 (6.82%) however T_3 (6.47%) and T_5 (6.42%) as well as T_3 (6.47%) and T_4 (6.48%) were found statistically at par with each other. On the other hand, T_4 (6.48%) and T_2 (6.53%) were found statistically at par with each other. The increase in sugar content of fruit is associated with the hydrolysis of non-sugar carbohydrates like starch, cellulose and hemicelluloses present in cell wall and in tissues in presence of enzymes pectinase, cellulose or hemicelluloses. This is being confirmed with work of Scheverria *et. al.*, (1989) who had reported increase in sugars in the juice during post harvest storage.

Table 4.7. Effect of different packaging films on total sugars (%) in Kinnow under ambient

conditions.

Treatments	**Days of storage**						
	0	**5**	**10**	**15**	**20**	**25**	**Mean**
T_1 (Shrink film 125 micron)	5.18^{a}	5.72^{e}	6.46^{d}	6.81^{c}	7.37^{d}	6.82^{e}	6.39
T_2 (Shrink film 25 micron)	5.18^{a}	5.57^{d}	6.1^{c}	6.44^{b}	7.04^{c}	6.53^{d}	6.14
T_3 (Cling film)	5.18^{a}	5.37^{b}	5.99^{ab}	6.35^{a}	6.95^{b}	6.47^{bc}	6.05
T_4 (Cellophane)	5.18^{a}	5.44^{c}	6.06^{bc}	6.44^{b}	7.03^{c}	6.48^{cd}	6.10
T_5 (LDPE)	5.18^{a}	5.32^{a}	5.95^{a}	6.31^{a}	6.91^{b}	6.42^{b}	6.01
T_6 (Control)	5.18^{a}	5.72^{e}	6.58^{e}	6.33^{a}	6^{a}	5.74^{a}	5.92
Mean	5.18	5.52	6.19	6.45	6.88	6.41	
SE	0.00	.038	.061	.041	0.10	.079	
SD	0.00	0.16	0.26	0.17	0.17	0.33	

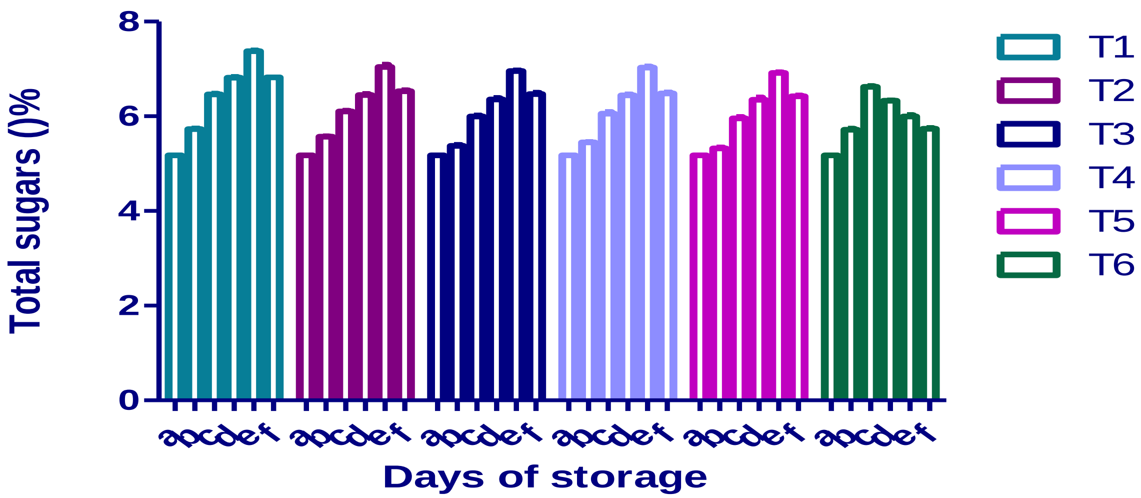

Figure 4.7. Effect of days of storage on total sugars (%) in Kinnow fruit under ambient conditions.

[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f= Twenty five day]

Sidhu *et. al.*, (2009) and Singh (2010) observed an increase in total, reducing, non-reducing sugars content with prolongation of storage period in fruits, wrapped with shrink film. Dhillon *et. al.*, (1977) found that mango and peach fruits wrapped in shrink or cling film registered higher sugars.

3.6 Vitamin C

The data on the effect of different packaging films on the vitamin C of Kinnow fruits stored at ambient conditions are presented in the Table 4.8 and Figure 4.8. It can be seen from the data that there was a continuous decline in vitamin C content with advancement of storage period irrespective of different packaging films. The maximum average vitamin C content (13.18 mg/100) was recorded in T_1, followed by T_2 (12.57 mg/100g), T_4 (12.32 mg/100g), T_3 (12.17 mg/100g) and T_5 (12.05 mg/100g) while the minimum average vitamin C content (11.03 mg/100g) was reported in T6 (control). During different storage interval from five days to twenty five days, the T_1 film packed fruits recorded maximum vitamin C content which ranged between 13.18 mg/100g - 23.24 mg/100g ml of juice and minimum vitamin C content in T_6 (control) ranged between 11.03 mg/100g-21.23 mg/100g. The interaction between treatment and storage was found to be significant. At zero day, all the treatments were statistically at par with each other, but at five day interval of storage all the treatments were significantly different from T_6 (control). The highest vitamin C was recorded in T_1 (23.24 mg/100g) and lowest vitamin C was recorded in T_6 [control (21.23 mg/100g)]. At ten day interval, all the treatments were found to be significantly different from control. The highest vitamin C was observed in T_1 [shrink film 125 micron (21.82 mg/100g)] and lowest vitamin C was found in T_6 [control (17.72 mg/100g)]. At fifteen, twenty and twenty five day of storage all the treatments were found to be significant over control. The highest vitamin C was recorded in T_1 [shrink film 125 micron (13.18 mg/100g)] as compare to T_6 [control (11.03 mg/100g)] at the end of 25 days. The decrease in ascorbic acid during storage may be due to the oxidation of L- ascorbic acid into dehydroascorbic acid as reported by Mapson, (1970). The influence of heat shrinkable films on maintaining higher ascorbic acid content in citrus fruits had also been reported by Ladaniya and Singh (2001) and Ladaniya (2003).

Table 4.8. Effect of different packaging films on Vitamin C (mg/100g) in Kinnow fruit under

ambient conditions.

Treatments	Days of storage						
	0	5	10	15	20	25	Mean
T_1 (Shrink film 125 micron)	24.5^a	23.24^f	21.82^f	19.43^f	15.6^f	13.18^f	13.18
T_2 (Shrink film 25 micron)	24.5^a	22.58^e	21.05^e	18.82^e	15.04^e	12.57^e	12.57
T_3 (Cling film)	24.5^a	22.39^c	20.03^c	18.41^c	14.72^c	12.17^c	12.17
T_4 (Cellophane)	24.5^a	22.47^d	20.4^d	18.72^d	14.92^d	12.32^d	12.32
T_5 (LDPE)	24.5^a	22.23^b	19.84^b	17.62^b	14.61^b	12.05^b	12.05
T_6 (Control)	24.5^a	21.23^a	17.72^a	15.83^a	13.25^a	11.03^a	11.03
Mean	24.5	22.36	20.14	18.14	14.69	12.22	
SE	0.00	0.14	.30	0.28	0.17	0.15	
SD	0.00	0.61	1.30	1.19	0.73	0.66	

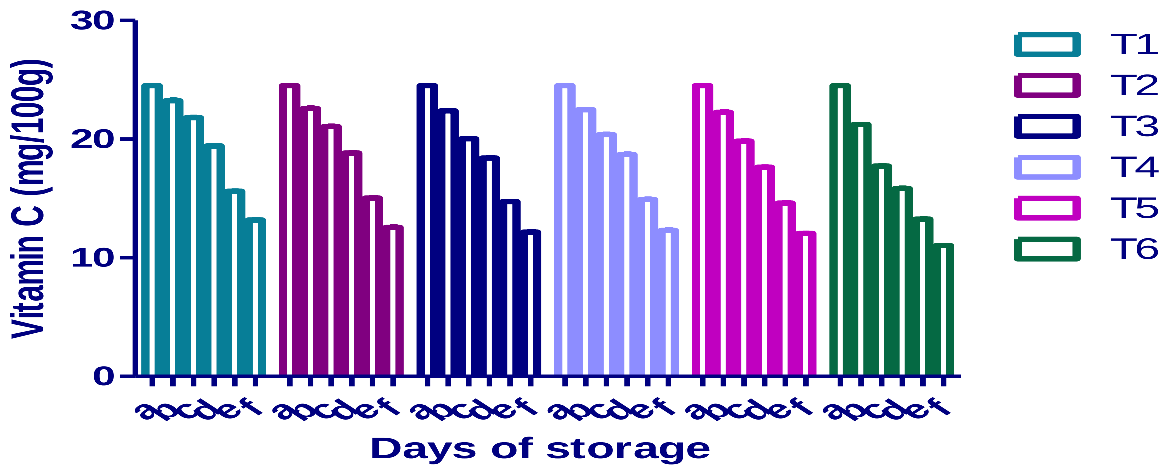

Figure 4.8. Effect of different packaging films on Vitamin C (mg/100g) in Kinnow fruit under ambient conditions.

[a= Zero day, b= Five day, c= Ten day, d= Fifteen day, e= Twenty day, f=Twenty five day]

These results are well supported by the findings of Seung and Kader (2000) who observed that ascorbic acid content in majority of mandarins including Kinnow is sensitive to destruction when subjected thermal shock temperatures, low relative humidity and physical damage to the fruit.

Chapter V

SUMMARY AND CONCLUSION

The present investigation entitled, "Effect of different packaging film on shelf life and quality of Kinnow" was conducted in the Postgraduate Horticulture laboratory, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2014-15. The plants of uniform size and spread were selected in an orchard of progressive farmer at Phuglana, Dist. Hoshiarpur for carrying out this study. Kinnow fruits were harvested in the first week of February 2015, at physiological mature stage. The fruits of uniform size and shape, free from diseases, bruises were sorted, washed and graded. Thereafter, fruits were tray packed with different packaging films i.e. T_1 [shrink film (125 micron)], T_2 [shrink film (25 micron)], T_3 (cling film), T_4 (cellophane) and T_5 (LDPE). The control fruits were kept un-packed. The fruits were stored under ambient conditions (21-22^o C and 45-48 % RH). The fruits were analyzed for various physico-chemical parameters i.e. at zero, five, ten, fifteen, twenty and twenty five days storage.

The result of present study was summarized below:

- Fruit firmness decreased with the prolongation of storage period in all the treatments. However, wrapping of fruits in T_1 [shrink film (125 micron)] and T_2 [shrink film (25 micron)] maintained higher average firmness under ambient conditions (1586.02 and 1524.46g compression force) as compare to T_6 [control (999.33g compression force)].
- Spoilage of fruits increased during storage. The fruits packed with T_1 [shrink film (125 micron)] and T_2 [shrink film (25 micron)] fruits recorded the lower spoilage (1.09 and 1.59 %) as compare to T_6 [control (4.69 %)].
- The TSS increased in T_1 [shrink film (125 micron)] and T_2 [shrink film (25 micron)] packed fruits up to twenty days of storage i.e.12.61 and 12.12%. However, in T_6 (control) TSS increased up to fifteen days (10.82%) only.
- Acidity in fruits decreased with the advancement of storage period. However, none of the packaging films altered the acidity of fruits significantly.

- Reducing sugars, non-reducing sugars and total sugars increased in T_1 [shrink film (125 micron)] and T_2 [shrink film (25 micron)] packed fruits up to twenty days of storage, whereas, only up to ten days in T_6 (control).
- The vitamin C content of the Kinnow fruits showed decreasing trend with the advancement of the storage period. However, packaging films resulted in slower reduction in the vitamin C as compared to control. Under ambient conditions, packaging films, T_1 [shrink film (125 micron)] and T_2 [shrink film (25 micron)] packed fruits showed the highest mean vitamin C content. while the lowest mean vitamin C was recorded in case of control.

From the present studies, it can be concluded that at ambient conditions (21-22^{o} C and 45-48 % RH) the Kinnow fruits tray packed in shrink film (125 micron) and shrink film (25 micron) can be stored for twenty days with minimum spoilage, desirable firmness and acceptable quality.

The application of shrink film (125 micron) and shrink film (25 micron) seems to hold promise in extending the marketability of Kinnow fruits under ambient conditions at 21-22^{o} C. The other films like cling film, cellophane and LDPE also found effective in extending the shelf life and quality of Kinnow fruits.

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Annexure - I

Average monthly meteorological data of year 2014-15

Month	Temperature (^{0}C)		RH (%)
	Maximum	Minimum	
August	34.2	25.1	80
September	34.5	22.2	81.9
October	32.3	15.1	83
November	26.9	10.9	63
December	17.6	6.9	80
January	15.6	6.5	85
February	22.2	10.5	79
March	25.5	13.3	76