

Effect of different packaging films on shelf life and quality of Citrus species (*Citrus Limon*).

THESIS

Submitted to the

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

MASTER OF SCIENCE
IN
(HORTICULTURE)

BY

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Under the supervision of
Dr. MADHU SHARMA



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**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 Citrus species (*Citrus Limon*)**” 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. Gurtej Singh (Registration No. 11310244)** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

(Signature of Supervisor)

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Assistant Professor

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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 Citrus lemon (*Citrus Limon*)**” submitted by **Gurtej 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 Citrus species (*Citrus Limon*)**” 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.

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LIST OF ABBREVIATIONS

/	per
%	Percent
@	At the rate of
μ	Micro
⁰ C	Degree Celsius
⁰ Brix	Degree brix
AR	<i>Analytical Reagent</i>
C ₂ K ₂ O 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 Citrus species (*Citrus Limon*).

ABSTRACT

The present investigation entitled, “Effect of different packaging film on shelf life and quality of Citrus species (*Citrus Limon*)” was conducted in the Postgraduate Horticulture laboratory, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during the year 2014-15. The plants of uniform size and spread were selected from Kot Fatuhi, 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., T1 [control], T2 [LDPE (25micron)], T3 [cellophane (30 micron)], T4 [cling film (10 micron)], T5 [Shrink film (125 micron)], and T6 [shrink film (25 micron)]. After packaging, consumer packs were stored at ambient conditions (21-22° C and 45-48 % RH). The results of experiment revealed that T₃ [cellophane (30 micron)], proved quite effective in reducing spoilage and maintained firmness and other quality attributes like total soluble solids, vitamin C content of the fruit. It was concluded that cellophane film improved the shelf life and maintained the quality of lemon fruits under ambient conditions as compared to unpacked or control fruits.

Key words: Lemon, Shrink film, Cling film, Cellophane, Quality, Moisture content, Firmness, Vitamin C

CHAPTER I

INTRODUCTION

Citrus Limon is a genus belonging to family Rutaceae of flowering plants. Citrus is commonly a good source of vitamin C. Citrus has been cultivated on an ever-widening area since ancient times. The best-known examples of citrus spp. are the oranges, lemons, grapefruit, and limes. India have 1078 thousand hectare area and 11147 thousand million tones production of citrus (Anonymous, 2014) in Punjab, citrus occupy 50.4 thousand hectare area with 1044.2 thousand tones production (Anonymous, 2013-14).

Citrus medica, pommelo, mandarine and papeda are four real species of citrus. Other known species have formed through artificial or natural hybridization. A study of the genetic origin of the lemon reported it to be hybrid between bitter orange (Bitter orange is hybrid between pommelo and mandarine) and citron (*Citrus medica*). Lemon is thought to originate in Asia (Anonymous, 2013). The tree has yellow color fruit. The juice of the lemon contains about 5% to 6% citric acid (USDA, 2013), which gives lemons a sour taste. Fat and cholesterol are not present in lemon. Lemon contain 53mg/100g vitamin C (USDA 2012-13). Lemons have copper, phosphorous, niacin, calcium, thiamin, and magnesium in significant amount. Healing of sore throat can also be done by lemon. Cancer, heart disease, kidney stone formation and scurvy can be prevented with lemon.

In India, area under lime and lemon is 286.4 thousand hectare with 2835.0 thousand million tonnes production (Anonymous 2014). Assam, Arunachal Pradesh, Bihar, Chhattishgarh, Delhi and Gujarat are major lemon producing states in India (Anonymous, 2014a). Punjab with other northern states have 65.9 thousand hectare area and 260.7 thousand million tonnes production of lime/lemon (Anonymous, 2014b). However, Ferozpur, Sri Mukatsar Sahib, Bathinda and Hoshiarpur are leading districts of lemon production and area in Punjab (Anonymous, 2014c).

In India, storage of lemon is carried out at 9°C to 10°C temperature and -3°C to -1°C freezing point for 6-8 weeks storage at 85-90% relative humidity (NHB 2014). The post harvest losses are more than 40% in India. Harvest fruits of lemon contain 65-95% water. But with time, because of respiration and transpiration, there is a loss up to 5-10 percent in fresh weight.

Postharvest losses start from farm and goes up to market. Lack of post harvest facilities affect shelf life and quality of lemon. There by, it is essential to reduce these losses by modern techniques of packing.

Modified atmosphere is the practice of modifying the composition of the internal atmosphere of a package in order to improve the shelf life . The modification process often tries to lower the amount of oxygen (O₂), moving it from 20.9% to 0%, in order to slow down the growth of aerobic organisms and the speed of oxidation reactions. As fruits are respiring products, there is a need to transmit gases through the film. Films designed with these properties are called permeable films. While selecting packaging films for fruits , the main characteristics to considered are gas permeability, water vapour transmission rate, mechanical properties, transparency, type of package and sealing reliability. Normally we use packaging films like LDPE (low density polyethylene), PVC (polyvinyl chloride), EVA (ethylene-vinyl acetate) etc.

At present there is need to develop cost effective method for enhancing shelf life and quality. In India cellophane, shrink, cling, LDPE etc. packaging films are available. These are helpful to act as cost effective method for enhancing shelf life and quality. Thereby present investigation, "The effect of different packaging films on shelf life and quality on *Citrus limon*" was carried out with the following objectives:-

1. To study the effect of different packaging films on shelf life and quality of lemon .
2. To identify the best packaging strategy.

REVIEW OF LITERATURE

The present investigation entitled, "Effect of different packaging films on shelf life and quality of Citrus species (*Citrus Limon*)" was conducted in the Department of horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2014-15. The lemon fruits of uniform size were collected from Kot Fatuhi, Dist. Hoshiarpur. The literature involves with following headings:

2.1 Packaging films

2.1.1 Shrink film (125 micron)

2.1.2 Shrink film (25 micron)

2.1.3 Polyethylene film or LDPE (Low density polyethylene (25 micron))

2.1.4 Cling film (10 micron)

2.1.5 Cellophane film (30 micron)

2.2 Physical parameters

2.2.1 Moisture content

2.2.2 Spoilage percentage

2.2.3 Fruit firmness

2.2.4 Fruit weight loss

2.3 Chemical parameters

2.3.1 Vitamin C

2.3.2 Sugar

2.3.3 Total soluble solids

2.1.1 Shrink film

Raghav and Gupta (2000) found that shrink-wrapped fruits were better than the unwrapped fruits in firmness, appearance, flavor and quality. Under ambient conditions, the shelf life of wrapped fruit increased from 2 to 8 weeks.

Sudhakar Rao *et. al.*, (2000) conducted experiment on cucumber using shrink wrap with polyethylene (PE) and reported that fruit firmness and freshness were good at ambient

temperature. While at 10 °C, shelf life was extended up to 24 days than normal life span as well as reduction in weight loss and respiration rate was also noticed. Singh and Sudhakar Rao (2005), Sonkar and Ladaniya (1999) and Risse *et. al.*, (1985) found similar results in papaya, mandarin & vegetables, 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 a 8°C, 15°C and 25°C. They observed that peel thickness, freshness and firmness of the fruit were retained whereas, weight loss was greatly reduced by shrink wrapping. They also reported that at 8°C for 12 weeks shrink wrapped 'Ganesh' pomegranates had weight loss of 1.2–1.3%, whereas at 15°C for 10 weeks they reported that weight loss of 2.2–3.7% by comparing with non-wrapped fruits that had weight loss of 20.4% and 30.7% at 8°C and 15 °C, respectively. Ladaniya *et. al.*, (2001) used heat-shrinkable films on 'Mosambi' (*Citrus sinensis*) fruits and found that slight decrease in fruit firmness in all most all the treatments after 20 and 40 days. D'Aquino *et. al.*, (2010), observed that after 6 weeks of storage at 8°C unwrapped and untreated control 'Primosole' pomegranate had a weight loss of 5.1%, while shrink or polyolephinic film-wrapped fruits lost only 0.6%, and weight loss increased up to 12.7% in control as against 3.1% for wrapped fruits after 12 weeks of cold storage.

Sharma *et. al.*,(2010) studied the effect of shrink film cryovac (9 micron), polyolefin (13 micron), and LDPE (25 micron) films on apple "Royal delicious". and revealed that cryovac (9 micron) as best film because it showed less physiological loss and good maintenance of total soluble solids.

2.1.3 Polyethylene film or LDPE (Low density polyethylene)

Phan *et. al.*,(1975); Robinon *et. al.*,(1975); and Wills *et. al.*,(1981) found low respiration rate with use of LDPE film than polypropylene (pp) material on carrot. Talhouk *et. al.*, (1999) found storability of 'Ahmar' loquat in modified atmosphere packaging using LDPE and HDPE. and They found that the use of polyethylene wraps delayed shrivelling of fruits and maintained their juiciness. Ben-Yehoshua (1978) reported that shelf life of citrus fruit could be doubled under ambient conditions by packaging them in high density polyethylene films. Rameshwar *et. al.*, (1979) wrapped mango fruits in 200 gauge polyethylene bag with 0.4% ventilation and stated

that the storage life of mangoes was extended by wrapping in polyethylene film with ethylene absorbent.

Dhatt *et. al.*, (1991) studied for 56 days and they found that the kinnow fruit individually seal packed in high density polythene film and tightly sealed with manual electric sealer maintained acceptable firmness. Albrigo and Fellers (1983); Ben-Yehoshua *et. al.*, (1979); Hale *et. al.*, (1981); Kawada and Hale (1980); Kawada and Albrigo (1979); Purvis (1983a) found that individual grapefruit sealed or wrapped in polyethylene film resulted in reduction of transpirational water loss and noticed delay of normal deterioration in seal-packed fruit. Albrigo and Ismail (1983); Ben-Yehoshua (1985); Burger and Davis (1986); Purvis (1983b); Stein (1986) found increase in shelf life and storage of different fruits and vegetables through packing in plastic films.

Ben-Yehoshua *et. al.*, (1983) and Sharkey *et. al.*, (1985) reported that peel coloration and firmness of lemons was delayed with the use of high-density polyethylene (HDPE) wraps at 17°C to 20°C. Golumb *et. al.*, (1984) found better healing of wounds caused by mechanical handling in grapefruits wrapped with HDPE film. Rana *et. al.*, (2002) observed that fruits of kinnow in polyethylene bags had the lowest physiological weight loss than fruits packed in paper lining. There was no fruit decay up to 28 days of storage. Alsadon *et. al.*, (2004) packed tomato fruits cultivars Red Gold in LDPE film and HDPE film and found that tomato could be stored up to 3 weeks at 15°C with slight loss in weight in case of LDPE.

Neeraj *et. al.*, (2004) studied the effect of HDPE, LDPP and PVC packaging on aonla fruits cultivar Chakaiya during storage and reported that 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. Ramin and Khoshbakhat (2008) studied HDPE (30 micron) effect on "kay" acid lime fruit stored from 10°C to 20°C and observed that at 10°C fruits were green and vitamin C was significant with less spoilage and less weight loss.

2.1.4 Cling film

Yuen *et. al.*, (1993) studied effect of cling film wrapping on mango fruit variety "Kensington pride" and observed that after 10 days that mango had attractive appearance and good eating quality.

Ladaniya (2003) observed the effect of stretchable cling with shrinkable cryovac and shrinkable LDPE on "Mosambi" orange storage at 20°C to 25°C and 25°C to 30°C and reported less weight loss and spoilage up to 40 days. Sonkar *et. al.*, (2009) worked on Kinnow mandarin by using stretchable cling film with til oil (4%), neem oil (6.0%), wax (2.5%), mustard oil (8.0%) and carbendazim (1000 ppm) under ambient conditions and observed good juice content and less physiological weight loss.

2.1.5 Cellophane film

Neeraj *et. al.*, (2003) reported an increase in shelf life of golden delicious apple under cold storage conditions. Kahlon and Uppal (2005) reported that shelf life increased up to 15 days at 28°C to 33°C temperature and 85 to 90% RH in mango variety "Chausa" packed with perforated polyethylene bags.

Ambros *et. al.*, (2008) studied the effect of microperforated polypropylene film on loquat and recorded less weight loss at 20°C for 4 days. Kantola & Helen 2001 and Mangaraj *et. al.*, (2009) reported that cellophane is good in packaging of fresh fruits and vegetables for improvement of shelf life. It provides water permeability, gas permeability and prevent contamination.

2.2 Physical Parameters

2.2.1 Moisture content.

Naik *et. al.*, (1993) recorded minimum changes in moisture content with harvested tomatoes. Tomatoes were packed in 300 gauge polyethylene. Babarinde G. O. and Fabunmi O.A. (2009) observed packaging material effects on Okra at room ($28 \pm 2^\circ\text{C}$) and refrigerating condition ($15 \pm 2^\circ\text{C}$) and found that okra storage with LDPE packaging under refrigeration observed better moisture. Grierson (1969) and Ben-Yehoshua (1978) observed packaging in polythene film creates microclimate and retard loss of moisture content.

2.2.2 Spoilage percentage.

Barmore *et. al.*, (1983) revealed that HDPE film reduced fruit spoilage by individual wrapping of citrus fruits. Ladaniya *et. al.*, (1997) observed less decay in individual wrapped

nagpur mandarin (*Citrus Reticulata*) with poly ethylene and cryovac heat shrinkable films as compared to tray-wrapped at ambient temperature (30-35⁰C and 25-30%RH) or refrigeration (6-7⁰C and 90-95%RH). Aquino *et. al.*, (1998) dipped Okitsu Satuma fruits in an emulsion containing 500 ppm of thiabendazole and then wrapped or non wrapped in groups of 8 with two different plastic films (Cryovac MD and MY, respectively with 19mm and 20mm thickness) and reported that incidence of decay was higher in wrapped fruits than non wrapped ones. Singh *et. al.*, et al (1988) treated kinnow fruits with fungicides and wax emulsion and stored them at 12-14⁰C after packing in ventilated polyethylene bags. They was observed that rotting was more in untreated fruits then those treated with different concentrations of fungicides and wax emulsion. Dhatt *et. al.*, (1999) stored the kinnow fruit at ambient temperature (11-23⁰C) after washing with water and surface disinfection with 100 ppm sodium hypochlorite solution followed by dipping in thiabendazole 500 ppm, imazalil 300, 500, 100 ppm and 2,4-D 250 and 500 ppm. They seal packed in 10 micron thick HDPE bags and reported least spoilage in case of imazalil 300 ppm + HDPE after 30 days of storage while fruits wrapped in HDPE film without dipped in disinfectant solution shows maximum spoilage (49%) at 60 days storage. Ladaniya *et. al.*, (2005) noticed that there was no chilling injury in nagpur mandarin fruits coated with Sta-fresh upto 75 days of storage. Sonkar *et. al.*, (2009) reported that kinnow fruits curing along with different coatings and packaging in stretch film resulted in better performance in respect of least rotting percentage under ambient conditions.

2.2.3 Fruit firmness

Scott *et. al.*, (1971) packed banana in sealed polyethylene bags remained hard in green conditions where as non packed fruits were found soft and ripened. Passam (1982) studied that individual packed mango cultivars in poly ethylene bags, resulted in higher fruit firmness and extended storage life by 8-10 days under ambient conditions. Smith *et. al.*, (1987) reported marked reduction in softening of "Discovery" apples. They packed in LDPE and held at 20⁰C. Ozdemir *et. al.*, (1994) reported that coating with samper fresh at 0.5, 1.0, and 2.0% followed by storage at 1C and 85-90% RH for six months in "Starking Delicious" apple showed greater firmness then untreated fruits. Du et al (1997) reported that "Shinko" pear and peach fruits

coated with chitosan were markedly firmer and less mature at end of storage. Lin et al (2008) noticed that chitosan coating in combination with ascorbic acid resulted in better firmness of "Yali" pear fruits than control. Sidhu *et. al.*, (2009) observed that soft pear fruits coated with citrashine were more firm as compared to control under cold storage.

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 Ganesh' pomegranate (*Punica granatum* L.) fruits stored at a 8°C, 15°C and 25°C and reported that firmness of the fruit were retained. Singh and Rao (2005) observed that individually shrink wrapped papaya cv. "Solo" fruits could be stored for 10 days at ambient temperature without loss of its firmness.

2.2.4 Fruit weight loss

Garg *et. al.*, (1971) packed dushehari mango in 200 gauge polythene bags having 0.65 perforation followed by storage at room temperature showed lower weight loss. Golomb *et. al.*, (1984) observed that sealing individually "Marsh Seedless" grape fruit in 0.015 mm thick HDPE sheet greatly reduced fruits weight loss under uncontrolled room conditions. Gilfillian (1985) compared unwaxed Valencia oranges wrapped in HDPE or LDPE with those of conventionally waxed and tissue paper wrapped fruits and observed minimum weight loss of film wrapped fruits with conventionally waxed fruits. Gorini and Testoni (1988) reported very positive result by packaging Italian oranges and lemons with HDPE of 15 micron and D950 of 15 micron and reduction in weight loss was obtained with films. Randhawa *et. al.*, (1999) stored the fruits of Foster and Duncan grape fruit, Jaffa sweet orange and kinnow mandarin individually sealed in HDPE and reported that percentage of physiological loss in weight was lower in grape fruit as compared to jaffa sweet orange and kinnow mandarin in given period of time.

Deshmukh *et. al.*, (1999) studied effect of film wrapping and low temperature (5-6 °C) on storage quality of sweet orange cv. Mosambi and reported that both the treatments were effective than control in reducing physiological weight loss. Perez-Guzman *et. al.*, (1999) reported that individually seal packaging with polyolefin 0.019mm and PVC 0.025mm of Dancy mandarin reduced weight loss under refrigeration. Park et al (1970) reported that pear fruits packed in polyethylene film shows less weight loss. Sandhu and Singh (2000) noticed that pear cv. "Le Conte" packed individually in HDPE and LDPE film resulted in lower weight loss.

2.3.1 Vitamin C.

Garg *et. al.*, (1971) packed Dushehari mango in 200 gauge polythene bags having 0.65 perforation. Storage at room temperature showed delay in vitamin C. Deily and Rizvi (1983); and Zoffoli *et. al.*, (1998) said that MAP retarded the decrease of vitamin C in peaches and nectarines. Soliva and Martin (2003) found similar results in pear during storage. . Babarinde G.O., and Fabunmi O.A. (2009) studied packaging material effects on Okra at room ($28 \pm 2^{\circ}\text{C}$) and refrigerator storage condition ($15 \pm 2^{\circ}\text{C}$) and found LDPE was better in okra storage with refrigerator than room storage and retained vitamin C.

2.3.2 Sugar

Angadi and Krishnamurthy (1992) conducted experiment on freshly harvested kinnow fruits with 3% waxol, packed in ventilated polythene bags and were stored at room (25°C) or lower temperature (10°C) and observed highest total sugar after 19 days of storage at room temperature as compared to untreated fruits. Kaushal and Thakur (1996) dipped the kinnow mandarin in 1% bavistin for five minutes and packed in sealed bags of 150 gauge polyethylene and stored for 8 weeks in evaporative cool chambers. They reported that there was more gradual increase in sugar content in sealed fruits as compared to non sealed in bags.

Singh *et. al.*, (1998) studied the effect of perforated polyethylene wrapping on mango cv. "Amarpali" and reported that perforated polyethylene films maintain minimum reducing sugar and total sugar than control.

2.3.3 Total soluble solids.

Maqbool Ahmad, Zahir Shah, Javed Durrani, Mohammad Ashraf Chaudhry and Ismail Khan (1989) studied on on blood red oranges at $8-19^{\circ}\text{C}$ with RH 55-90%. Fruits were dipped in 1000 ppm thiabendazole for one mintue. After this fruits were packed in different packing films. Cellophane followed by polyethylene was good to maintain high TSS value with increase in number of days. Storage was gone up to 5 weeks. Rosita Salari, Hojjat Karazhiyan and Seyed Ali Mortazavi (2008) researched on Iranian date varieties (Kabkab. Piarome and Sayer). They studied on physiochemical properties. Stored for six month at 25, 5 and -18 degrees centigrade

temperatures. Polyethylene, polypropylene and cellophane were used as packaging material. Decrease in TSS was noticed with these packaging films.

MATERIALS AND RESEARCH METHODOLOGY

The present investigation entitled, "Effect of different packaging films on shelf life and quality of Citrus species (*Citrus Limon*)" was conducted in the Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2014-15. The lemon fruits of uniform size were collected from Kot Fatuhi, Dist. Hoshiarpur.

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 26⁰C. The mean maximum summer (May to July) temperature ranges from 35 to 39.4⁰C rising to a maximum of 40⁰C in May to June. The mean winter (December to February) minimum temperature ranges from 4⁰C to 6⁰C dropping to a minimum of 3.7 ⁰C- 4.4 ⁰C 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.

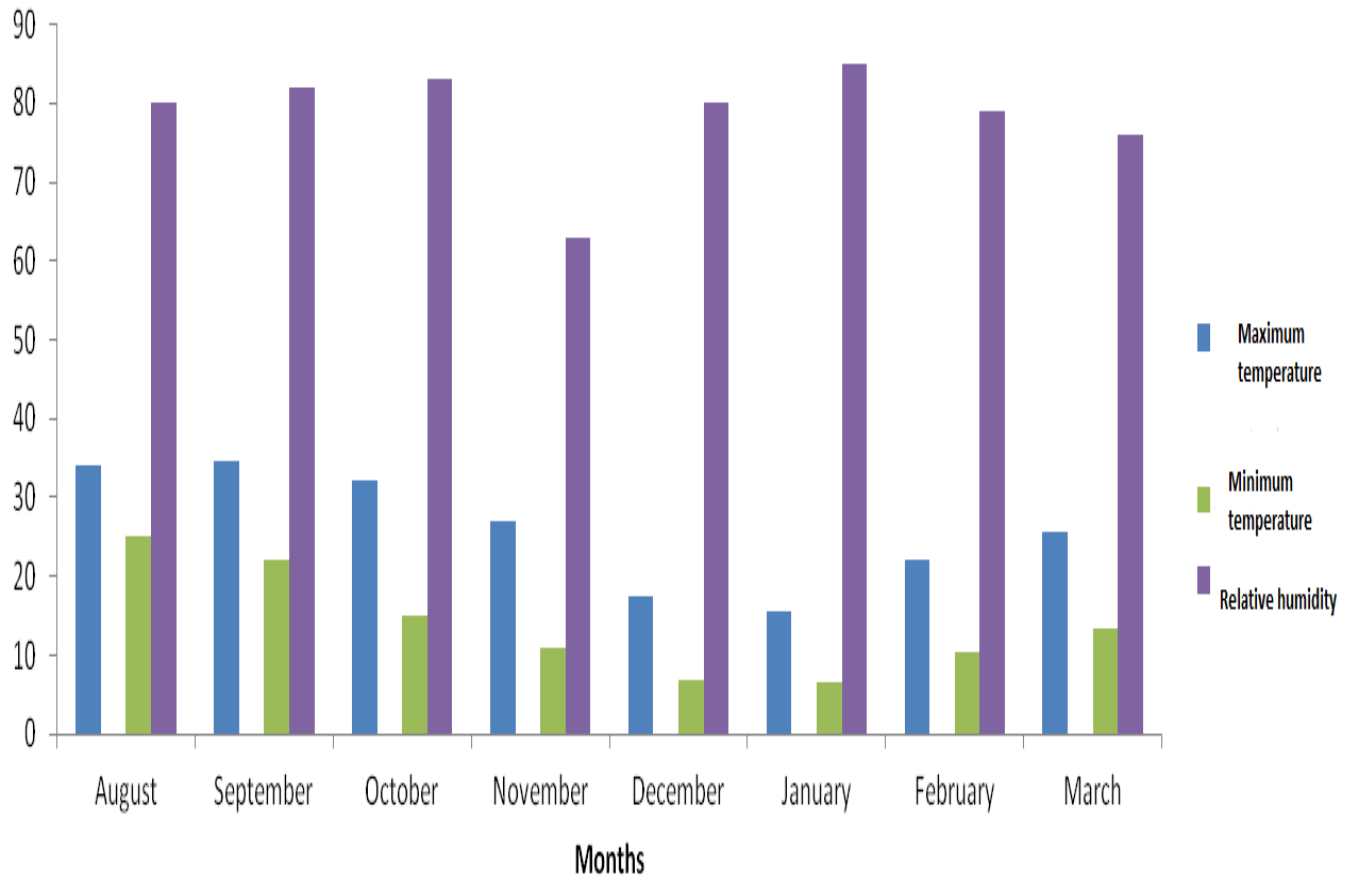


Fig. 3.1: Average monthly temperature of year 2014.

3.3 Preparation of fruit samples

Harvesting was done at yellow stage of lemon with help of secateur. Disease free and uniform size fruits were selected. Fruits were collected in plastic bags and were shifted to School of Agriculture, Lovely Professional University, Phagwara. Fruits were cleaned, washed and graded in laboratory.

3.4 Packaging films

Packaging films were purchased from Ludhiana market. Following packaging films were used :-

1. Shrink film (125 micron)
2. Shrink film (25 micron)
3. Polyethylene film or LDPE (25 micron)
4. Cling film (10 micron)
5. Cellophane film (30 micron)

Experimental details

Number of treatments: 6

Number of replications: 3(5 fruits in each plate).

Storage interval: 5(5, 10, 15, 20, 25 days).

Storage conditions: 21°C – 22 °C and 45-48% RH.

Treatments

T1 - Zero control

T2 - LDPE (25 micron).

T3 - Cellophane film (30 micron).

T4 - Cling film (10 micron).

T5 - Shrink film (125 micron).

T6 - Shrink film (25 micron).

Observations recorded

1. Physical parameters

1.1 Moisture content or percentage

Moisture content was calculated by subtracting oven dry weight (DW) of sample from fresh weight (FW) of sample. Then value was expressed in terms of grams. Moisture percentage was calculated by using following formula

$$\text{Moisture percentage} = \frac{\text{FW} - \text{DW}}{\text{FW}} \times 100$$

1.2 Spoilage percentage

Spoilage percentage was calculated by following formula:-

$$\text{Spoilage percentage} = \frac{\text{Number of fruits spoiled}}{\text{Total number of fruits}} \times 100$$

1.3 Fruit firmness

Fruit firmness was calculated with the help of penetrometer. By inserting needle of penetrometer fruits firmness can be calculated. Readings were expressed in terms of kg.

1.4 Fruit weight loss

Fruit weight loss was measured with weight machine. Readings were presented in gram unit. Following formula was used for total number of fruits in packaging:

Weight of fruits with during packaging - Weight of fruits with removed packaging

For single fruit weight following formula was used:

Total weight of fruits / Total number of fruits

2. Chemical parameters

2.1 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 color, 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.

2.2 Sugar

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).

$$\text{Reducing sugars (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution}}{\text{Titre} \times \text{wt. of sample (g)} \times 1000} \times 100$$

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.

Titre X 2.5

Factor for Fehling's solution = 1000

(g of invert sugar)

mg of invert sugar = g of invert sugar X 1000

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).

$$\text{Total sugars (\%)} = \frac{\text{mg of invert sugar X Dilution}}{\text{Titre (after inversion) X Wt. of Sample (g)}} \times 100$$

Non-reducing Sugars (%)

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

$$\text{Non- reducing sugars} = [\text{Total Sugar (\%)} - \text{Reducing Sugar (\%)}] \times 0.95$$

3. 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.

RESULTS AND DISCUSSION

The present investigation, "Effect of different packaging films on shelf life and quality on Citrus species (*Citrus Limon*)" was carried out in the Department of horticulture, School of Agriculture, Lovely Professional University, Phagwara during year 2015-16. The results obtained from this investigation are described in this chapter.

4.1 MOISTURE CONTENT

All treatments had different effect on moisture content of lemon at 21-22° C and 45-48 % RH. It was noticed that there was rise in moisture content in cellophane from 0 day to 15th day. In cellophane packaging film after 15th day there was little decrease in moisture content on 20th and 25th day reading. On 25th day it was found that only cellophane packaging film have higher moisture content i.e. 36.92 % than others packaging films. It means cellophane was successful to prevent moisture loss at large level. 2nd higher moisture content was found in cling film i.e. 31.27 %. From all treatments control had minimum moisture content i.e.22.51%. Result is explained with the help of table no.4.1, 4.2 and figure 4.1 and 4.2.

Wrapping with packaging films creates microclimate retards loss of moisture content (Grierson (1969) and Ben-Yehoshua (1978)). Cellophane reported to be good in packaging of fresh fruits and vegetables for improvement of shelf life like in tomato. It provides water permeability, gas permeability and prevents contamination (Kantola. and Helen 2001, Mangaraj et al. 2009). Storage of Iranian Dates was done for six month at temperatures (25, 5 and -18 degrees centigrade). Iranian Dates with cellophane showed decrease in moisture content at 25°C. With time, moisture content decreases during storage for all packaging (Rosita Salari, Hojjat Karazhiyan and Seyed Ali Mortazavi 2008).

Table 4.1 Effect of different packaging films on moisture content (%) of lemon under ambient conditions

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	32.19 ^b	37.82 ^c	31.18	31.83 ^a	27.41 ^a	22.51 ^a
T2 - LDPE	37.51 ^c	29.57 ^{ab}	27.61	32.74 ^a	32.7 ^b	30.8 ^c
T3 - Cellophane	29.67 ^a	28.68 ^a	30.46	37.33 ^b	36.45 ^c	36.92 ^d
T4 - Cling	28.07 ^a	32.66 ^b	26.39	34.83 ^{ab}	31.77 ^b	31.27 ^c
T5 - Shrink (125)	28.28 ^a	29.21 ^a	29.42	32.63 ^a	27.17 ^a	26.21 ^b
T6 - Shrink (25)	29.23 ^a	28.87 ^a	26.56	32.89 ^a	31.71 ^b	30.74 ^c
MEAN	30.82	31.13	28.6	33.71	31.2	29.74
SE	0.83	0.86	0.67	0.61	0.81	1.12
SD	3.56	3.67	2.84	2.61	3.44	4.75

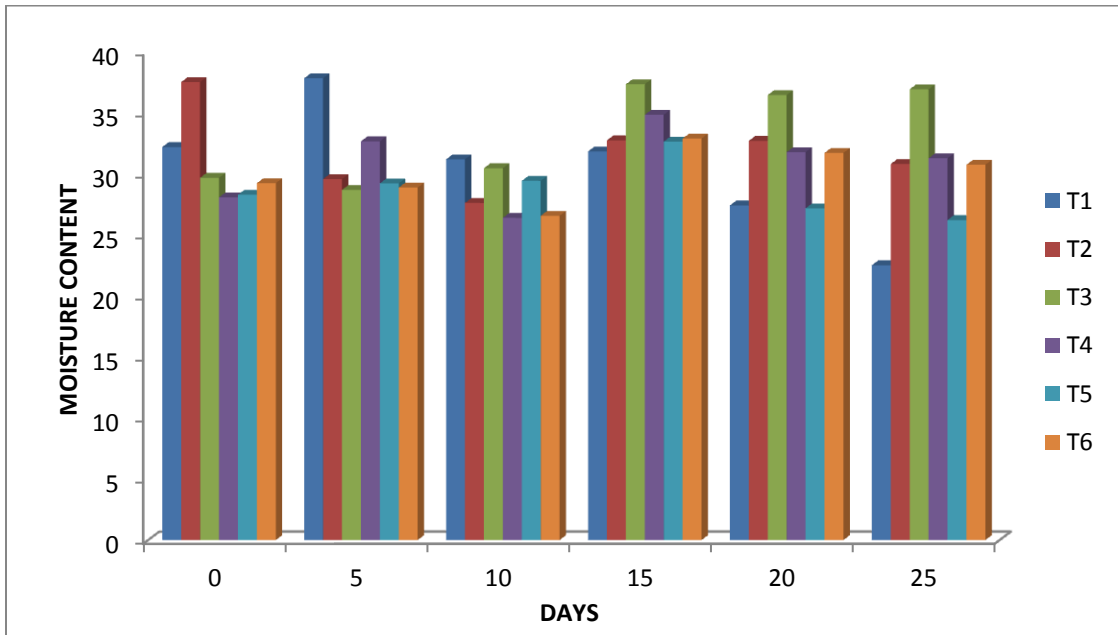


Figure 4.1 Effect of different packaging films on moisture content (%) of lemon under ambient conditions (21°C -22°C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125 micron) and T6 - Shrink (25 micron)

Table 4.2 Effect of treatments on moisture content (%) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	32.19	37.5	29.67	28.07	28.28	29.23
5	37.82	29.57	28.68	32.66	29.21	28.87
10	31.18	27.61	30.46	26.39	29.42	26.56
15	31.83	32.74	37.33	34.83	32.63	32.89
20	27.41	32.7	36.45	31.77	27.17	31.71
25	22.51	30.8	36.92	31.27	26.21	30.74
MEAN	30.49	31.82	33.25	30.83	28.82	30
SD	5	3.47	3.92	3.52	2.7	2.53
SE	1.17	0.81	0.92	0.83	0.63	0.59

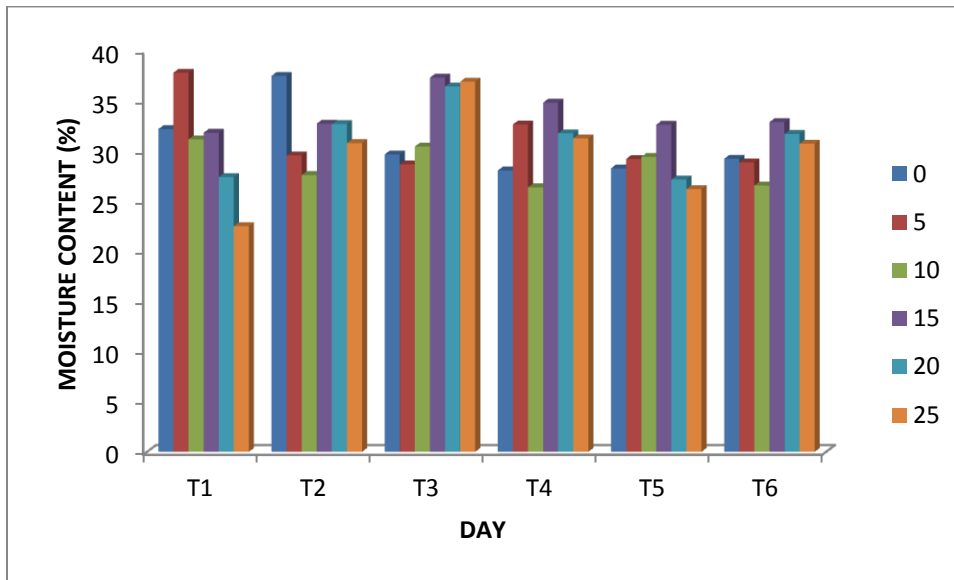


Figure 4.2 Effect of treatments on moisture content (%) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

4.2 Spoilage percentage

Spoilage percentage was noticed on 10th day in control, cling and shrink (125). On 10th day cling showed 40% spoilage percentage. It was highest than other packaging films. On 15th day shrink (25) showed 60% spoilage. It was highest spoilage % on 15th day. On 20th day control had spoilage 66%, LDPE had spoilage 66%, and shrink (125) had spoilage 66% showed highest spoilage %. In these packaging films water vapors were formed. Late spoilage was occurred in cellophane i.e. on 20th day. In cellophane, fruit length more than 6 cm and breadth 5.5 cm was observed. This fruit size was present only in cellophane. In other packaging films length of fruit was less the 6 cm and breadth was less than 5 cm. Little damage to fruit was also found in cellophane. That damage was less than other damages of different packaging films. Result is also explained with the help of table 4.3, 4.4 and figure 4.3 and 4.4.

At 25⁰ C spoilage was at fast rate but at 5⁰ C cellophane showed decrease in spoilage of Iranian Dates (Rosita Salari, Hojjat Karazhiyan and Seyed Ali Mortazavi 2008). Barmore *et. al.*, (1983) revealed that HDPE film reduced fruit spoilage by individual wrapping of citrus fruits. Ladaniya *et. al.*, (1997) observed less decay in individual wrapped nagpur mandarin (*Citrus Reticulata*) with poly ethylene and cryovac heat shrinkable films as compared to tray-wrapped at ambient temperature (30-35⁰C and 25-30%RH) or refrigeration (6-7⁰C and 90-95%RH). Aquino *et. al.*, (1998) dipped Okitsu Satuma fruits in an emulsion containing 500 ppm of thiabendazole or left untreated and then either wrapped or non wrapped in groups of 8 with two different plastic films (Cryovac MD and MY, respectively 19mm and 20mm thickness) and reported that incidence of decay was higher in wrapped fruits than non wrapped ones.

Table 4.3 Effect of different packaging films on spoilage (%) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	0	0	20	25	66	100
T2 - LDPE	0	0	0	40	66	100
T3 - Cellophane	0	0	0	0	60	100
T4 - Cling	0	0	40	33	50	100
T5 - Shrink (125)	0	0	20	25	66	100
T6 - Shrink (25)	0	0	0	60	50	100
MEAN	0	0	13.13	30.5	59.66	100
SE	0	0	3.61	4.38	1.73	0
SD	0	0	15.33	18.58	7.36	0

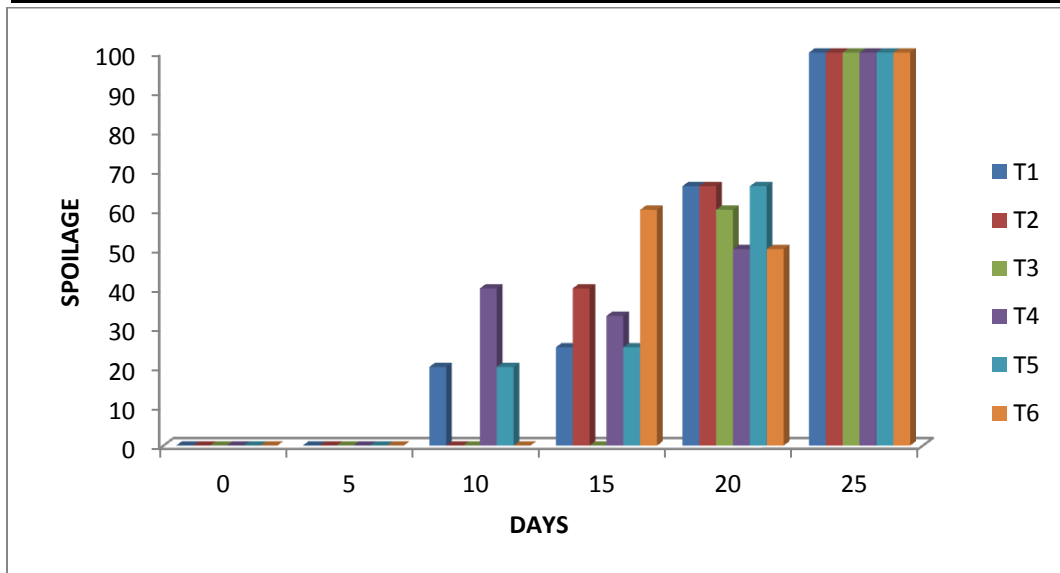


Figure 4.3 Effect of different packaging films on spoilage % of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.4 Effect of treatments on spoilage (%) of lemon shelf life and quality at 21⁰C -22⁰C and 45-48% RH

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	0	0	0	0	0	0
5	0	0	0	0	0	0
10	20	0	0	40	20	0
15	25	40	0	33	25	60
20	66	66	60	50	66	50
25	100	100	100	100	100	100
MEAN	35.16	34.33	26.66	37.16	35.16	35.00
SD	37.48	39.59	40.58	34.89	37.48	9.26
SE	8.83	9.33	9.56	8.22	8.83	39.29

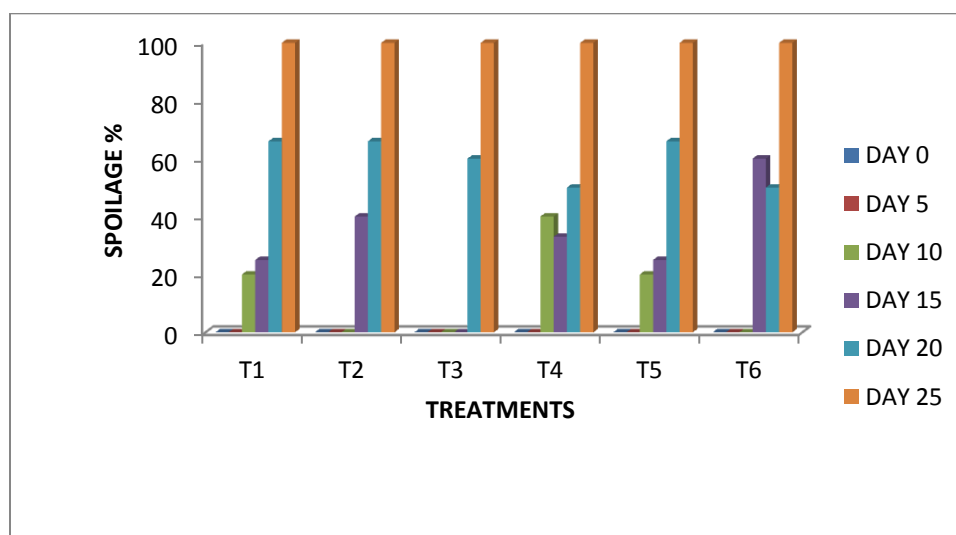


Figure 4.4 Effect of treatments on spoilage (%) of lemon shelf life and quality at 21⁰C -22⁰C and 45-48% RH

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

4.3 Fruit firmness.

From 0 day to 25th day all treatments showed large variations in firmness for example 0.12(kg), 0.7(kg), 0.9 (kg) etc. Only cellophane packaging film showed little change in firmness from 0 day to 25th day. Cellophane packaging film showed 0.12 to 0.11 (kg) change. Cellophane packaging film was able to maintain good firmness. Lemon fruit of cellophane was soft then other fruits. Hard skin of fruit was prevented in cellophane. Skin of lemon fruit of other treatments was hard. Good color and attractive skin of fruit were also noticed in cellophane. Fruit spoilage of cellophane packaging film was occurred later than other packaging films. Table no. 4.5, 4.6 and figure.4.5 and 4.6 are presenting obtained values.

Research was done on blood red oranges at 8-19⁰C with RH 55-90%. Fruits were dipped in 1000 ppm thiabendazole for one mintue. After this fruits were packed in different packing films. Cellophane followed by polyethylene was good to maintain external characters i.e. fruit firmness and fruit appearence (Maqbool Ahmad, Zahir Shah, Javed Durrani, Mohammad Ashraf Chaudhry and Ismail Khan (1989)). Smith *et. al.*, (1987) reported marked reduction in softening of "Discovery" apples. They packed in polyetylene and held at 20⁰C. Scott *et. al.*, (1971) packed banana in sealed polyethylene bags remained hard in green conditions where as non packed fruits were found soft and rippened. Passam (1982) studied that individual packed mango cultivars in poly ethylene bags, resulted in higher fruit firmness and extended storage life by 8-10 days under ambient conditions.

Table 4.5 Effect of different packaging films on firmness (kg/cm^2) of lemon under ambient conditions (21°C - 22°C and 45-48% RH).

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	0.12	0.11 ^{ab}	0.63	0.63 ^{ab}	0.73 ^b	0.66 ^b
T2 - LDPE	0.12	0.11 ^{ab}	0.37	0.37 ^{ab}	0.83 ^b	0.7 ^{bc}
T3 - Cellophane	0.12	0.12 ^b	0.12	0.11 ^a	0.11 ^a	0.11 ^a
T4 - Cling	0.12	0.11 ^{ab}	0.37	0.63 ^{ab}	0.83 ^b	0.76 ^c
T5 - Shrink (125)	0.13	0.11 ^a	0.63	0.9 ^b	0.73 ^b	0.66 ^b
T6 - Shrink (25)	0.12	0.11 ^{ab}	0.63	0.86 ^b	0.76 ^b	0.76 ^c
MEAN	0.12	0.11	0.46	0.58	0.66	0.61
SE	0	0	0.09	0.09	0.06	0.05
SD	0	0	0.4	0.39	0.26	0.23

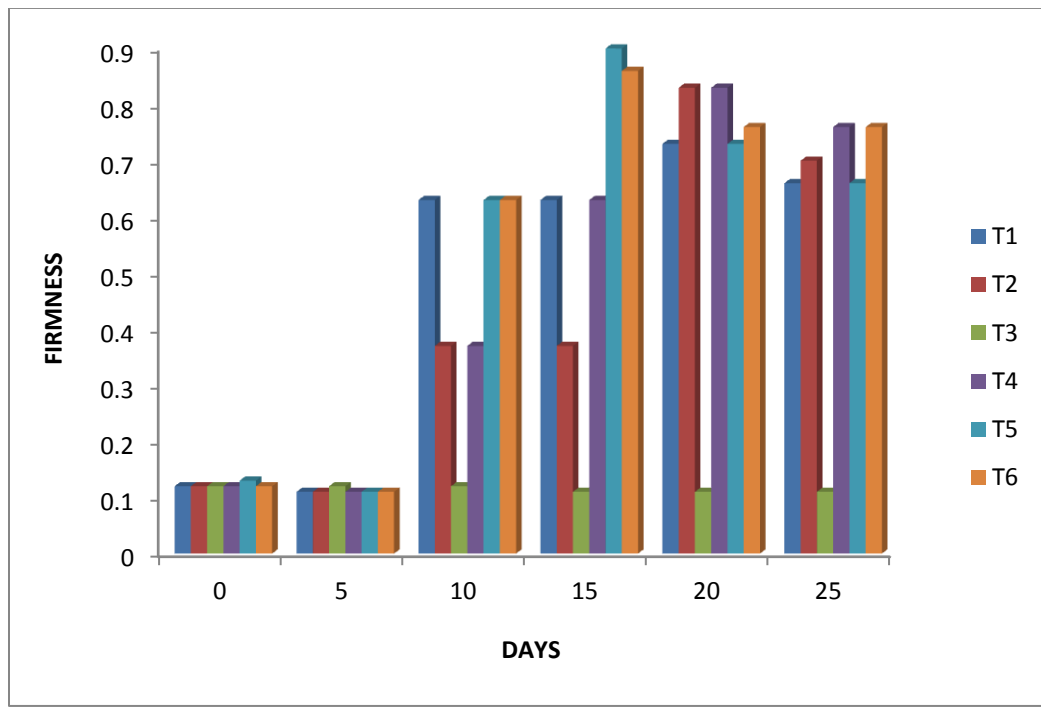


Figure 4.5 Effect of different packaging films on firmness of lemon under ambient conditions (21°C - 22°C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.6 Effect of treatments on fruit firmness (kg/cm^2) of lemon under ambient conditions (21°C - 22°C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	0.12	0.12	0.12	0.12	0.13	0.12
5	0.11	0.11	0.12	0.11	0.11	0.11
10	0.63	0.37	0.12	0.37	0.63	0.63
15	0.63	0.37	0.11	0.63	0.9	0.86
20	0.73	0.83	0.11	0.83	0.73	0.76
25	0.66	0.7	0.11	0.76	0.66	0.76
MEAN	0.48	0.42	0.11	0.47	0.53	0.54
SD	0.34	0.35	0	0.37	0.34	0.35
SE	0.08	0.08	0	0.08	0.08	0.08

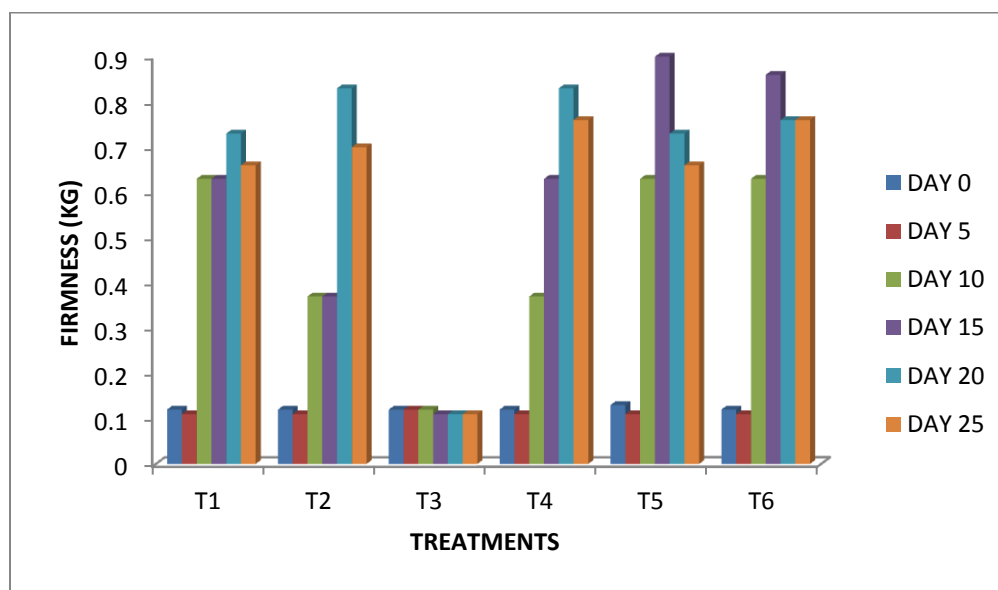


Figure 4.6 Effect of treatments on fruit firmness (kg/cm^2) of lemon under ambient conditions (21°C - 22°C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

4.4 Fruit weight loss

Total highest weight loss of all treatments was occurred on 5th day. On the basis of single fruit weight loss highest weight loss was of control i.e. 8.93 g and minimum weight loss was noticed in cellophane i.e. was 2.6g on 5th day. On 25th day higher weight loss was of control and that was 6.06g. Overall highest weight loss was occurred in control during experiment from packaging to 25th day. Minimum weight loss was occurred in cellophane during all days of experiment. Weight loss of cellophane packaging film was between 2.06 - 2.6g. Second minimum weight loss was present in LDPE and it was present between 2.53 -4.05g. All observations recorded during study are also with the help of table no. 4.7, 4.8 and figure.4.7and 4.8.

Garg *et. al.*, (1971) packed dushehari mango in 200 gauge polythene bags having 0.65 perforation followed by storage at room temperature showed lower weight loss. Golomb *et. al.*, (1984) observed that sealing individually "Marsh Seedless" grape fruit in 0.015 mm thick HDPE sheet greatly reduced fruits weight loss under uncontrolled room conditions. Gilfillian (1985) compared unwaxed Valencia oranges wrapped in HDPE or LDPE with those of conventionally waxed and tissue paper wrapped fruits and observed minimum weight loss of film wrapped fruits with conventionally waxed fruits. Gorini and Testoni (1988) reported very positive result by packaging Italian oranges and lemons with HDPE of 15 micron and D950 of 15 micron and reduction in weight loss was obtained with films. Randhawa *et. al.*, (1999) stored the fruits of Foster and Duncan grape fruit, Jaffa sweet orange and kinnow mandarin individually sealed in HDPE and reported that percentage of physiological loss in weight was lower in grape fruit as compared to jaffa sweet orange and kinnow mandarin in given period of time.

Perez-Guzman *et. al.*, (1999) reported that individually seal packaging with polyolefin 0.019mm and PVC 0.025mm of Dancy mandarin reduced weight loss under refrigeration. Park et al (1970) reported that pear fruits packed in polyethylene film shows less weight loss. Sandhu and Singh (2000) noticed that pear cv. "Le Conte" packed individually in HDPE and LDPE film resulted in lower weight loss.

Table 4.7 Effect of different packaging films on weight loss (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	0	8.93 ^f	8.06	7.2 ^f	6.6 ^d	6.06 ^c
T2 - LDPE	0	4.05 ^b	3.2	2.86 ^b	2.86 ^a	2.53 ^{ab}
T3 - Cellophane	0	2.6 ^a	2.6	2.46 ^a	2.46 ^a	2.06 ^a
T4 - Cling	0	5.13 ^c	4.66	3.6 ^c	3.46 ^b	2.73 ^b
T5 - Shrink (125)	0	8.33 ^e	7.93	6.2 ^e	6.2 ^d	5.73 ^c
T6 - Shrink (25)	0	6.23 ^d	6	4.06 ^d	3.93 ^c	2.73 ^b
MEAN	0	5.88	5.41	4.4	4.25	3.64
SE	0	0.54	0.51	0.42	0.38	0.39
SD	0	2.31	2.19	1.78	1.64	1.67

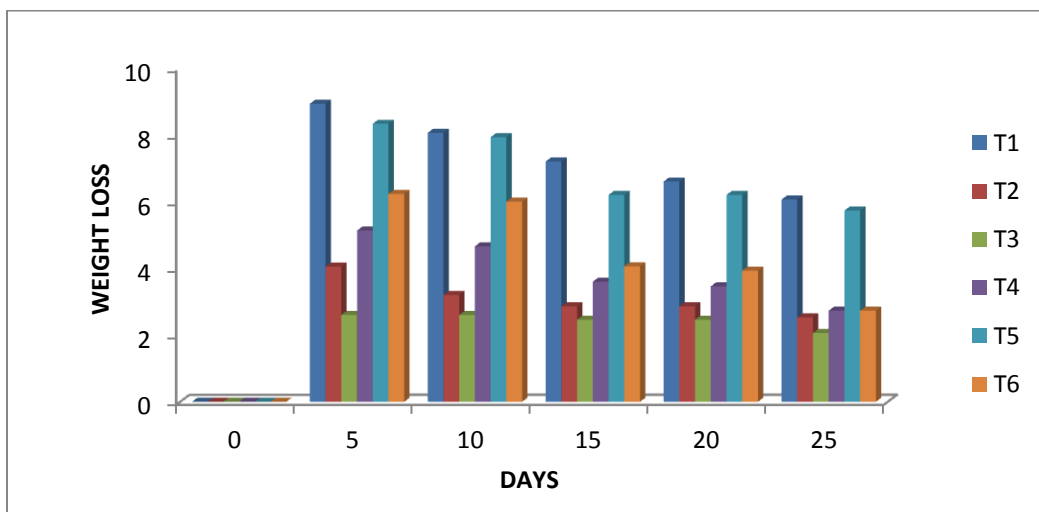


FIGURE 4.7 Effect of different packaging films on weight loss (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH)

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.8. Effect of treatments on weight loss (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	0	0	0	0	0	0
5	8.93	4	2.6	5.13	8.33	6.23
10	8.06	3.2	2.6	4.66	7.93	6
15	7.2	2.86	2.46	3.6	6.2	4.06
20	6.6	2.86	2.46	3.46	6.2	3.93
25	6.06	2.53	2.06	2.73	5.73	2.73
MEAN	6.14	2.58	2.03	3.26	5.73	3.82
SD	2.99	1.31	0.95	1.71	2.82	2.16
SE	0.7	0.31	0.22	0.4	0.66	0.51

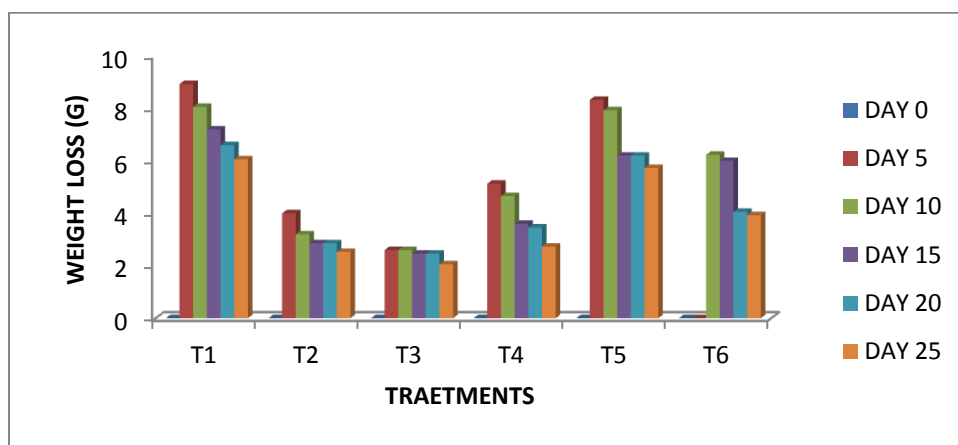


Figure. 4.8 Effect of treatments on weight loss (g) of lemon under ambient conditions.

[T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125 micron) and T6 - Shrink (25 micron)]

4.5 Vitamin C

Decrease in vitamin was noticed in all treatments. Highest loss of vitamin C was occurred in control that was 21.49 (mg/100ml) vitamin C on 25th day. Only cellophane showed less decrease in vitamin C with increase in number of days. Cellophane was only that packaging film that have vitamin C more than 30 mg. On 25th day 31.73 (mg/100ml) vitamin C was observed. Cellophane prevented decrease in vitamin than the other packagins films. Second best result was obtained in LDPE with 22.75 (mg/100ml) vitamin C on 25th day. Observed valued are also explained with the help of table no.4.9, 4.10 and figure 4.9 and 4.10

Similar result was also found in cellophane with blood red oranges at 8-19⁰C with RH 55-90% (Maqbool Ahmad, Zahir Shah, Javed Durrani, Mohammad Ashraf Chaudhry and Ismail Khan (1989)). Garg *et. al.*, (1971) packed dushehari mango in 200 gauge polythene bags having 0.65 perforation followed by storage at room temperature showed delay in vitamin C. Deily and Rizvi (1983); Zoffoli *et. al.*, (1998) said that MAP retarded the decrease of vitamin C in peaches and nectarines. Soliva and Martin (2003) found similar results in pear during storage. . Babarinde G.O., and Fabunmi O.A. (2009) studied packaging material effects on Okra at room (28 ± 2°C) and refrigerator storage condition (15 ± 2°C) and found LDPE was better in okra storage with refrigerator than room storage and retained vitamin C.

Table 4.9 Effect of different packaging films on vitamin C (mg/100ml) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

Treatments	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 – Control	40.31	36.89 ^a	35.49	30.89 ^a	26.51 ^a	21.49 ^a
T2 - LDPE	40.6	38 ^{ab}	35.77	32.16 ^b	30.17 ^{cd}	22.75 ^a
T3 - Cellophane	41.15	38.79 ^b	37.22	36.08 ^c	32.62 ^d	31.73 ^b
T4 - Cling	40.93	38.14 ^{ab}	35.74	33.22 ^b	28.28 ^{abc}	22.34 ^a
T5 - Shrink (125)	41.05	37.61 ^{ab}	35.18	33.31 ^b	26.81 ^{ab}	22.35 ^a
T6 - Shrink (25)	40.91	37.95 ^{ab}	35.69	33.09 ^b	29.87 ^{bcd}	22.6 ^a
MEAN	40.82	37.9	35.86	33.12	29.05	23.88
SE	0.14	0.22	0.2	0.4	0.6	0.89
SD	0.59	0.94	0.85	1.7	2.57	3.8

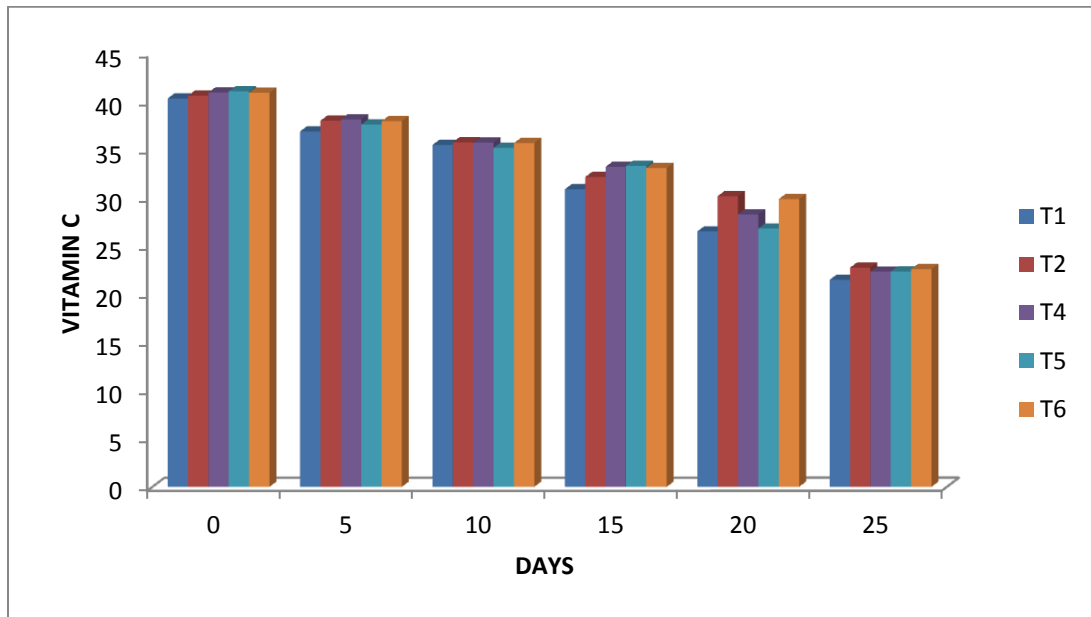


Figure 4.9 Effect of different packaging films on vitamin C (mg/100ml) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.10 Effect of treatments on vitamin C (mg/100ml) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	40.31	40.6	41.15	40.93	41.05	40.91
5	36.89	38	38.79	38.14	37.61	37.95
10	35.59	35.77	37.22	35.74	35.18	35.69
15	30.89	32.16	36.08	33.22	33.31	33.09
20	26.51	30.17	32.62	28.28	26.85	29.87
25	21.49	22.75	31.73	22.34	22.35	22.60
MEAN	31.95	33.24	36.26	33.11	32.72	33.35
SD	6.64	6.03	3.57	6.44	6.62	1.45
SE	1.56	1.42	0.84	1.51	1.56	6.16

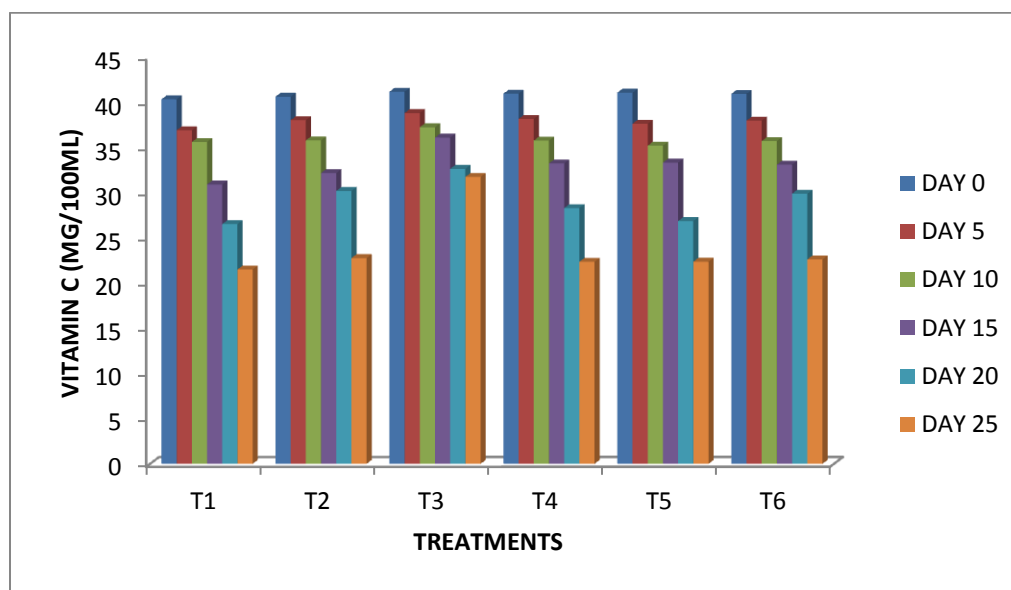


Figure 4.10 Effect of treatments on vitamin C (mg/100ml) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

4.6 Sugar.

Non reducing sugar and total sugar showed little decrease with increase in number of days. But no change in reducing sugar was occurred during all treatments. Overall it was noticed that cellophane packaging film act as good to maintain sugar content than other treatments. Only cellophane maintain total sugar content between 2 - 2.28g. Minimum 2g sugar was noticed in cellophane on 25th day. In other treatments total sugar goes below 2g on 25th day. Cling, shrink 25 and LDPE presented second best treatments in total sugar i.e. 1.96g and non reducing sugars with 0.96g on 25th day. In case of non reducing sugar cellophane was best to maintain it with 1g and in other treatments reducing sugar goes below 1g on 25th day. More decrease in non reducing occurred in control and shrink 125 and 0.93g reducing sugar was noticed on 25th day. Readings are expressed with the help of tables no. 4.11(reducing sugar), 4.12 (non reducing sugar), 4.13 (total sugar) and figure 4.11, 4.12, 4.13.

Such type of result was found in storage of Iranian dates. It was done for six month at 25degrees centigrade temperatures. Decrease in sugar content was noticed with cellophane in Iranian dates (Rosita Salari, Hojjat Karazhiyan and Seyed Ali Mortazavi 2008). Angadi and Krishnamurthy (1992) conducted experiment on freshly harvested kinnow fruits with 3% waxol, packed in ventilated polythene bags and were stored at room (25⁰C) or lower temperature (10 ⁰C) and observed highest total sugar after 19 days of storage at room temperature as compared to untreated fruits. Singh *et. al.*, (1998) studied the effect of perforated polyethylene wrapping on mango cv. "Amarpali" and reported that perforated polyethylene films maintain minimum reducing sugar and total sugar than control.

Table 4.11 Effect of different packaging films on reducing sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	1	1	1	1	1	1
T2 - LDPE	1	1	1	1	1	1
T3 - Cellophane	1	1	1	1	1	1
T4 - Cling	1	1	1	1	1	1
T5 - Shrink (125)	1	1	1	1	1	1
T6 - Shrink (25)	1	1	1	1	1	1
MEAN	1	1	1	1	1	1
SE	0	0	0	0	0	0
SD	0	0	0	0	0	0

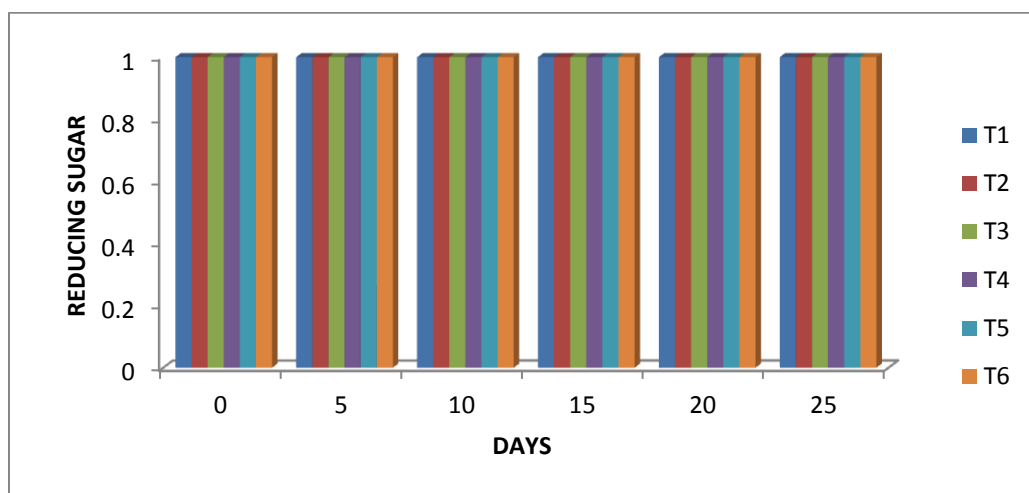


Figure 4.11 Effect of different packaging films on reducing sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.12 Effect of different packaging films on non reducing sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	1.27	1.26 ^{ab}	1.2	1.03 ^a	1 ^a	0.93 ^a
T2 - LDPE	1.27	1.26 ^{ab}	1.15	1.06 ^a	1.06 ^a	0.96 ^a
T3 - Cellophane	1.27	1.28 ^b	1.26	1.23 ^b	1.23 ^b	1 ^a
T4 - Cling	1.27	1.26 ^{ab}	1.24	1.03 ^a	1.03 ^a	0.96 ^a
T5 - Shrink (125)	1.27	1.26 ^{ab}	1.18	1 ^a	1 ^a	0.93 ^a
T6 - Shrink (25)	1.27	1.26 ^a	1.18	1.03 ^a	1.03 ^a	0.96 ^a
MEAN	1.27	1.26	1.2	1.06	1.06	0.96
SE	0	0	0.02	0.02	0.02	0.01
SD	0	0.01	0.08	0.09	0.09	0.05

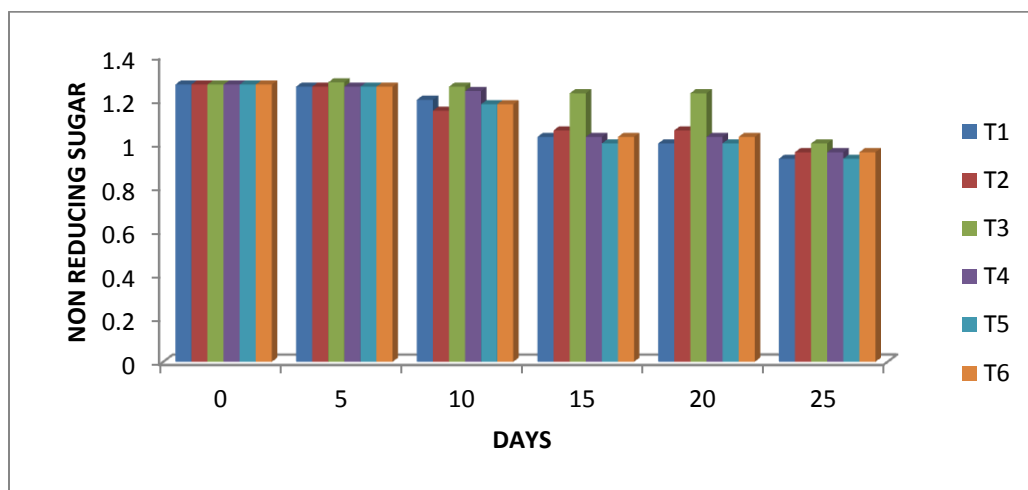


Figure 4.12 Effect of different packaging films on non reducing sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.13 Effect of different packaging films on total sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

Treatments	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	2.27	2.26 ^{ab}	2.2	2.03 ^a	2 ^a	1.93 ^a
T2 - LDPE	2.27	2.26 ^{ab}	2.15	2.06 ^a	2.06 ^a	1.96 ^a
T3 - Cellophane	2.27	2.28 ^b	2.26	2.23 ^b	2.23 ^b	2 ^a
T4 - Cling	2.27	2.26 ^{ab}	2.24	2.03 ^a	2.03 ^a	1.96 ^a
T5 - Shrink (125)	2.27	2.26 ^{ab}	2.18	2 ^a	2 ^a	1.93 ^a
T6 - Shrink (25)	2.27	2.26 ^a	2.18	2.03 ^a	2.03 ^a	1.96 ^a
MEAN	2.27	2.26	2.2	2.06	2.06	1.96
SE	0	0	0.02	0.02	0.02	0.01
SD	0	0.01	0.08	0.09	0.09	0.05

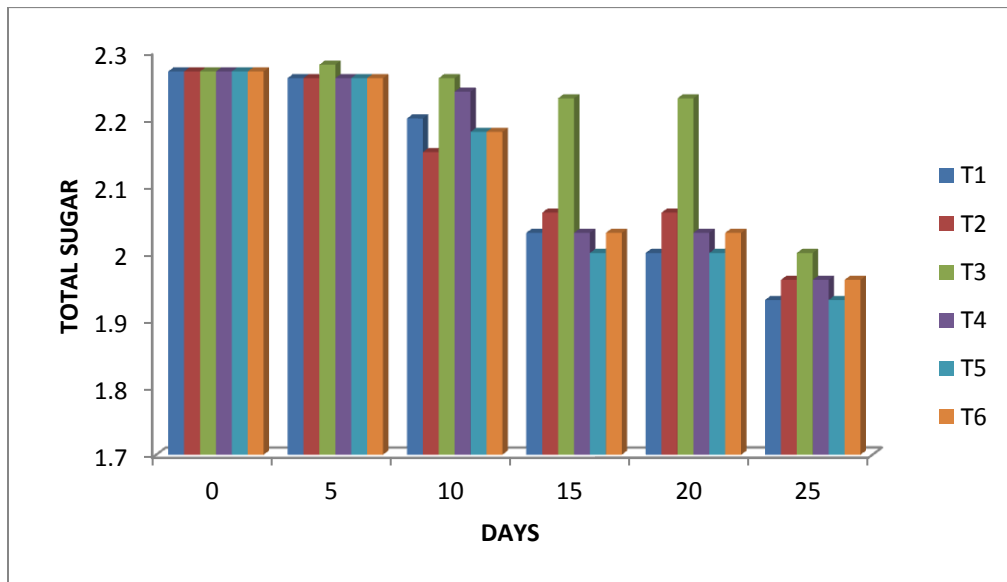


Figure 4.13 Effect of different packaging films on total sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.14 Effect of treatments on reducing sugar (g) of lemon under ambient conditions (21°C -22°C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	1	1	1	1	1	1
5	1	1	1	1	1	1
10	1	1	1	1	1	1
15	1	1	1	1	1	1
20	1	1	1	1	1	1
25	1	1	1	1	1	1
MEAN	1	1	1	1	1	1
SD	0	0	0	0	0	0
SE	0	0	0	0	0	0

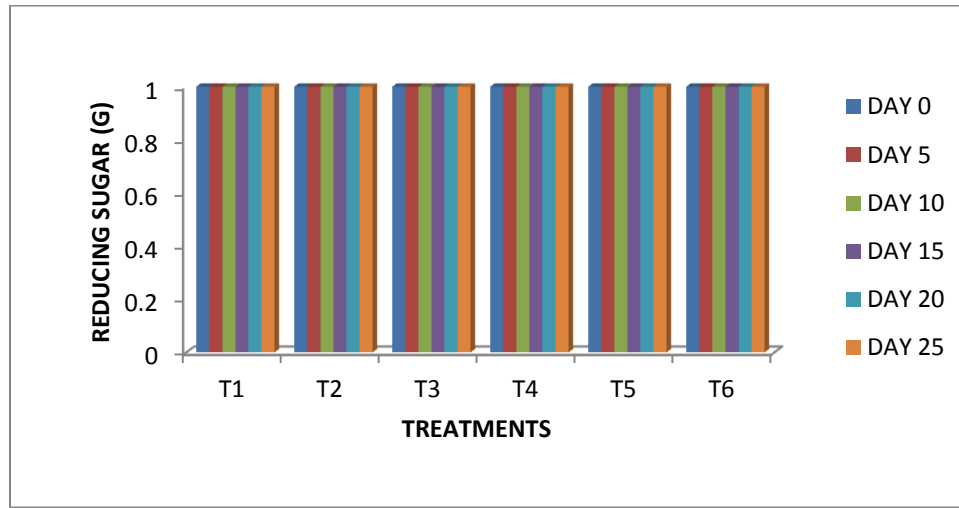
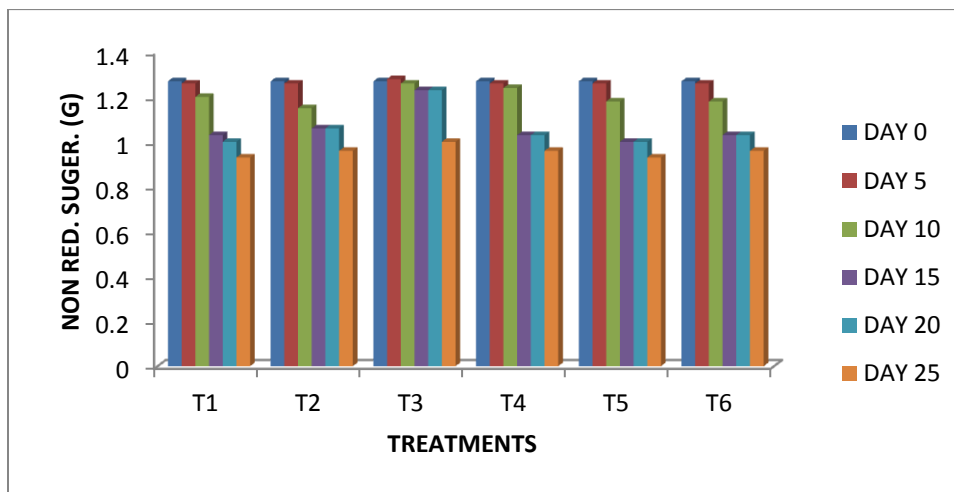


Table 4.6.1.b. Effect of treatments on reducing sugar (g) of lemon under ambient conditions (21°C -22°C and 45-48% RH).

Note:- T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.6.2.b. Effect of treatments on non reducing sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	1.27	1.27	1.27	1.27	1.27	1.27
5	1.26	1.26	1.28	1.26	1.26	1.26
10	1.2	1.15	1.26	1.24	1.18	1.18
15	1.03	1.06	1.23	1.03	1	1.03
20	1	1.06	1.23	1.03	1	1.03
25	0.93	0.96	1	0.96	0.93	.96
MEAN	1.11	1.13	1.21	1.13	1.1	1.12
SD	0.15	0.12	0.1	0.13	0.14	0.03
SE	0.03	0.02	0.02	0.03	0.03	0.12

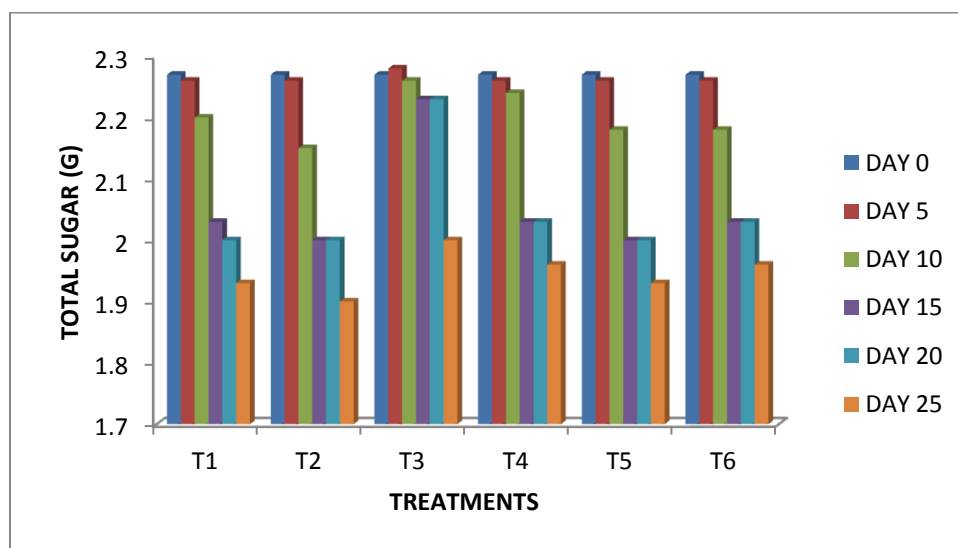


GRAPH 4.6.2.b. Effect of treatments on non reducing sugar (g) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

Note:- T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.6.3.b Effect of treatments on total sugar (g) of lemon under ambient conditions (21°C -22°C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	2.27	2.27	2.27	2.27	2.27	2.27
5	2.26	2.26	2.28	2.26	2.26	2.26
10	2.2	2.15	2.26	2.24	2.18	2.18
15	2.03	2	2.23	2.03	2	2.03
20	2	2	2.23	2.03	2	2.03
25	1.93	1.9	2	1.96	1.93	1.96
MEAN	2.11	2.13	2.21	2.13	2.1	2.12
SD	0.15	0.12	0.1	0.13	0.14	0.12
SE	0.03	0.02	0.02	0.03	0.03	0.03



GRAPH NO 4.6.3. Effect of treatments on total sugar (g) of lemon under ambient conditions (21°C -22°C and 45-48% RH).

Note:- T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

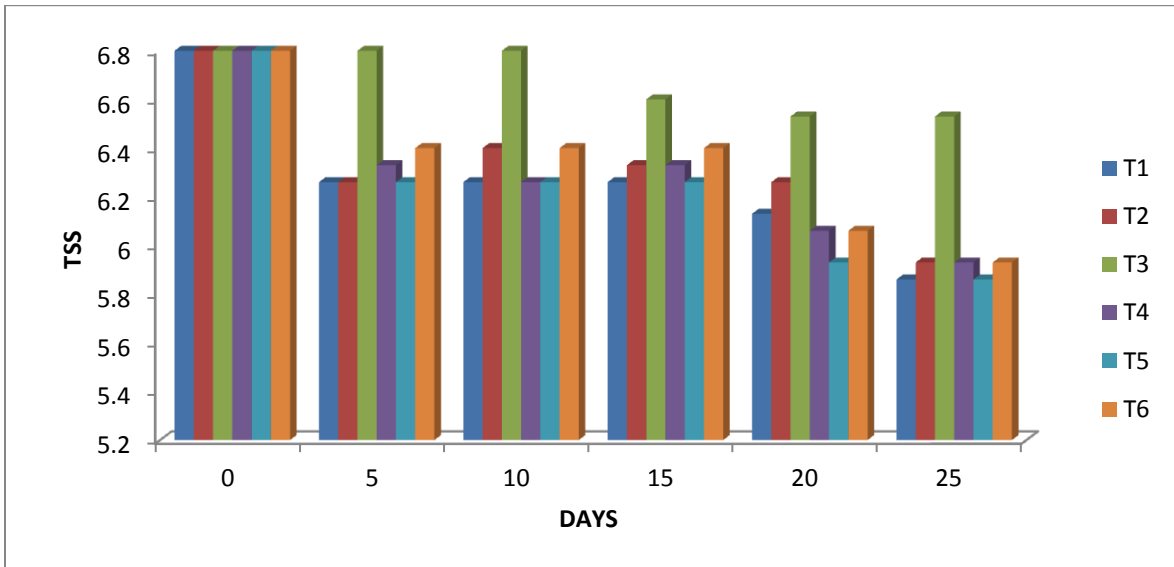
4.7 Total soluble solids.

With increase in number of storage days decrease in TSS was noticed. Lowest TSS found on 25th day in cellophane was 6.53 and that was highest value of TSS from other packaging films on last day i.e. 25th day. TSS 6.8 was present in all treatments during first day. Cellophane was able to maintain TSS from 6.8 to 6.53 from starting point of research to end of research. On 25th day all treatments have TSS less than 6. However LDPE, shrink 25 and cling were on second place with 5.93 TSS value on last day i.e. 25th day. Control and shrink 125 had lowest value of TSS i.e. 5.86 on last day of research. Observed values are explained with the help of table no.4.7.a, 4.7.b and 4.7.b and graph no.4.7.a and 4.7.b.

Same result was found in storage of Iranian dates. It was done for six month at 25, 5 and -18 degrees centigrade temperatures. Decrease in TSS was noticed with cellophane in Iranian dates (Rosita Salari, Hojjat Karazhiyan and Seyed Ali Mortazavi 2008). Research was done on blood red oranges at 8-19⁰C with RH 55-90%. Fruits were dipped in 1000 ppm thiabendazole for one minute. After fruits were packed in different packing films. It was noticed that cellophane followed by polyethylene had high TSS value with increase in number of days (Maqbool Ahmad, Zahir Shah, Javed Durrani, Mohammad Ashraf Chaudhry and Ismail Khan (1989)).

Table 4.7.a. Effect of different packaging films on TSS (⁰Brix) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

TREATMENTS	DAYS OF STORAGE					
	0	5	10	15	20	25
T1 - Control	6.8	6.26 ^a	6.26	6.26 ^a	6.13 ^{ab}	5.86 ^a
T2 - LDPE	6.8	6.26 ^a	6.4	6.33 ^a	6.26 ^b	5.93 ^a
T3 - Cellophane	6.8	6.8 ^b	6.8	6.6 ^b	6.53 ^c	6.53 ^b
T4 - Cling	6.8	6.33 ^a	6.26	6.33 ^a	6.06 ^{ab}	5.93 ^a
T5 - Shrink (125)	6.8	6.26 ^a	6.26	6.26 ^a	5.93 ^a	5.86 ^a
T6 - Shrink (25)	6.8	6.4 ^a	6.4	6.4 ^a	6.06 ^{ab}	5.93 ^a
MEAN	6.8	6.38	6.4	6.36	6.16	6.01
SE	0	0.04	0.04	0.03	0.05	0.06
SD	0	0.21	0.2	0.14	0.21	0.26



GRAPH NO.4.7.a Effect of different packaging films on TSS (⁰Brix) of lemon under ambient conditions (21⁰C -22⁰C and 45-48% RH).

Note:- T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

Table 4.7.b. Effect of treatments on TSS (⁰Brix) of lemon shelf life and quality under ambient conditions (21⁰C -22⁰C and 45-48% RH).

DAY	TREATMENTS					
	T1	T2	T3	T4	T5	T6
0	6.8	6.8	6.8	6.8	6.8	6.8
5	6.26	6.26	6.8	6.33	6.26	6.4
10	6.26	6.4	6.8	6.26	6.26	6.4
15	6.26	6.33	6.6	6.33	6.26	6.4
20	6.13	6.26	6.53	6.06	5.93	6.06
25	5.86	5.93	6.53	5.93	5.86	5.93
MEAN	6.26	6.33	6.67	6.28	6.23	6.33
SD	0.29	0.27	0.13	0.29	0.32	0.06
SE	0.07	0.06	0.03	0.06	0.07	0.29

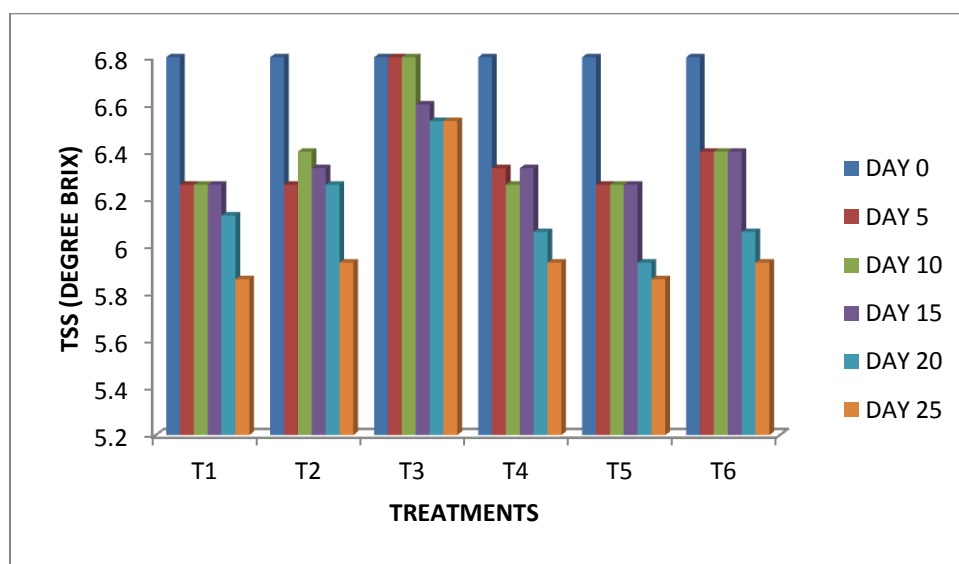


Figure4.7.b. Effect of treatments on TSS (⁰Brix) of lemon shelf life and quality under ambient conditions (21⁰C -22⁰C and 45-48% RH).

Note:- T1 - Control, T2 - LDPE, T3 - Cellophane, T4 - Cling, T5 - Shrink (125) and T6 - Shrink (25)

SUMMARY AND CONCLUSION

The present investigation entitled, “Effect of different packaging film on shelf life and quality of Citrus species (*Citrus Limon*)” 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 from Kot Fatuhi, Dist. Hoshiarpur for carrying out this study. Lemons fruits were harvested at yellow stage on 10th february. The experiment was laid out in a completely randomized design (CRD) with three replications. There were six treatments viz., T₁ [control], T₂ [LDPE (25micron)], T₃ [cellophane (30 micron)], T₄ [cling film (10 micron)], T₅ [Shrink film (125 micron)], and T₆ [shrink film (25 micron)]. After packaging, consumer packs were stored at ambient conditions (21-22° C and 45-48 % RH). The results of experiment revealed that T₃ [cellophane (30 micron)], proved quite effective in reducing spoilage and maintained firmness and other quality attributes like total soluble solids, vitamin C content of the fruit.

Result of study

1. Moisture content was maintained good than all other treatments.
2. Spoilage occurred late than all other treatments.
3. Fruit firmness was maintained good than all other treatments.
4. Color of fruit was maintained.
5. Shelf life was increased and quality was good.
6. Fruit appearance was good.
7. Appearance of water inside cellophane was less than all other packaging's.

From present investigation it is concluded that cellophane 30 micron packaging is less cost method to increase shelf life of lemon up to 20 days with good quality.

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