STUDIES ON THE EFFECT OF VARIOUS PACKAGING MATERIALS AND WAXING ON SHELF LIFE AND FRUIT QUALITY OF KINNOW MANDARIN (*Citrus reticulata* Blanco)

M.Sc. (Hort.) Thesis

by

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DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA,
RAIPUR (Chhattisgarh)

2021

STUDIES ON THE EFFECT OF VARIOUS PACKAGING MATERIALS AND WAXING ON SHELF LIFE AND FRUIT QUALITY OF KINNOW MANDARIN (*Citrus reticulata* Blanco)

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Sudhir Soni

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

In

Horticulture
(Fruit Science)

U.E. ID No. 20192613 **ID No. 20192613**

JULY, 2021

CERTIFICATE – I

This is to certify that the thesis entitled **"Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)"** submitted in partial fulfilment of the requirements for the degree of **Master of Science in Horticulture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Sudhir Soni** under my/our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: 01-09-21

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	(Dr. R.R. Saxsena)	

CERTIFICATE – II

This is to certify that the thesis entitled **"Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)"** submitted by **Sudhir Soni** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Science in Horticulture** in the Department of **Fruit Science** has been approved by the external examiner and Student's Advisory Committee after an oral examination, under the chairmanship of Head of the Department.

Date: 18-11-21

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Major advisor _____

Faculty Dean _____

Approved/Not approved

Director of Instructions _____

ACKNOWLEDGEMENT

Research is creating new knowledge. Research needs the close co-operation of the friends and colleagues and the guidance of experts in the field to achieve something worthwhile with light patience, vigour and dedication of the person. Education plays vital role in personal and social development and teacher plays a fundamental role in imparting education.

I take this golden opportunity to express my heartfelt sense of gratitude to those who helped me to make my research possible. These words are small acknowledgement but never fully recomposed for their great help and cooperation.

I would like to acknowledge my indebtedness and render my warmest thanks to my learned and revered advisor Dr. Hemant Kumar Panigrahi, Assistant Professor, Indira Gandhi Krishi Vishwavidyalaya, Raipur and Chair Person of my Advisory Committee, who made this work possible. His friendly guidance, keen interest and expert advice have been invaluable throughout all stages of the work.

I feel proud to convey my heartfelt sense of gratitude to Dr. Deepti Patel, Assistant Professor, Department of Fruit Science, IGKV, Raipur, for their regular encouragement, timely advice whenever required, for enriching with productive scientific discussions and above all for being an excellent human being during the most trying time in this tenure of research work.

I express my sincere gratitude to the worthy members of my advisory committee, to Dr. Alok Tiwari Professor Dept. of Soil Science, and Dr. R. R. Saxena, Professor, Department of Agriculture Statistics and Social Science for their inspiring guidance and critical assessment of the manuscript.

I wish to record my grateful thanks to Dr. S. K. Patil, Hon'ble Vice Chancellor, Dr. R.K. Bajpai, Director Research Service, Dr. G.K. Das, Director of Instructions and Dr. M.P. Thakur, Dean, College of Agriculture, IGKV, Raipur for providing necessary facilities technical and administrative supports for conductance of this research work.

I express my gratification and venerable regards to Dr. Vijay Kumar, Head of the Department of Fruit Science for extending necessary facilities as and when required.I am immensely thankful to Dr. G.L. Sharma, Dr. G. D. Sahu, Dr. (Smt.) Pushpa Parihar and other technical and non-technical staff members of the

Department of Fruit Science, IGKV, Raipur for their co-operation and support during my work period for their encouragement and constant help throughout course of my studies. I extend my thanks to other non-teaching staff of Department of Fruit Science for their timely cooperation.

I would like to express my sincere gratitude to Dr. Madhav Pandey (Librarian, Nehru Library, IGKV, Raipur) and all other members of the Nehru Library for giving me their kind help during the study.

I wish to express my regards and heartful thanks to the support of non-technical staff of my department, Ganpat Bhaiya and sanjay bhaiya for their help during this piece of work.

I take this precious moment to express my deep sentiments and indebtedness to my other dept. Senior and friends Roopesh netam sir, Saurabh toppo sir, Chhaviraj bhagel sir, Nikunj sir, Suresh sahu, Ravi shankar sahu, Utkarsh sharma, Aswan bhoi, Akanand, Yogendra, Krishna, Gireesh, Pramod, Helli, Mahesh whose support and help led me to achieve my destination successfully. Without her precious support it would not be possible to finish my research.

I can hardly overlook the co-operation, timely help, moral support extended by my fellow classmates shri Jaspal sahu sir, Kai michi Tani, Eshwar, Mehattar, Ashish, Maksudan, Sannat, Ajay, Vinod, Jagdish, Amita, Kiran, Aisha, Reshma, Priyanka, Anjali, Chetna and Gunja who boosted me up in periods of mental stress and strain.

I wish to express my cordial and honest thanks to my seniors Gulshan sir, Aniket sir, Dipak sir, Dipesh sir, Pooja mam, Asnth mam, Romila mam, Gupta sir, Mandal sir, Nikunj sir for their kind support and encouragement during my study. I am also thankful to my friends Ravindra, Sachin, Nagendra, Shivam, Pinki, Ayushi for playing a par excellent role by showering friendly attitude, love, generous, right guidance and encouragement to complete my thesis work.

The dictionary falls short of words to express my irrepressible feelings and heartiest gratitude to my biggest assets of my life, my parents Mr. Radheshyam Soni and Smt. Atvareen Soni, my elder siblings Sunita, Sunil, Reshma for their filial affection, obstinate sacrifice, pampered support, sincere prayer and blessings which had been the vital source of inspiration.

I would like to convey my cordial thanks to all those who helped me directly or indirectly to fulfil my dream.

01-09-21

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ABBREVIATION	DESCRIPTION	ABBREVIATION	DESCRIPTION
%	Per cent	C.D.	Critical difference
Ha	Hectare	d.f.	Degree of freedom
Kg	Kilogram	Equi. Wt	Equivalent Weight
g	Gram	NS	Non-significant
ml	Milliliter	Ppm	Parts per million
T	Treatment	RH	Relative humidity
PP	Propylene	*	Fruit get spoiled
+	Add/plus	DAS	Days after storage
Var	Variety	NaOH	Sodium Hydroxide
µ	Microns	CFB	Corrugated fiber board boxes
&	And	CRD	Completely Randomized Design
˚B	Brix	SEd	Standard Error of difference
Fig	Figure	Cm	Centimeter
Mg	Milligram	Temp.	Temperature
cv.	Cultivar	°C	Degree Celsius
Viz	Namely	TSS	Total soluble sugars
=	Equal to	LOS	Level of significance
Wt	Weight	Kg/ha	Kilogram per hectare
X	Multiplied by	*et al.*	And others/co-worker
Min.	Minutes	SEm±	Standard Error of means
i.e.,	that is	LDPE	Low density polyethylene
No.	Number	HDPE	High density polyethylene
Max	Maimum	PLW	Physiological loss in weight

THESIS ABSTRACT

a) Title of the Thesis	:	Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)
b) Full Name of the Student	:	Sudhir Soni
c) Major Subject	:	Fruit Science
d) Name and Address of Major Advisor	:	Dr. Hemant Kumar Panigrahi Asstt. Professor, Department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.)
e) Degree to be awarded	:	M.Sc. (Hort.) Fruit Science

Signature of Major Advisor

Date: 01-09-21

Signature of Student

Signature of Head of the Department

ABSTRACT

The present experiment entitled **"Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)"** was conducted during the year 2020-2021 at Processing Laboratory, Department of Fruit Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The experiment was laid out in Completely Randomized Design, which consisted of 11 treatments and replicated thrice.

Under the present study, the packaging materials were used individually as well as in combinations with 10 % wax for treatment of fruits *viz.* T_0-Control (untreated), T_1-LDPE 25 µ, T_2-HDPE 15 µ, T_3-Polypropylene 25 µ, T_4-Shrink film 15 µ, T_5-Cling film 15 µ, T_6-LDPE 25 µ with 10 % wax, T_7-HDPE 15 µ with 10 % wax, T_8-Polypropylene 25 µ with 10 % wax, T_9-Shrink film 15 with 10 % wax and T_{10}-Cling film 15 µ with 10

% wax. The treated kinnow mandarin fruits were stored up to 25 days under ambient condition to analysis the physico-chemical composition, shelf-life and sensory parameters. All the data were recorded at every 5 days interval during storage period.

The present study revealed that the treatment T_{10}-cling film 15 µ with 10 % wax and T_9-shrink film 15 µ with 10 % wax combination were found effective for enhancing the physical, physiological and quality parameters of kinnow mandarin.

Amongst the various packaging and waxing treatments, cling film 15 µ with 10 % wax recorded the maximum fruit diameter (5.17 cm), fruit length (5.03 cm), total fruit weight (647.34 g), peel per cent (31.95) and juice per cent (54.37) as compared to rest of the treatments after 25 days of storage under ambient condition. Similarly, the same treatment exhibited the minimum physiological loss in weight (4.75 %), waste materials (13.68 %) and spoilage (18.74 %) of fruit at 25 days of storage.

In case of quality traits, the treatment cling film 15 µ with 10 % wax registered highest pH (4.10), total soluble solids (14.45 %), total sugar (7.48 %), reducing sugar (4.08 %), non-reducing sugar (3.40 %), ascorbic acid (19.43 mg/100 ml juice), TSS: acid ratio (23.68) and sugar: acid ratio (12.26). However, the acidity (0.61 %) was found to be lowest under the same treatment at the end of the experiment.

With regard sensory parameters, the highest score for colour appearance (8.27), taste (7.47) and flavour (7.56) were achieved under the treatment cling film 15 µ with 10 % wax, while the lowest score for colour appearance, taste and flavour (6.50, 6.30 and 6.39, respectively) were observed under the treatment T_3 (Polypropylene 25 µ). However, the fruits kept under control treatment (T_0) were completely discarded due to microbial spoilage at 25^{th} days of storage.

Based on the results of present experiment, it can be concluded that among the different packaging materials and waxing treatments, the treatment T_{10} (cling film 15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax) showed the best result under the ambient condition. Therefore, the treatment cling film 15 µ with 10 % wax (T_{10}) followed by shrink film 15 µ with 10 % wax (T_9) can be recommend for enhancing physico-chemical composition and shelf life of kinnow mandarin.

शोधग्रंथ सारांश

अ) शोध का शीर्षक	:	किन्नों संतरा (*साइट्रस रेटिकुलेटा* ब्लेंको) के भंडारण अवधि एवं फलों की गुणवत्ता पर विभिन्न पैकेजिंग सामग्रियों एवं वैक्सिंग के प्रभाव का अध्ययन
ब) छात्र का नाम	:	सुधीर सोनी
स) प्रमुख विषय	:	फल विज्ञान
द) मुख्य सलाहकार का नाम और पता	:	डॉ. हेमंत कुमार पाणिग्रही (सहायक प्रध्यापक) फल विज्ञान विभाग, कृषि महाविद्यालय रायपुर (छत्तीसगढ़)
ई) प्रदान की जाने वाली उपाधि	:	एम.एस.सी. (उद्यानिकी) फल विज्ञान विभाग

छात्र के हस्ताक्षर

प्रमुख सलाहकार के हस्ताक्षर

दिनांक : 01-09-21

विभागाध्यक्ष के हस्ताक्षर

सारांश

वर्तमान प्रयोग "किन्नों संतरा (*साइट्रस रेटिकुलेटा* ब्लेंको) के भंडारण अवधि एवं फलों की गुणवत्ता पर विभिन्न पैकेजिंग सामग्रियों एवं वैक्सिंग के प्रभाव का अध्ययन" पर ग्यारह उपचारों को तीन पुनरावृत्तियों में पूर्ण यादृच्छिक डिजाइन का उपयोग करते हुए कृषि महाविद्यालय, इंदिरा गाँधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) के अन्तर्गत स्थापित फल विज्ञान विभाग के फल प्रसंस्करण प्रयोगशाला में वर्ष 2020–2021 में किया गया।

वर्तमान प्रयोग में पैकेजिंग सामग्रियों को एकल रूप में तथा 10 प्रतिशत मोम के संयोजन के साथ उपचारों के रूप में लिया गया जो कि निम्नानुसार है उपचार $टी_0$ – नियंत्रण (अनुपचारित), उपचार $टी_1$ – एल.डी.पी.ई. 25 माइक्रॉन, उपचार $टी_2$ – एच.डी.पी.ई. 15 माइक्रॉन, उपचार $टी_3$ – पॉलीप्रोपाईलीन 25 माइक्रॉन, उपचार $टी_4$ – श्रिंक फिल्म 15 माइक्रॉन, उपचार $टी_5$ – क्लिंग फिल्म 15 माइक्रॉन, उपचार $टी_6$ – एल.डी.पी.ई. 25 माइक्रॉन के साथ 10 प्रतिशत मोम, उपचार $टी_7$ – एच.डी.पी.ई. 15 माइक्रॉन के साथ 10 प्रतिशत मोम, उपचार $टी_8$ – पॉलीप्रोपाईलीन 25 माइक्रॉन के साथ 10 प्रतिशत मोम, उपचार $टी_9$ – श्रिंक फिल्म 15 माइक्रॉन के साथ 10 प्रतिशत मोम और उपचार $टी_{10}$ – क्लिंग फिल्म 15 माइक्रॉन के साथ 10 प्रतिशत मोम। विभिन्न उपचारों से उपचारित किन्नों संतरा के फलों को उसकी भौतिक–रासायनिक संगठन, भंडारण अवधि एवं सवेंदी मानकों का विश्लेषण करने हेतु 25 दिनों तक परिवेशी दशा में भंडारित किया गया। भंडारण की अवधि में प्रत्येक 5 दिनों के अंतराल पर उसके सभी मानकों के डेटा का विश्लेषण किया गया।

वर्तमान अध्ययन से प्रकट होता है कि किन्नों संतरा के भौतिक गुणों, शारीरिक रचना एवं गुणवत्ता मापदंडो में बढ़ोत्तरी हेतु उपचार $टी_{10}$ (क्लिंग फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम) तथा उपचार $टी_9$ (श्रिंक फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम) प्रभावी पाया गया।

विभिन्न प्रकार के पैकेजिंग एवं मोम उपचारों में, क्लिंग फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम ($टी_{10}$) के अंतर्गत 25 दिनों के भंडारण के बाद परिवेशी दशा में फल का व्यास (5.17 से.मी.), फल की लम्बाई (5.03 से. मी.) फलों का कुल वजन (647.34 ग्रा), छिलका प्रतिशत (31.95) एवं जूस प्रतिशत (54.37) अन्य उपचारों की तुलना में अधिकतम दर्ज की गई जबकि सामान उपचार के अंतर्गत ही फलों की वजन में कमी (4.75 प्रतिशत), अवांछित सामग्री प्रतिशत (13.68) एवं फल विनष्ट होने का प्रतिशत (18.74) न्यूनतम दर्ज की गई।

गुणवत्ता सम्बन्धी मानको, जैसे – पी.एच (4.10), कुल विलेय ठोस (14.45 प्रतिशत), कुल शर्करा (7.48 प्रतिशत), अपचायक शर्करा (4.08 प्रतिशत), अन–अपचायक शर्करा (3.40 प्रतिशत), एस्कॉर्बिक अम्ल (19.43 मि.ग्रा/100 मि.ली. जूस), कुल विलेय ठोसः अम्ल अनुपात (23.68) एवं शर्कराः अम्ल अनुपात (12. 26) का अधिकतम मान क्लिंग फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम ($टी_{10}$) के अंतर्गत दर्ज की गई जबकि इसी उपचार के अंतर्गत ही अम्लता का न्यूनतम मान (0.61 प्रतिशत) प्राप्त हुआ।

संवेदी मानकों के संबंध में, जैसे रंग स्वरूप (8.27), स्वाद (7.47) एवं सुवास (7.56) का अधिकतम मान (स्कोर) क्लिंग फिल्म 15 माइक्रॉन तथा 10 प्रतिशत मोम ($टी_{10}$) के अंतर्गत प्राप्त हुआ जबकि इन मानकों (रंग स्वरूप, स्वाद एवं सुवास) का न्यूनतम मान (क्रमशः 6.50, 6.30 और 6.39) उपचार $टी_3$ (पॉलीप्रोपाईलीन 25 माइक्रॉन) के अंतर्गत देखी गई। 25 दिनों के भंडारण अवधि पर, नियंत्रण ($टी_0$) उपचार के अंतर्गत रखे गये फलों को पूर्णतः खराब पाये जाने के कारण बाहर कर दिया गया था।

वर्तमान प्रयोग के परिणाम के आधार पर यह निष्कर्ष निकाला जा सकता है, कि विभिन्न पैकेजिंग सामग्रियों एवं मोम के उपचारों में, उपचार $टी_{10}$ (क्लिंग फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम) एवं उसके बाद उपचार $टी_9$ (श्रिंक फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम) परिवेशी दशा में सर्वोत्तम पाया गया। अतः किन्नो फलों के भौतिक–रासायनिक संघटन एवं भंडारण अवधि में उतरोत्तर बढ़ोत्तरी हेतु क्लिंग फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम (उपचार $टी_{10}$) एवं उसके बाद श्रिंक फिल्म 15 माइक्रॉन एवं 10 प्रतिशत मोम (उपचार $टी_9$) को अनुसंशित किया जा सकता है।

CHAPTER - I
INTRODUCTION

The kinnow is an interspecific cross between two citrus cultivars, "King (*Citrus nobilis*) and Willow Leaf" (*Citrus deliciosa*), that was initially introduced in 1915 at the University of California's Citrus Experiment Station by Howard B. Frost. After a 20-year evaluation period, the kinnow mandarin was recognized as the latest citrus hybrid for commercial production in 1935. Its features are something like mandarin and sweet orange and its skin is neither loose nor tight. It was brought to the Punjab Agriculture College and Research Institute, Lyallpur (Pakistan) in 1940. However, Dr. J.C. Bakhshi introduced in India 1954 from Research Centre of California (USA) it to the Punjab Agriculture University and Regional Fruit Research Station, Abohar. In the beginning of experiment four plants were conserved in the citrus collection of Regional Fruit Research Station, Abohar. After evaluating its consistent performance at the research station, kinnow was recommended for commercial production. Since then, it has emerged as one of the number one fruit, both in area and production and has brought the "Golden Evolution" in the Punjab. It's a high-yielding mandarin hybrid that is widely grown in India and Pakistan's Punjab region. The tree grows quickly, vigorously and vertically, with a significant tendency for alternative bearing.

The fruit is medium in size with moderately to slightly oblate having both base and apex flattened or slightly depressed. Rind are thin, rather adherent for a mandarin but peel able, tough and leathery, surfaces very smooth and glossy, sometimes faintly pitted, color yellowish-orange at maturity (Ladaniya *et al.* 2008). Segments 9 to 10 firm, separating fairly easily, axis solid to semi-hollow. Flesh color deep yellowish-orange, very juicy. It is an early bearer of superior fruit quality and excessive juice content, flavour rich, aromatic and distinctive (Jawandha *et al*. 2014). Seed numerous, polyembryonic and cotyledons pale greenish-yellow and matures in mid-season (Ladaniya *et al*. 2008). Fruit holds well on tree with little puffing.

Kinnow cultivation is becoming more popular in the tropics and subtropics as a result of its adaptability, high yield, and higher economic return. The kinnow

fruit ripens from December to February for commercial harvesting. In various states, the maximum harvesting season for kinnow varies from November (Jammu & Kashmir), December-January (Haryana), January (Himachal Pradesh and Rajasthan) and January-February (Punjab) (Anonymous, 2018). In India, the orange group, which includes mandarin and kinnow, produced 6.79 million tonnes on 0.47 million hectares of land (Mahawar *et al.* 2020). In general, 60 to 70% of the fruits grown in India are consumed domestically, with only 2% being exported. Just 1% of overall demand goes to the export market. Post-harvest losses account for 20-30% of all stored fruits. Qualitative losses, rather than quantitative losses, are more complicated to evaluate in post-harvest losses (Kader, 2005). However, between 28% and 31% of citrus fruits are thrown away due to unsuitable storage of fruits after harvest and poor packing causes major losses in quality and quantity (Miri *et al*. 2018). The post-harvest loss of vitamins, minerals, biochemical compounds and antioxidants, etc occurs during the storage of fruits, in which ascorbic acid being the most susceptible to post-harvest losses (Kalt 2005).

In mandarin, an account of 20-25% loss has been estimated due to transportation of fruits from field to market (PHLRD, 2005). Qualitative losses, in sense of caloric and nutritive value, non-acceptability by consumers and poor edibility are more difficult to measure than quantitative losses of fresh fruits. Among for stored fruits, post-harvest losses account to 20-30%. In most of the storability studies for fruits, it is found that the levels of CO_2 and O_2 inside package changed due to fruit internal respiration and permeability of the film, which resulted in recommendation of modified atmosphere packaging (MAP) for fresh fruit storage (Geeson, 1989).

MAP was first concluded in 1927 as a way to extend the shelf-life of apples by storing in lower O_2 and higher CO_2 concentrations. It was first used as modified atmosphere storage in the year 1930 to transport fruit in the holds of ships by increasing CO_2 concentrations for long-distance transport, where it was found to enhance the shelf life up to 100 % (Davies, 1995 and Mangaraj *et al.* 2009).

The modified atmosphere built up around the produce brings about beneficial effects for extending the shelf life of product. Mixture is made of

primarily of O_2, CO_2 and N_2 with small amounts of noble gases. Packaging in plastic films manipulates the atmosphere surrounding of the produce. MAP generally restricts air movements, allowing the product's normal respiration process to increase the carbon dioxide content and reducing oxygen content of air inside the package. The expected benefits of MAP are reduction of respiration rate and ethylene production, inhibition of ripening senescence, minimization of water loss and nutrient decomposition, inhibition of microbial growth and microbial spoilage, extension of shelf life with quality attributes and in reduction of water loss.

Packaging film provides a water-saturated environment around the fruits, reducing water loss. It reduces the rate of respiration, transpiration and other metabolic activities in fruits (Dhillon *et al*. 2016). Also as result, metabolic weight loss is reduced, deterioration is reduced and fruit colour and texture appearance preserved are maintained for a longer period (Sharma *et al*. 2012). The importance of packaging is very necessary for postharvest activities of horticultural crops. However, its role is still underestimated in our nation.

Edible coatings have been long used to maintain the quality and extend the shelf-life of many fresh fruits *viz.* apple, citrus. They have been used directly on fruit surfaces as a thin coating. There are several modes of application for applying edible coatings *viz.* dipping, spraying, or brushing which create a modified atmosphere (Mchugh and Senesi, 2000)**.** Basically, the use of food-grade wax coatings on fresh fruits has been allowed by the Indian govt and with the adoption of this technique, many wax formulations are now available by suppliers markets.

Generally, the edible film or covering is any kind of substance used to wrapping or coating different fruits to prolong their storability and that may be consumed with or without removal (Pavlath and Orts, 2009).

So, the influence of these waxes coating plays an important role in monitoring the storability of fresh fruits, especially kinnow mandarin. Waxes are the most effective edible compounds for preventing weight loss (retaining moisture), inhibiting microorganisms, slowing aerobic respiration and improving attractiveness (Suput *et al*. 2015). The function of these waxes alone or in

conjunction with packaging required a great deal of emphasis on correlating the positive mode of applicability to information.

The research work on effect of various packaging materials and waxing on shelf life and fruit quality on kinnow mandarin is still meagre in India as well as in Chhattisgarh. Therefore looking to the above facts in view the present investigation entitled **"Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)"** has been carried out at Processing Laboratory, department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.) during 2020-2021 with the following objectives:

1. To study the effect of various packaging materials and waxing on physical parameters of kinnow fruit.
2. To study the effect of various packaging materials and waxing on physiological loss in weight and shelf life of kinnow during storage.
3. To study the effect of various packaging materials and waxing on chemical composition and sensory evaluation of kinnow fruits during storage.

CHAPTER-II
REVIEW OF LITERATURE

Kinnow mandarin is a non-climacteric fruit, due to low respiration rate, they don't undergo rapid physiological changes and has lesser ethylene evaluation as compared to climacteric fruits under normal condition.

The kinnow mandarin arrives in the market during the month of November. However, the demand for kinnow peaks up with the beginning of summer, but under ordinary storage conditions, it can't usually be kept for a longer period as it starts deteriorating. The quality of the fruits can be retained for a longer period of time by adopting several modified packaging methods, which enhances the shelf life and ensuring the availability of good quality kinnow in the markets with minimum spoilage of the fruit.

The research work on effect of different packaging materials and waxing on kinnow is still meager in India and this work has been conducted first time in Chhattisgarh. This chapter deals with available review of literature on a foresaid topic have been summarized under the following headings:

2.1 Effect of various packaging materials and waxing on physical parameters of kinnow and other fruit crops.

2.2 Effect of various packaging materials and waxing on physiological loss in weight and shelf life of kinnow and other fruit crops during storage.

2.3 Effect of various packaging materials and waxing on chemical composition and sensory evaluation of kinnow and other fruit crops during storage.

2.1 Effect of various packaging materials and waxing on physical parameters of kinnow and other fruit crops.

Randhawa *et al.* (2009) studied the shelf-life of kinnow mandarin by the use of HDPE packaging, followed by edible oils (neem, mustard, coconut, and olive oils) and wax (citrashine) coating. After the completion of study, they determined that the highest juice recovery per cent were obtained from the neem oil cum HDPE treated fruits, whereas the least per cent were noticed in control fruits at 45 days of storage. It was also observed that the entire treatment combined with HDPE recovered higher juice per cent than other treatments.

Ahmad *et al.* (2013) studied that the impact of various post-harvest treatments and storage conditions for the consistency of kinnow. The highest juice per cent was found in zero energy cool chamber, followed by cold storage and the lowest juice per cent was found in fruits stored at room temperature. Further, it was revealed that during the initial stage, the juice per cent (started at 40.18%) increased in entire treatments at similar pattern and storage situations, but decreased gradually as the storage period extended.

Rokaya *et al.* (2016) concluded that wax combined with bavistin found to be most effective and recorded highest juice per cent (49.56%) among all other treatments during the storage.

Sohi *et al.* (2016) investigated the effect of different packaging materials on the storage life and quality attributes of kinnow, where the fruits were packed in LDPE film, LDPE film with 0.01 per cent perforation, LDPE film containing 0.02 per cent perforation, HDPE film, HDPE film containing with 0.01 per cent perforation, HDPE film with 0.02 per cent perforation, polypropylene film, polypropylene film with 0.01 per cent perforation and control fruits was without packed. The experimental results revealed that the maximum juice percentage (42.61%) was observed in LDPE tray packaging with 0.01 % perforation and the minimum juice recovery (30.22%) was found under the control.

Choudhary *et al.* (2017) reported that the polythene packaging registered the highest juice percentage (50.50 %) on pears, which the minimum (34.29 %) was noted in linseed oil coated pears during the 24 days of the observation period as compared to rest of the treatments.

Hayat *et al.* (2017) concluded that the maximum juice per cent (45.36 and 39.70 %) was obtained from the fruits treated with citrus wax at 30 and 45 days of storage period in Kagzi lime. While, the minimum juice percentage (35.13 and 32.94 %) was recorded under untreated control fruits at 30 and 45 days of the storage period.

Baswal *et al.* (2020) observed the influence of MAP films on shelf life and fruit quality of kinnow during cold storage and concluded that the fruit packed in PP-film (25μ) with pinholes obtained significantly maximum juice recovery per cent (47.10 %) as compared to control (42.63 %) and other MAP treatments.

Miri *et al.* (2018) studied the influence of wax, polyethylene film (19 μm thickness) and storage time on the quantitative and qualitative characteristics and shelf life of 'kinnow' mandarin (*Citrus reticulata* Blanco) stored at 5°C for 90 days. Results showed that the fruits packaged under polyethylene film registered maximum average fruit weight (104.6 g), pulp weight (41.0 g), juice weight (37.7 g) and peel weight (26.0 g). Whereas the minimum fruit weight (80.2 g), pulp weight (34.7 g), juice weight (27.8 g) and peel weight (17.5 g) was observed under the control fruits.

Manisha and Gandhi (2019) analysed the influence of various coatings materials with polythene packaging on shelf life and quality of kinnow mandarin. They observed that the minimum reduction in fruit length (1.22 mm), fruit breadth (4.24 mm) and fruit weight (3.07 g) was achieved under the polythene packaging as compared to other treatments at 28 days of the observation period.

Paudel *et al.* (2019) studied different packaging materials along with GA_3 application on kinnow mandarin, which was individually wrapped or combined with GA_3. The result revealed that the fruits treated with GA_3 and perforated polyethylene yielded the maximum amount of juice (33.63%) at 24 days of storage among all other treatments.

Rashid *et al.* (2019) reported that the kinnow mandarin treated with fomesa wax and 30 % coconut oil recorded the highest juice recovery per cent and peel per cent at 90 days of storage period.

Acharya *et al.* (2020) studied various post-harvest treatments to enhance shelf life and quality parameters of kinnow mandarin. After the research, they found that the perforated plastic obtained the maximum juice recovery percentage (36.12%), while the control treatment had the lowest juice recovery percentage (26.70%), which was statistically equivalent to newspaper wrapping (27.24 %).

Gidagiri *et al.* (2020) investigated the benefits of Zeolite-LDPE Composite bags for extending the shelf life of acid lime fruit stored at room temperature. From the experimental data, they found that the juice recovery per cent of acid lime showed decreasing trend with the progress of the observation period. However, the Chlorine-zeolite-LDPE composite bag with CFB expressed the highest proportion of fruit juice at the end of storage (50.01 %).

Joshi *et al.* (2020) recorded the maximum juice per cent (43.72 %) under wax combined with bavistin treated fruits, which was statistically at par with the estimation of wax 10%, bavistin 0.1%, eucalyptus oil (2%), cinnamon oil (2%) and 1 % calcium chloride but the lowest juice per cent (33.89%) was obtained in untreated control fruits during the 41 day of storage period.

Thapa *et al.* (2020) conducted an experiment to study the effect of different post-harvest treatment on prolonging the shelf life and quality of sweet orange (*Citrus sinensis* Osbeck) stored at ambient room condition for 40 days. From the experimental results, they concluded that the percentage of juice decreased day to day in all the treatments during the storage period. Fruits treated with wax registered the highest juice per cent (31.43%), while control fruits had the lowest juice per cent (27.81%).

2.2 Effect of various packaging materials and waxing on physiological loss in weight and shelf life of kinnow and other fruit crops during storage

Ladaniya (2003) investigated the impact of heat-shrinkable wrapping and stretchable cling films on ‘Mosambi' orange processed at 25°C and 40–45% relative humidity. It was found that cling film wrappings showed minimum physiological loss in weight and minimized the deterioration rate up to 40 days of storage.

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

Randhawa *et al.* (2009) investigated the shelf-life of ‘kinnow’ mandarin with the use of high-density polyethylene (HDPE) packaging and edible oils

(neem, mustard, coconut, and olive oils) and wax (citrashine) coating. After the experiment they concluded that the maximum percentage of loss in weight was observed under olive oil (8.51 %) as compared to other treatments.

Sonkar *et al.* (2009) revealed that the kinnow fruits packed with cling film performed best with respect to physiological loss in weight per cent under atmospheric conditions.

Kore and Kabir (2011) observed that the guava fruits treated with wax emulsion (0.2 %, 0.4 % and 0.8 %) in combination with 200-gauge polyethylene's significantly reduced physiological loss in weight per cent for a longer time (9^{th} day of storage).

Pongener *et al.* (2011) reported that the packaging of peach fruit with shrink films recorded the least physiological loss in weight per cent (0.85 %) up to 28 days under 0-1°C and 90-95% relative humidity in cold storage.

Bisen *et al.* (2012) examined the shelf life of kagzi lime with Calcium chloride, $KMnO_4$ and edible coatings such as coconut oil, mustard oil, sesamum oil, castor oil and liquid paraffin wax. The treated fruits were kept at room temperature between 25° and 30°C, with 60 to 70% RH for 18 days. They concluded that coconut oil had the major impact on reduction of physiological loss in weight (9.67%) in kagzi lime.

Jawandha *et al.* (2014) studied the influence of LDPE and HDPE film packaging with various chemicals (citrashine wax, 0.1% bavistin) on the room storage of kinnow mandarin. After the study, it was found that the kinnow mandarin treated with 3 % boric acid under LDPE film packaging (without perforated) showed the lowest percentage of weight loss.

Sharma *et al.* (2012) conducted an experiment on effect of different packaging materials on shelf-life and PLW per cent of kiwi fruit and found that the fruits wrapped with 9 μ cryovac shrink film recorded the minimum physiological loss in weight (2.3%) as compared to all other treatments at18^{th} day of storage at ambient condition.

Hassan *et al.* (2014) evaluated the influence of wax coating on the fruit quality of tangerine citrus and showed that the combination of 12 % wax coating stored at 5°C proved to be the most effective treatment for maintaining the least physiological loss in weight (16.88 %).

Hemalatha *et al.* (2015) investigated the role of surface coating on PLW percentage of sweet orange. The treatment consisted 2,4-D 500 ppm + wax 6 %, GA_3 500 ppm + wax 6 % and benzyl adenine 50 ppm + wax 6 %. They revealed that the sweet orange treated with BA 50 ppm + wax 6% expressed the minimum physiological loss in weight per cent.

Mandal (2015) examined the kinnow fruits treated with lac-wax, citrashine and individually shrink wrapped in LDPE (19μ) and packed in 4 kg CFB boxes and stored under ambient conditions. From the experimental evaluation, they noticed that maximum PLW % was recorded in control fruit (16.16%), whereas, shrink-wrapped (10.37%) and lac-wax (11.92%) treated fruit significantly reduced PLW % after 21 days of storage.

Singh and Yadav (2015) evaluated the effect of packaging material and evaporative cooled storage environment on quality characteristics of kinnow fruits and they noticed that the rate of loss in weight was slower in initial days, but after few days PLW % was comparatively increased in entire treatments during the storage period. They noticed that highest PLW (15.92%) was recorded under 100 gauge LDPE bags with 1% perforation in ambient condition but the lowest PLW (3.57%) was noticed under evaporative cool chamber with rice husk ash (ECC RHA) + 100 gauge LDPE bags with 1% perforation during 28 days of storage period of fruit.

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

Mahajan *et al.* (2016) conducted an experiment and reported that minimum mean physiological loss in weight for kinnow mandarin was obtained under the treatment shrink film packaging, while the maximum mean value (12.2 % PLW) was showed by untreated control fruits during 25 days of storage period.

Rokaya *et al.* (2016) reported that wax combination with bavistin was most effective in minimizing physiological weight loss after four weeks of storage. Further they conceded that kinnow fruit can be stored up to more than four weeks if fruits are treated with wax and bavistin and stored at 14-18°C and 45-73 % relative humidity.

Sohi *et al.* (2016) studied the effect of various packaging materials *viz.* LDPE film, LDPE film with 0.01 per cent perforation, LDPE film containing 0.02 per cent perforation, HDPE film, HDPE film containing 0.01 per cent perforation, HDPE film with 0.02 per cent perforation, polypropylene film, polypropylene film with 0.01 per cent perforation and control in which fruits was kept without packed. After the study they concluded that the lowest mean physiological loss in weight (0.42%) was observed under the fruits packed in polypropylene film without perforation as compared to all other treatments followed by LDPE and HDPE without perforation (0.43%)

Bhattarai and Shah (2017) studied the effect of several packaging materials on post-harvest status of mandarin (*Citrus reticuleta* Blanco) and stated that minimum physiological loss in weight (0.28 %) was noted in fruits treated with 20 µ plastic with 5 holes wrapping, however the maximum physiological loss in weight was found in control (10.02 %).

Choudhary *et al.* (2017) observed that pear fruits packed with polythene packaging showed the lowest physiological loss in weight (0.972 g) as compared to other treatments during the storage period of 24 days and further they concluded that this particular treatment showed lower effect on the quality of the fruit at ambient condition.

Hayat *et al*. (2017) investigated the impact of various wax covering materials and modified atmosphere packaging (MAP) on storage life and quality of 'kaghzi lime' (*Citrus aurantifolia* Swing.) The fruits of kagzi lime were treated with citrus wax (wood resins (18%), imazalil (0.3%), thiabendazloe (0.5%)), PHRC SCM Wax [9% absolute solids (castor and shellac-based wax)], MAP and the natural product with no treatment as control. During the 45 days of storage period, it was revealed that the highest percentage weight loss (33.46%) was recorded under control treatment, whereas MAP showed the lowest physiological loss in weight (1.04%), which was followed by citrus wax (18.35%).

Thakur *et al.* (2017) conducted an experiment using shrink film wrapper for enhancing the shelf-life of apple and concluded that apple fruits wrapped with shrink film (25 µ) showed the least PLW (1.85 %) at the fourth week of storage, which was the lowest weight loss as compared to the fruits wrapped in shrink film 15 μ (3.35 %).

Watharkar *et al.* (2017) investigated the physiological loss in weight % of grapes (*Vitis vinifera*) with the use of low-density polyethylene (LDPE) 100 gauges and polypropylene film of 90 gauges. The results revealed that PLW (0.55%) was observed minimum under LDPE film 100 gauges as compared to louver allay film and polypropylene film.

Baswal *et al.* (2020) studied the impact of MAP Films on shelf life and quality of kinnow fruit under cold storage. After the completion of research, they concluded that the fruit packed under PP-film (25 µ) with pinholes showed significantly minimum physiological loss in weight per cent (0.47 %) as compared to control (6.68 %).

Miri *et al.* (2018) evaluated the influence of wax, polyethylene film (19 µm thickness) and storage time on the quantitative and qualitative characteristics and shelf life of 'kinnow' mandarin stored at 5°C for 90 days. They revealed that the fruit wrapped in polyethylene film had the lowest PLW (4.1 %), while control fruits had the highest PLW (26.4 %) in kinnow fruit.

Rana and Siddiqui (2018) concluded that guava fruit wrapped with cling film minimized the physiological loss in weight (1.49 %) at 24 days of storage period.

Rao and Shivashankara (2018) reported that the physiological loss in weight of modified atmosphere packed pomegranates was 1% even after 4 months of storage as compared to 23.5 per cent in non-packed fruits measured at low temperature.

Manisha and Gandhi (2019) analyzed the influence of various coatings materials with polythene packaging treatments like wax coating, polythene wrapping, oil coating and waxing cum polythene on shelf life and quality of kinnow mandarin and concluded that the minimum PLW per cent (1.84 %) was obtained in polythene packaging as compared to all other treatments at 28^{th} days of storage period.

Nagaraju *et al.* (2019) studied the effect of different packaging materials on shelf life and quality of guava fruits. The guava fruit was packed under various packaging material *viz.* HDPE 1% perforation + $KMnO_4$, HDPE 2% perforation + $KMnO_4$, HDPE non perforation + $KMnO_4$, LDPE 1% perforation + $KMnO_4$, LDPE 2% perforation + $KMnO_4$, LDPE non perforation + $KMnO_4$ and control without packaging. Their experimental result concluded that the least physiological loss in weight (1.38 %) was expressed under un-perforated LDPE on the 15^{th} day of storage.

Paudel *et al.* (2019) conducted a trial using different packaging materials (like corrugated box, perforated plastic packaging, newspaper) and GA_3 on kinnow mandarin wrapped individually or in combination with GA_3. After their trial, it was found that those fruits treated under GA_3 combined with perforated polyethylene exhibited the lowest per cent of physiological loss in weight (1.99%) during the entire storage time.

Rashid *et al.*(2019) studied the impact of botanical extracts and commercial coating materials on kinnow mandarin (*Citrus reticulata* L.) and concluded that fruit treated with 30% coconut oil recorded the lowest 11.70% of physiological loss in weight.

Srivastava and Said (2019) conducted an investigation on shelf-life of pomegranate fruit by using different modified atmosphere packagings (200-gauge HDPE, 300 gauge HDPE and silicone membrane system). They observed that the fruit packed with 200-gauge HDPE showed lower PLW per cent (6-8 %) under atmospheric conditions at 55–60 days, whereas the value of PLW in control fruits increased to 12 per cent under 10 days of storage period.

Acharya *et al.* (2020) conducted a research using several post-harvest treatments for prolonging shelf life and quality of kinnow mandarin. As per their research, they concluded that post-harvest treatment with perforated plastic showed least PLW per cent (16.32%), while the control fruits expressed the maximum PLW per cent (35.47%), which was found statistically equivalent to newspaper wrapping (33.28 per cent).

Bhandari *et al.* (2020) evaluated the effect of post-harvest treatments on the shelf life and quality of sweet orange (*Citrus sinensis*) and found that the physiological loss in weight varied from 2.580 % (on the 7^{th} days) to 15.83 % (on the 28^{th} days) with the highest value observed in untreated control fruits during the 28^{th} days of storage period.

Gidagiri *et al.* (2020) reported that packaging of fruit with Chlorine-zeolite-LDPE composite bag + CFB indicated the least physiological loss in weight (17.04%) of kinnow fruits among the whole treatments at the end of storage.

Joshi *et al.* (2020) studied the role of various post-harvest treatments on quality and shelf life of kinnow and found that the juice per cent reduced with storage time in all the treatments. They observed the maximum juice per cent (43.72%) under wax combined with bavistin treated fruits, which was statistically at par with the mean values of wax 10%, bavistin 0.1%, eucalyptus oil (2%), cinnamon oil (2%) and 1 % calcium chloride. However, the lowest juice per cent (33.89%) was obtained in untreated control fruits on the 41 day of storage period.

Thapa *et al.* (2020) conducted an experiment by using different post-harvest treatments for extending the shelf life and maintaining the quality of sweet orange (*Citrus sinensis* Osbeck) up to 40 days of storage in ambient conditions. They observed that the fruits treated with paraffin wax registered the lowest PLW%

ranging from 0.904 to 5.83 per cent, while the untreated fruits as controls expressed the highest physiological loss in weight (1.14 to 7.41 per cent) at the 40^{th} days of the storage period.

Singh *et al.* (2020) revealed that the guava fruits packed with low density polyethylene films (50μm) delayed the change of physiological loss in weight under storage. They also reported that guava fruits can be stored up to 16 days at room temperature but the storage period can be increased for 32 days at low temperature of 5±2°C.

2.3 Effect of various packaging materials and waxing on chemical composition and sensory evaluation of kinnow and other fruit crops during storage

Hussain *et al.* (2004) studied the packaging of citrus fruits with polyethylene and revealed that this treatment had a significant influence on shelf life and the retention of flavor, texture and external color appearance.

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

Randhawa *et al.* (2009) analyzed the influence of HDPE film packaging by edible oils (neem, mustard, coconut and olive oils) and wax (citrashine) coating on kinnow mandarin. They revealed that citrashine wax expressed the maximum total soluble solids (12.4 %), whereas application of neem oil with HDPE packed fruits recorded the highest acidity (0.68 %) at 45 days of storage period.

Kore and Kabir (2011) studied the impact of carnauba wax emulsion treatments in different concentrations (0.1 %, 0.2 %, 0.4 % and 0.8 %) in combination with 140 and 200-gauge polyethylene film on guava fruit. They observed that the wax emulsion combined with 200 gauge of polyethylene packaging had significant effect on total soluble solids and acidity of guava fruits.

Bisen *et al.* (2012) examined the shelf life of kagzi lime treated with calcium chloride, $KMnO_4$ and edible coatings such as coconut oil, mustard oil, sesamum oil, castor oil and liquid paraffin wax. The treated fruits were kept at room temperature between 25 to 30^{o} C and 60 to 70% RH for 18 days. They found that oil emulsed with coconut oil, caused significant reduction of acidity (1.52 per

cent) and increased ascorbic acid content of fruit juice (49.43 mg/ 100 ml of juice).

Ahmad *et al.* (2013) investigated the impact of various post-harvest treatments and storage conditions for the consistency of kinnow fruit up to 60 days and reported that fruits stored at cold temperature (4±1°C and RH 85-95%) and ZECC (12-22°C and RH 85-95%) showed lower physico-chemical changes than those stored at room temperatures (18-32°C, RH 45-65%).

Hassan *et al.* (2014) evaluated the influence of wax coating on the chemical fruit quality and organoleptic scores of tangerine citrus (kinnow mandarin). Fruits were coated with three various concentrations of wax emulsion (10, 12 and 15%) and stored at two temperature levels (5 and 25°C) with 85-90% relative humidity. Their results revealed that the combination of 12% wax coating and storage at 5°C proved to be the most effective for increasing chemical properties and oranoleptic scores.

Jawandha *et al.* (2014) studied the effect of modified atmosphere packaging on storage of Baramasi lemon (*Citrus limon* (L.) Burm). The experiment comprised of five treatments *viz.*, HDPE packaging, LDPE packaging, wax coating, bavistin treatment and control (untreated). They revealed that the fruits treated with bavistin @ 0.1% and packed with LDPE bags maintained the best fruit quality in terms of high sensory quality, juice content, acidity and low spoilage percentage during 50 days of ambient storage.

Mahajan and Singh (2014) reported that kinnow mandarin packed under shrink film significantly enhanced the organoleptic quality characteristics up to 20 days, which later gradually decline. However, the fruits under the control treatment, increased the sensory score at 5 days of storage and thereafter declined at a faster rate. They found that the maximum mean organoleptic grade (7.76) was obtained in shrink film wrapped mandarin.

Hemalatha *et al.* (2015) analyzed the role of growth regulators on shelf-life of sweet orange and reported that BA 50ppm + wax 6% (30.95) recorded the minimum spoilage per cent, skin color score (1.56) as compared to other treated fruits, whereas maximum spoilage per cent (51.13%) and the color score (2.57) was recorded in control fruits.

Jhalegar *et al.* (2015) assessed the role of surface coating of lac-based wax, Citrashine, P-104 and Niprofresh on quality of kinnow. They concluded that the surface coatings enhanced the storability and quality of kinnow fruits up to 60 days.

Mandal (2015) examined the kinnow fruit treated with lac-wax, citrashine and individually shrink wrapped in LDPE (19μ), which was later packed in four kg CFB boxes stored under ambient conditions. The individually shrink-wrapped fruits expressed the maximum TSS per cent (11.37%) during 7 days of storage and thereafter TSS per cent declined. However, these treated wrapped fruit maintained the highest TSS (10.37) on the 21 days of storage, but the maximum acidity per cent (0.88%) was found in lac-wax treated and control fruits.

Singh and Yadav (2015) evaluated that the effect of different packaging materials and evaporative cooled storage environment on quality characteristics of kinnow fruits and they noticed that the 100 gauge LDPE (Low-Density Polyethylene) bag combined with rice husk ash (RHA) under evaporative cool chamber maintained the superior quality of kinnow in terms of highest overall acceptability, but showed the lowest pH (4.23).Whereas, the fruits treated under 100 gauge LDPE with 1% perforation recorded the highest pH (4.51) and TSS (12.91 %) at ambient condition.

Dhillon *et al.* (2016) concluded that fruits wrapped with LDPE showed the maximum spoilage per cent (9%) as compared to unpacked control fruits (5%). However, higher organoleptic sensory score was recorded in shrink film wrapped fruits.

Mahajan *et al.* (2016) conducted an experiment by using several packaging films for extending the shelf-life and quality traits of kinnow mandarin. According to their experimental results they conducted that the shrink RD-106 film was found to be most efficient in preserving the consistency of TSS, Acidity and Vit C than other treatments during 25 days of storage.

Pippal *et al.* (2016) observed that the chemical quality of kinnow by using several chemicals (2, 4-Dichlorophenoxy acetic acid 50 and 100 ppm and Gibberellic acid 50 and 100 ppm) and different types of packaging materials (Corrugated boxes, perforated polythene and newspaper), which were applied

individually or in combination. After 20 days of storage they concluded that the highest values of total soluble solids (13.12 %), total sugar (9.56 %) and ascorbic acid (14.17 mg/100 ml juice) was obtained under fruits treated with combination of 2,4-D 100 ppm and perforated polythene.

Rokaya *et al.* (2016) investigated the post-harvest treatments on kinnow fruits and concluded that wax combination with bavistin was the most effective in obtaining maximum vitamin C and TSS, while the acidity was recorded least in the fruits treated with same treatment.

Sohi *et al.* (2016) investigated the effect of various packaging materials on storage life and quality of kinnow fruits packed in LDPE film, LDPE film with 0.01 per cent hole, LDPE film containing 0.02 per cent hole, HDPE film, HDPE film containing 0.01 per cent perforation, HDPE film with 0.02 per cent perforation, polypropylene film, polypropylene film with 0.01 per cent perforation and control in which fruits which was kept without packing. They observed that the maximum TSS (10.87 %) was registered under LDPE tray packaging with 0.02 % perforation and the minimum TSS (9.57 %) was noticed in HDPE tray packaging without perforation.

Hayat *et al.* (2017) found the highest TSS (7.59%) under untreated fruits during 45 days of storage period, whereas the lowest TSS (7.24%) was found under the fruits treated with citrus wax.

Singh *et al.* (2017) revealed that the fruits wrapped with cling film and wax (10%) gave the highest value for total sugar (6.11%), total soluble solids (12.22%) and pH (4.27). However, that same treatment showed the minimum value of ascorbic acid and acidity.

Watharkar *et al.* (2017) studied the influence of different packaging materials on shelf life and quality of grapes cv. Thomson seedless. Their experimental study concluded that the quality parameters like ascorbic acid content and acidity was least affected with the LAF packaging than others. The decrease in acidity (%) and ascorbic acid content under louver allay film was found 2.80 mg/100g and 0.03 % respectively, whereas in LDPE packaging it was 1.54mg/100g and 0.03 %, respectively. Further they concluded that the

polypropylene film was the most effective packaging material to retain TSS values up to 14.92 %.

Baswal *et al.* (2020) analyzed the impact of MAP Films on shelf-life and quality of kinnow fruit during cold storage. They observed that there was an increased spoilage percentage of fruits (3.70 % to 59.72 %) despite using the MAP treatments. However, the fruit packed under polypropylene film (25 μ) with pinholes significantly reduced the loss of spoilage (2.50 %) as compared to control (10.83 %) and other MAP treatments.

Mahajan *et al.* (2018) studied the role of physico-chemical and bioactive compounds on the quality and post-harvest shelf-life of kinnow fruit during different stages of maturity. They studied three various groups of kinnow fruit (large, medium and small) and recorded TSS value was ranged from 9.74 to 11.06 % and the acidity varied from 0.68 to 0.96 %. They further concluded that the highest TSS per cent was recorded in the month of January, whereas the maximum acidity per cent was obtained in November in all the groups of kinnow fruit.

Miri *et al.* (2018) evaluated the influence of wax, polyethylene film (19 μm) and storage time on the quantitative and qualitative characteristic as well as shelf life of 'kinnow' mandarin (*Citrus reticulata* Blanco) stored at 5°C for 90 days. The results revealed that the fruits packaged with polyethylene film resulted the TSS values (10.1 and 11.3 %) at the beginning and end of the storage period respectively.

Rao and Shivashankara (2018) recorded the highest total soluble solids of pomegranate (15.75%) in LDPE and acidity (0.90%) in croyovac shrink BDF. Similaly, the highest ascorbic acid (7.8 mg) and sugars (12.73 %) were recorded under D - 955 treatment after 4 week of storage period.

Sharma *et al.* (2018) reported that the fruits wrapped with different thickness of shrink-films (*i.e.*, 125 μ and 25 μ) expressed the highest value for respective total soluble solids (10.96%, 10.51%), acidity (0.53%, 0.53%), ascorbic acid (19.62 mg, 19.09 mg) and total sugar (6.37%, 6.15%) as compared to other treatments during the 25 days of the observation period.

Sharma *et al.* (2018) reported that kinnow mandarin wrapped with Shrink film (125 μ and 25 μ) showed the lowest value of spoilage per cent (1.09% and 1.59%, respectively) among the all treatments after 25 days of storage.

Paudel *et al.* (2019) conducted a trial on the effect of different packaging materials (corrugated box, perforated plastic packaging & newspaper) and GA_3 on kinnow mandarin which was wrapped individually or in combination with GA_3. After completion of investigation they found that the fruits treated under GA_3 combined with perforated polyethylene showed lowest per cent of TSS (12.83 %), whereas the highest value of total soluble solids was recorded in control fruits (14.20 %).

Rashid *et al.* (2019) investigated the effect of botanical extracts and commercial coating materials on kinnow mandarin. They reported that fomesa wax along with 30% coconut oil recorded lowest TSS per cent (9.25%) after 15 days of storage, while the TSS (11.44%) was found highest after 90 days of storage. However, the maximum acidity (1.10%) and ascorbic acid (40.60 mg) was recorded in fomesa wax treated fruits.

Bhandari *et al.* (2020) evaluated the effect of post-harvest treatments on shelf life and quality of sweet orange (*Citrus Sinensis*). The maximum TSS value was obtained in control ranging from 8.55 % (7 days) to 11.80 % (21 days). However, TSS decreased marginally on the 28 days of storage compared to the 21 days and the minimum TSS value was found in cinnamon oil (8.75 %), but they were not statistically significant with others. The lowest (4.28 %) pH value was observed in calcium chloride treated fruits and the highest acidity (0.1%) was recorded under bavistin treated fruits at 28 days of storage period.

Gidagiri *et al.* (2020) reported that kinnow fruits packed under CFB showed the least TSS (7.57 %) than all other treatments at the end of storage. However, the highest acidity was obtained under Chlorine-zeolite-LDPE composite bag with CFB (7.33 %).

Joshi *et al.* (2020) examined the impact of various post-harvest treatments on quality and shelf life of kinnow and they concluded that fruits treated with 10 % wax combined with bavistin resulted the highest value of total soluble solids (15.45 %).

Thapa *et al.* (2020) conducted an experiment by using various post-harvest treatments to prolong the shelf-life and quality of sweet orange up to 40 days in ambient condition. As per their observation, they noticed that the TSS % increased

day to day in all the treatments. Further they concluded that untreated control fruits registered the highest TSS (15.04 %), while wax-treated fruits had the lowest TSS (12.18 %). However, maximum acidity was recorded with aloe vera treated fruits (1.4 % at 5 days to 0.91% at 40 days) and lowest acidity was noticed under paraffin wax treated fruits (1.32 % at 5 days to 0.75% at 40 days) during storage period.

CHAPTER – III
MATERIALS AND METHODS

The present investigation entitled **"Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)"** was carried out at processing laboratory, Department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.) during the academic year 2020-2021. The experiment was conducted to study the post-harvest storage stability of kinnow mandarin fruits at ambient condition. Details regarding the materials used and the techniques adopted throughout the course of investigation are mentioned in this chapter.

A description of the experiment material kinnow mandarin was collected from the College of Horticulture and Research Station, Chitrakote Road, Kumharavand, Jagdalpur Dist-Bastar, Chhattisgarh. Fully grown uniform sized fruits were harvested at proper stage of maturity and brought to the laboratory for experimental purpose. The methods, protocols and statistical techniques for the present study were analyzed, which are summarized under the following headings**.**

3.1 Geographical Situation

Raipur is located at east central part of India, which is situated in the central plains of Chhattisgarh, bordering east by the Mahanadi River. Its coordinates are 21.25 ºN latitude and 81.63 ºE longitudes at an altitude of 298.15 meters above the central plains.

3.2 Climatic Condition

Raipur, the place of inquiry, falls under sub-humid climate. It comes under the country's seventh agro-climatic region, *i.e.* eastern plateau and hills & Chhattisgarh plains in state. The annual average rainfall is 1486 mm, out of which about 90 per cent is received during monsoon *i.e.* June to mid-September. During rabi season *i.e.* December to February, on an average only 8 mm of rainfall is being received. An average temperature of the town falls under 35.4ºC, where May is considered as the hottest month of the year. In December, the average

temperature falls to 20.2ºC, which is the lowest average temperature of the entire year.

3.3 Weather condition

The meteorological data namely temperature (ºC), sunshine (hours), relative humidity (%), wind velocity (kmph), evaporation (mm) and rainfall (mm) during the crop growth periods are depicted in Fig.3.1 and Appendix A.

3.4 Experimental Materials

3.4.1 Fruits for experiment

The experimental material, kinnow mandarin was collected from the College of Horticulture and Research Station, Chitrakote Road, Kumharavand, Jagdalpur Dist-Bastar, Chhattisgarh. Fully grown uniform sized fruits were harvested at proper stage of maturity and brought to the Processing Laboratory, Department of Fruit Science, College of Agriculture, IGKV, Raipur for the present investigation. The fruits were sorted, washed and dried, there after divided into required lots for further handling during the experiment.

3.4.2 Packaging materials for fruits

The various packaging films used in this experiment was locally purchased from Shastri Market Raipur. The materials used for the experiment were *i.e.* LDPE (Low density polyethylene-25 micron), HDPE (High density polyethylene-15 micron), Polypropylene (25 micron), Shrink film (15 micron), Cling film (15 micron) and wrappers (Fig. 3.2).

3.4.3 Coating materials for fruits

Edible paraffin wax was used as coating materials, which was purchased locally from Shastri Market Raipur and were used for coating of fruit.

3.4.4 Equipments used during experiment

Different equipment and materials like - vernier calipers, electronic weighing machine, heat polythene sealer, scissors, hand juice extractor, trays, pH meter, hand refractometer, burette, pipette, beaker, conical flask and measuring cylinder has been used during experiment.

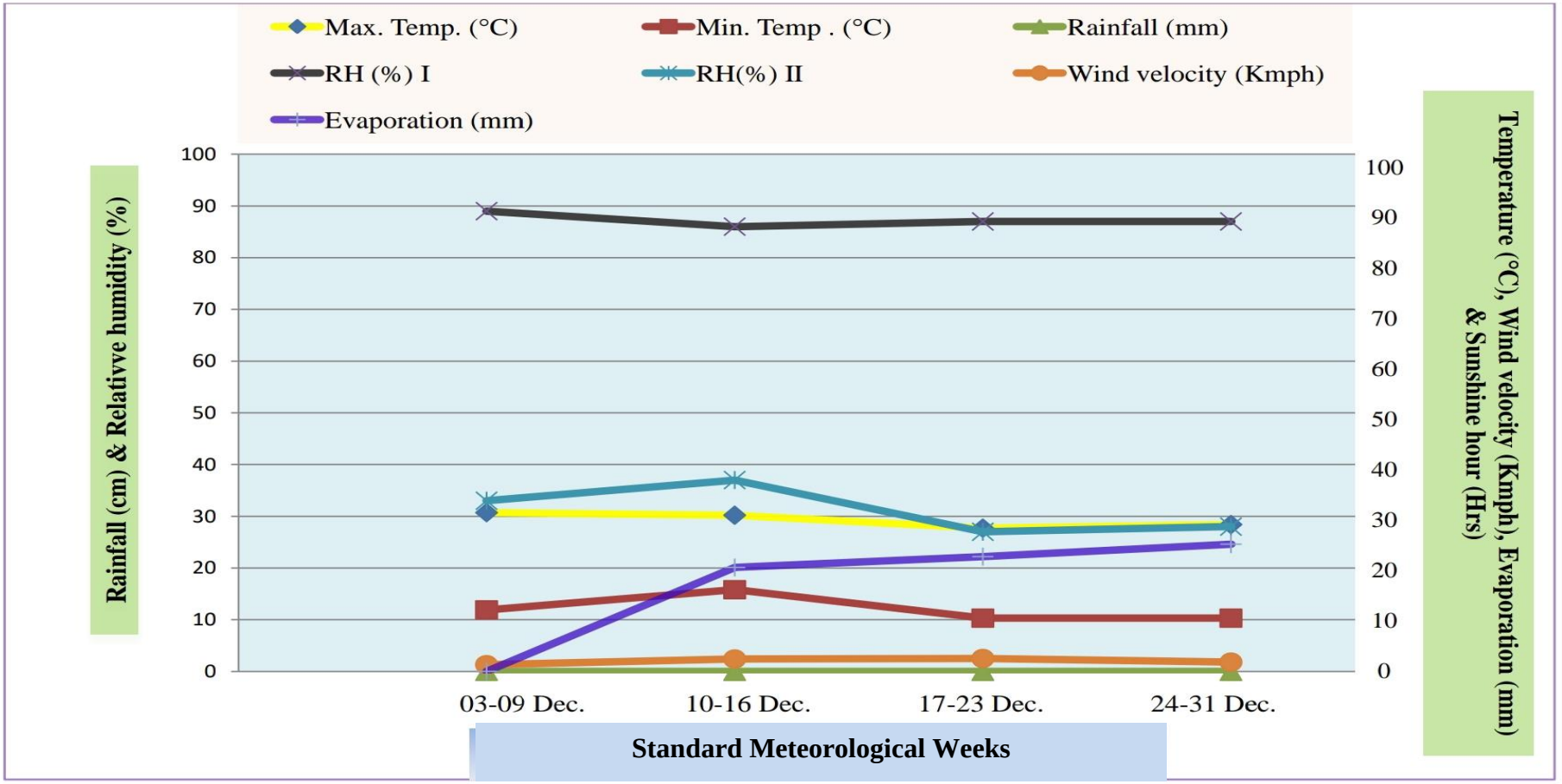
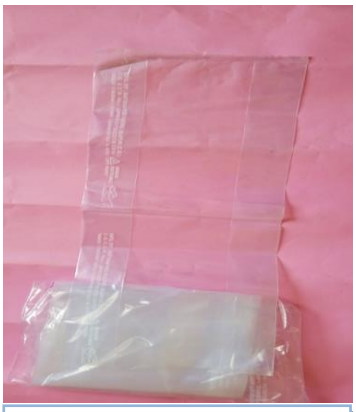


Fig. 3.1: Meteorological data during experimental period (03/12/2020 to 31/12/2020)

Fresh fruits of kinnow mandarin



HDPE FILM (15 µ)

LDPE FILM (25 µ)

Paraffin wax

Polypropylene film (25 µ)

SHRINK FILM (15 µ)

CLING FILM (15 µ)

Polythene heat sealer

Plate 3.1: Different packaging materials, paraffin wax and heat sealer machine used during experiment

3.5 Experimental Details:

- Fruit : Kinnow mandarin (***Citrus reticulata*** **Blanco**)
- Design of Experiment : Completely Randomized Design (CRD)
- Number of Treatments : 11
- Number of Replications : 03
- Number of fruits/treatments : 06
- Total number of fruits taken under study : 198
- Month of Experiment : December, 2020

3.6 Treatment Details:

The investigation was conducted in Completely Randomized Block Design (CRD) with three replications. The details of the experiment are given as follows:

Table 3.1 Treatment details

S. No.	Treatments	Notations used
1.	Control (Room temperature)	T_0
2.	LDPE (25 micron)	T_1
3.	HDPE (15 micron)	T_2
4.	Polypropylene (25 micron)	T_3
5.	Shrink film (15 micron)	T_4
6.	Cling film (15 micron)	T_5
7.	LDPE (25 micron) + wax (10%)	T_6
8.	HDPE (15 micron) + wax (10%)	T_7
9.	Polypropylene (25 micron) + wax (10%)	T_8
10.	Shrink film (15 micron) + wax (10%)	T_9
11.	Cling film (15 micron) + wax (10%)	T_{10}

LDPE-Low density polyethylene, HDPE-High density polyethylene.

3.7 Observations recorded

The following observations were recorded at five days interval during the storage period.

A. Physical parameters of fruits

1. Fruit diameter (cm)
2. Fruit length (cm)
3. Total fruit weight (g)
4. Physiological loss in weight (%)
5. Peel per cent
6. Fruit waste material (%)
7. Juice per cent
8. Juice: Peel ratio

B. Chemical composition of fruits

1. pH
2. Total soluble solids (%)
3. Acidity (%)
4. TSS: Acid ratio
5. Total sugar (%)
6. Reducing sugar (%)
7. Non-reducing sugar (%)
8. Sugar: Acid ratio
9. Ascorbic acid (mg/100 ml)

C. Sensory Score

1. Spoilage per cent
2. Color appearance
3. Flavor
4. Taste

3.8 Experiment Methodology

For the present study, fresh and fully grown uniform sized fruits were harvested at maturity stage from College of Horticulture and Research Station,

Chitrakoot Road, Kumharavand, Jagdalpur Dist-Bastar and brought to the Processing Laboratory of Fruit Science, CoA, IGKV, Raipur for further studies.

The kinnow mandarin fruits were subjected to post harvest treatments *i.e.* washed, clean and dried. The fruits were treated with different packaging materials individually as well as in combinations with wax 10 %. The experiment was laid out in Completely Randomized Design, which consisted of 11 treatments and three replications. A total of 198 fruits were used for experiment. Under each packaging material, a total of 6 fruits were packed. The treatments from T_6 to T_{10} were coated with wax 10 % before packaging, whereas treatments from T_1 to T_5 were not treated with wax 10 %. The control treatment was purely used *i.e* without packaging material and wax 10 %. Further, the packaging materials were sealed with the help of polythene heat sealer machine (except control fruit). Thereafter, the treated fruits were kept in different trays under ambient conditions (22^o to 24^o C) along with control in the processing laboratory, Department of Fruit Science, College of Agriculture, IGKV, Raipur. The experiment was kept for 25 days to study the influence of various packaging films on shelf life and quality parameters of kinnow mandarin. Observations were recorded at five days interval during the storage period.

Fresh fruit of kinnow

Washing and drying of fruit

Waxing of fruit

Wrapping and storing

Measurement of length and diameter of fruit

Weighing of fruit

Weighing of fruit peel and juice extraction

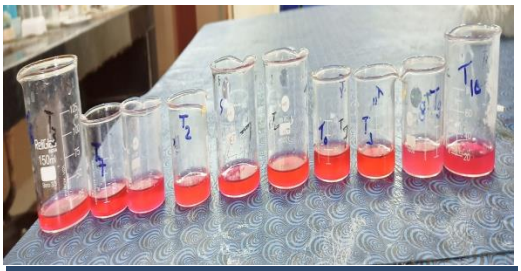
Plate 3.2 (a): procedure followed during physical & chemical analysis and sensory evaluation of kinnow mandarin fruit during

Analysis of ascorbic acid

Analysis of TSS

Analysis of pH

Analysis of total and reducing sugars



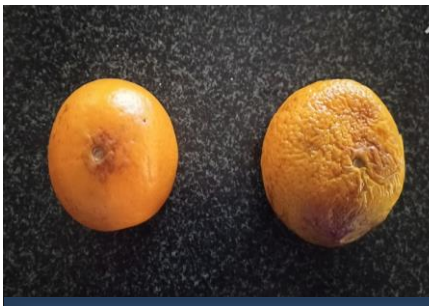
Analysis of Acidity

Condition of fruit after 15 days of storage in best treatment and control

Evaluation of sensory parameters

Plate 3.2 (b): procedure followed during physical & chemical analysis and sensory evaluation of kinnow mandarin fruit during

Spoiled fruit



Fruit condition after 25 days of storage

Fruit condition after 25 days of storage

Plate 3.2 (c): procedure followed during physical & chemical analysis and sensory evaluation of kinnow mandarin fruit during storage

Plate 3.3 : A glimpses of various packaging materials and waxing treatments used during experiment

For statistical analysis, complete randomized design (CRD) was adopted to study the significant differences among different packaging films related to storage studies at 5% level of significance as suggested by Gomez and Gomez (1985). The mean data were further subjected to Duncan's MRT at 5 % level significance.

3.9 Methodology followed to record the observations

3.9.1 Physical parameters of fruits

3.9.1.1 Fruit diameter (cm)

The diameter of the fruit was measured from the equatorial diameter of the fruit using vernier callipers at 5, 10, 15, 20 and 25 days during the storage period and was expressed in cm.

3.9.1.2 Fruit length (cm)

The length of the fruit was measured from base to top of the fruit using vernier calliper at an interval of five days during the storage period and it was denoted in centimetres.

3.9.1.3 Fruit weight (g)

The already selected fruits from each treatment and replications were weighed using electronic balance. The mean fruit weight was calculated and expressed in grams.

3.9.1.4 Physiological loss in weight (%)

The physiological loss in weight (PLW) was observed with the help of electrical weighing balance. The weight of kinnow mandarin fruits was taken on alternate days during storage period and the percentage of physiological loss in weight of fruit was calculated using the following formula:

$$\text{Physiological loss in weight (\%)} = \frac{W_1 - W_2}{W_1} \text{ X } 100$$

Where,

W_1 = Fresh fruit weight (g)

W_2 = Fruit weight (g) at 5, 10, 15, 20 and 25 days during the storage period.

3.9.1.5 Peel per cent

The fruit peel was removed by hand and it was weighed with electronic balance machine. The peel per cent of fruits was determined on the basis of total fruit weight and it was calculated with the help of following formula:

$$\text{Peel per cent} = \frac{\text{Weight of fruit peel (g)}}{\text{Weight of fruit (g)}} \text{ X } 100$$

3.9.1.6 Fruit waste material (%)

The fruit waste material (%) was measured through the weight of the waste substance left after extracting the juice from the fruit. Its value was measured with the help of the following formula:

$$\text{Fruit waste material (\%)} = \frac{\text{Weight of the waste substance (g)}}{\text{Weight of fruit (g)}} \text{ X } 100$$

3.9.1.7 Juice per cent

The juice was extracted with the help of hand juice extractor. The juice per cent was calculated by dividing the juice quantity with weight of the fruit.

$$\text{Juice per cent} = \frac{\text{Juice quantity (g or ml)}}{\text{Weight of fruit (g)}} \text{ X } 100$$

3.9.1.8 Juice: Peel ratio

The ratio of juice and peel was estimated by dividing the juice and peel per cent.

$$\text{Juice: peel ratio} = \frac{\text{Juice per cent}}{\text{Peel per cent}}$$

3.9.2 Chemical composition of fruits

The fruit juice of kinnow mandarin was extracted manually with the help of hand juice extractor for the determination of various chemical compositions of fruits. Its evaluation was followed as per the method suggested by Ranganna (1986) and Nelson (1994) for the following parameters.

3.9.2.1 pH

The pH of kinnow mandarin juice was assessed by using an automated digital pH meter. The desired quantity of kinnow fruit juice (50 ml) was taken in 125 ml beaker, then a digital pH meter was dipped into juice and the value of the pH reading was observed.

3.9.2.2 Total soluble solids (%)

The total soluble solids were determined with the help of Erma hand refractometer ranged between 0-30 percent and was expressed in per cent. The following procedure was adopted for the estimation of total soluble solids:

(1) Single or two drops of juice was placed on prism of refractometer with the help of clean glass rods.
(2) The cover of refractometer was closed gently and the inlet was projected towards the light.
(3) The reading was followed by placing the eye in the eye lens portion and the reading was noted. After each observation, the specimen was cleaned with muslin cloth. The reading was taken 23-24^{o}C room temperature.

3.9.2.3 Acidity (%)

The acidity was estimated by titrating 10 ml of fruit juice sample against 0.1N NaOH (Sodium hydroxide) using phenolphthalein as an indicator. The end point appeared as light pink colour (Ranganna, 1986). The acidity was expressed in per cent.

$$\text{Acidity (\%)} = \frac{\text{Titre x Normality of alkali} \times \text{Volume made up} \times \text{Equivalent weight of acid}}{\text{Vol. of sample taken for estimation} \times \text{Wt. or volume of sample taken} \times 1000} \times 100$$

3.9.2.4 TSS: Acid ratio

The total soluble solids: acid ratio was determined by dividing the total soluble solids (%) with acidity (%).

$$\text{TSS: Acid ratio} = \frac{\text{Total soluble solids (\%)}}{\text{Acidity (\%)}}$$

3.9.2.5 Total sugar (%)

A measured amount (25 ml) of the juice was taken into 250 ml conical flask in which 5 ml concentrated hydrochloric acid and 5g citric acid were added and the solution was kept for 24 hours (hydrolyzation) at ambient condition. Thereafter, the solution was neutralized with 1N NaOH and the volume was made up to the mark (250 ml) with distilled water. This solution was then titrated against Fehling's A and B as done previously, in case of reducing sugars and calculated the total sugar (%) using the following formula:

$$\text{Factor for Fehling solution (g/ml)} = \frac{\text{Titrate value} \quad \text{X } 2.5}{1000} \text{ X } 100$$

$$\text{Total sugar as invert sugar (\%)} = \frac{\text{Factor} \quad \text{x} \quad \text{Volume made up} \quad \text{x } 100}{\text{Titre x} \quad \text{Volume of sample taken}}$$

$$\text{Sucrose per cent} = [\text{\% of total sugar as invert sugar} \quad - \quad \text{reducing sugar (\%)}] \text{ x } 0.95$$

$$\text{Total Sugar (\%)} = \text{reducing sugar \% + sucrose \%}$$

3.9.2.6 Reducing sugar (%)

The reducing sugar was estimated as described by Ranganna (1986) and Nelson Somogyis (1994).

Reagents

- Fehling's solution A: Prepared by dissolving 69.28g copper sulfate in distilled water, and then volume was made up to 1 liter
- Fehling's solution B: Prepared by dissolving 346 g potassium sodium tartrate and sodium hydroxide (NaOH) 100 g in distilled water and then volume was made up to 1 liter
- Methylene blue indicator (1%): Dissolved 1g in 100 ml water
- Phenolphthalein indicator
- Neutral lead acetate (45%) solution
- Potassium oxalate (45%) solution
- Standard invert sugar solution: AR sucrose 9.5 mg and concentration HCl volume made up to 100 ml

Standard invert sugar solution

For standard invert sugar, 9.5 mg sucrose (AR) was taken into 1 litre volumetric flask in which 5 ml concentrated HCl was added along with 100 ml of distilled water in the flask. The solution was allowed to stand for further 3 - 5 days at ambient condition for inversion and then volume was made upto mark with distilled water (1 ml = 2.5 mg of invert sugar). 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.

Preparation of extract

The sample of 25 ml juice was taken into 250 ml conical flask and dissolved with 100 ml distilled water. Thereafter, 2 ml of lead acetate was added in the solution. The mixture was stirred well with glass rod and kept for 10 minutes. Further, it was de-leaded with 10 ml potassium oxalate solution. This process was necessary to get clarified solution. The volume was made up to 250 ml with distilled water. The contents were mixed and let it stand for some times and then filtered through filter paper. The filtrate was used for the estimation of reducing sugars.

Estimation of Reducing sugar (%)

For the estimation of reducing sugar, 5 ml Fehling's solution A + 5 ml Fehling's solution B was taken into a conical flask and diluted to about 10 ml with distilled water. The sugar extract or solution was transferred in a burette and titrated against boiling Fehling's A and B solution by using methylene blue indicator and titration was continued until brick red precipitate was formed. The reducing sugars content was calculated and expressed in per cent.

$$\text{Factor for Fehling solution (g/ml)} = \frac{\text{Titre value} \quad \text{X } 2.5}{1000} X\ 100$$

$$\text{Reducing sugar (\%)} = \frac{\text{Factor} \quad \text{x} \quad \text{Volume made up}}{\text{Titre x Volume of sample taken}} \quad \text{X } 100$$

3.9.2.7 Non-reducing sugar (%)

Non-reducing sugar was determined by subtracting the value of reducing sugar from total sugar. The non-reducing sugar was expressed in percentage.

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

3.9.2.8 Sugar: Acid ratio

The Sugar: acid ratio was estimated by dividing the total sugar (%) with acidity (%).

3.9.2.9 Ascorbic acid (mg/100g or ml)

The ascorbic acid of juice was analysed by the procedure given by Ranganna (1997).

Reagents

- Preparation of 3% Meta phosphoric acid (HPO3) solution

Take 60 g of meta-phosphoric acid (glacial stick) and dissolve in 2 lit 63 ml distill water.

- Preparation of standard ascorbic acid

100 mg of L-ascorbic acid was weighed and the volume was made up to 100 ml along with 3% Meta phosphoric acid**.** By adding 3 per cent HPO_3 (1ml = 0.1 mg ascorbic acid), 1 ml of this solution was diluted to 10 ml.

- Preparation of dye solution

52 mg (0.052 g, 52/1000) of sodium salt 2, 6-Dichlorophenols-indophenol (DCPIP) was dissolved in 150 ml of hot distilled water containing 42 mg (0.042 g) sodium bicarbonate ($NaHCO_3$). After cooling, it was diluted with 200 ml distilled water and stored in refrigerator, which was standardized every day.

- Estimation of dye solution

5 ml L-ascorbic acid solution with same amount of HPO_3 was titrated against 2, 6– Dichlorophenols-indophenol. The end point was judged by light pink colour. The dye factor was evaluated as per the following formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

- Preparation of sample:

10 ml of juice sample was mixed with 100 ml of 3% HPO3 and later it was filtered.

- Estimation of ascorbic acid

Standard ascorbic acid solution with HPO_3 solution was titrated against the dye solution till the pink colour appeared. This method was repeated for fruit juice sand the ascorbic acid was denoted by mg /100 ml.

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

3.9.3 Sensory evaluation of fruits

The organoleptic evaluation of packaging materials with 10 % wax coating wrapped fruits for assessing the color appearance, taste and flavor acceptability were conducted by a panel of six judges, who scored on 9.0 point hedonic scale i.e. 9-Like extremely, 8-Like very much, 7-Like moderately, 6-Like slightly, 5-Neither like nor dislike, 4-Dislike slightly, 3- Dislike moderately, 2-Dislike very much and 1- Dislike extremely. The achieved characters with mean scores of 5 or more out of 9 marks were considerable acceptable.

3.9.3.1 Spoilage per cent

The percentage of spoiled fruits under each treatment (both wrapped and unwrapped-control fruits) was observed by visual observation and the spoilage (%) of fruit was estimated by counting the spoiled fruits at five days intervals during the storage period. Thereafter, the whole number of spoiled fruits was divided by total number of fruits taken under study and it was converted to percentage. The spoilage per cent of fruit was calculated by using the formula given by Kaur and Verma (2002).

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

3.9.3.2 Color appearance

Marks were given on the basis of the attraction of color appearance of the fruits by the panel of judges.

3.9.3.3 Flavor

The fruits flavor was classified as excellent pleasant, good and satisfactory and points were assigned based on the flavor as evaluate by the judges.

3.9.3.4 Taste

The taste of fruits was classified as very sweet, sweet, moderately sweet and unsweet and marks were given accordingly by the panel of judges.

3.10 Statistical analysis

The experiment was laid out in Completely Randomized Design. The data recorded on various aspects in Fruit Science Laboratory were subjected to statistical analysis of variance technique as given by Gomez and Gomez (1985). The significant differences between treatments were compared with the critical difference at 5 % level of significance. The statistical analysis of the data was done in the following ways for each character.

Table 3.2: Skeleton of analysis of variance (ANOVA)

Source of variation	Degree of freedom	Sum of square	Mean sum of square	$F_{cal.}$	$F_{tab.}$
Treatment	(t-1)	TrSS	TrMS = TrSS/DF	TrMS/MSE	
Error	(rt-t)	ESS	EMS = ESS/DF		
Total	rt-1	TSS			

t = number of treatments, r = number of replications

The 'F' test was applied to judge the overall significance of various treatments in general. Comparison of individual treatment was made with the help of critical difference at 5 % level of significance, which were calculated as given below:

$$\text{SE(m)} \pm \text{for treatment} = \sqrt{\frac{EMS}{No.of\ replication}}$$

SE(d) for treatments = SE(m) × √ 2

C.D. for treatment = SE (d) x 't' value at 5% error degree of freedom

$$\text{CV (\%)} = \sqrt{\frac{\text{EMS}}{GM}}$$

Where, SE(m) = Standard Error of means SE(d) = Standard Error of difference

C.D. = Critical difference

CHAPTER – IV
RESULTS AND DISCUSSION

The present investigation entitled “Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)” was carried out in processing laboratory, Department of Fruit Science, College of Agriculture, IGKV, Raipur to determine the effect of packaging and waxing treatments on the shelf life and physico-chemical changes of fruits stored in open and polythene wrapped environments in ambient conditions during the storage period. The present chapter deals with the observations concerning various aspects of physical parameter, chemical composition characters and sensory evaluation of kinnow mandarin as influenced by different packaging materials at ambient condition during storage.

The data has been presented in tabular form as well as supported by graphical representation, whenever necessary. Data recorded on various aspects during the course of study revealed interesting facts, which are briefly described in this chapter under the following headings.

4.1 Physical parameters of kinnow mandarin

The physical parameters of kinnow fruits were recorded for the following variables *i.e.* fruit diameter (cm), fruit length (cm), fruit weight (g), physiological loss in weight (%), peel per cent, fruit waste material (%), juice per cent and juice: peel ratio, respectively which are presented in Table 4.1.1 to 4.1.8 and graphically depicted from Fig. 4.1.1 to 4.1.8.

4.1.1 Fruit diameter (cm)

The observations regarding fruit diameter (cm) of kinnow mandarin showed significant differences among the different packaging treatments at 5, 10, 15, 20 and 25 days of storage at ambient condition, which are summarized in Table 4.1.1 and graphically illustrated under Fig. 4.1.1.

At 5 days of storage of kinnow mandarin, the highest fruit diameter (5.97 cm) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), which

showed significantly superior among all the other treatments. Similarly, the treatments T_9, T_5, T_6 & T_8 and T_7, T_1, T_4 & T_2 having respective fruit diameter values 5.90, 5.89, 5.85 & 5.83 and 5.79, 5.71, 5.69 & 5.65 cm were found non-significant differences with each other at 5% level of significance. While, the lowest fruit diameter (5.09 cm) was recorded under the treatment T_0 (control).

After 10 days of storage of kinnow mandarin, the maximum fruit diameter (5.85 cm) was noticed under the treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically similar with T_9 (shrink film 15 µ with 10 % wax) with mean fruit diameter of 5.78 cm. Similarly, the treatments T_5, T_6 & T_8 and T_1, T_4 & T_7 having the respective fruit diameters 5.70, 5.69 & 5.66 and 5.61, 5.59 & 5.55 cm were found statistically at par with each other under the present experiment. Whereas, the minimum fruit diameter (4.45 cm) was registered under the treatment T_0 (control).

At 15 DAS, it was observed that the highest mean value of fruit diameter (5.73 cm) was observed under the treatment T_{10} (cling film with 10 % wax), which was followed by T_9 - shrink film 15 µ with 10 % wax treatment with fruit diameter of 5.60 cm. The treatments T_4 & T_1 and T_6 & T_2 and T_7 & T_5 with respective fruit diameters 5.19 & 5.29 and 5.34 & 5.41 and 5.46 & 5.48 cm were statistically equivalent with each other at 5% level of significance. While, the minimum value of fruit diameter (3.39 cm) was recorded in T_0 (untreated fruits), which was succeeded by T_3 (4.98 cm) during the storage period.

At 20 DAS, statistically significant differences were found among various treatments with respect to the fruit diameter. The fruit diameter decreased with increased storage days. The treatment T_{10} (cling film 15 µ with 10 % wax) exhibited the highest fruit diameter (5.57 cm) of kinnow mandarin. It was also significantly superior from all other treatments. The lowest diameter of fruit (4.58 cm) was recorded under the treatment T_3-Polypropylene 25 µ, whereas no any fruit was retained under T_0 (control untreated) for recording observation at 20 DAS as the fruits were spoiled and therefore discarded.

At 25 days after storage, statistically similar trend was observed among various treatments with respect to fruit diameter. The maximum fruit diameter

(5.17 cm) was registered under the same treatment T_{10} (cling film 15 µ with 10 % wax, which was statistically at par with the treatment T_9 (shrink film 15 µ with 10 % wax) having the average fruit diameter 5.10 cm under the present experiment. Similarly, the treatments T_2 & T_1 and T_4, T_8 & T_7 and T_6 & T_5 with average fruit diameters of 4.52 & 4.66 and 4.70, 4.71 & 4.81 and 4.95 & 5.02 cm, respectively were statistically non-significant with each other at 5% level of significance. The minimum fruit diameter (4.31cm) was noticed under the treatment T_3-Polypropylene. While, no any fruits were retained under control (T_0) for observation as the fruits were spoiled and discarded.

It is evident from the result obtained under the present investigation that the various packaging materials had significantly influenced the diameter of fruit as compared to control and there was decreasing trend of fruit diameter with the increasing storage period. Among the various treatments of packaging material, the maximum diameter of fruit (5.97 and 5.17 cm) was registered under the treatment cling film 15 µ with 10 % wax coated packed fruit (T_{10}) at 5^{th} and 25^{th} days of storage, while the minimum diameter (5.09. 4.45 and 3.39 cm) of fruit was recorded under T_0 (control) during 5, 10 and 15 days of observation respective, whereas no fruits were found to be retained under control for 20 and 25 days of observation. The decrease in fruit diameter with the increase in storage period might be due to increased moisture loss through respiration and transpiration, which affected the fruit shape and weight, ultimately resulted in Shrinkage of fruits. The highest reduction of diameter was measured under control fruits, because this fruit was treated without polythene wrapped or wax coated and stored under ambient conditions, which caused absence of barrier enabling to moisture loss, as compared to all other with or without wax coated wrapped fruit. Whereas, in case of fruits stored under packed condition, the lowest reduction of fruit diameter might be due to modified atmosphere created inside the packaging material, which might have acted as a physical barrier resulting in reduced respiration and transpiration. In addition, shrinkage mainly occurred due to water loss by transpiration and loss of carbon reserves due to respiration. The results from the present study are similar with the findings of Bhatnagar (2012), Singh *et al.* (2017) and Manisha and Gandhi *et al.* (2019) in kinnow fruits.

4.1.2 Fruit length (cm)

The observations regarding fruit length (cm) of kinnow mandarin showed significant differences among the various packaging materials at 5, 10, 15, 20 and 25 days of storage at ambient condition, which are summarized in Table 4.1.2 and graphically illustrated in Fig. 4.1.2.

At 5 days storage of kinnow mandarin, the maximum fruit length (5.89 cm) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax), followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the fruit lengths 5.69 and 5.61 cm, respectively. Similarly, the treatments T_3, T_2 & T_8 and T_7 & T_1 and T_4 & T_6 having the corresponding fruit lengths 5.10, 5.13 & 5.19 and 5.25 & 5.31 and 5.37 & 5.41 cm were found statistically similar with each other at 5 % level of significance. Although, the minimum fruit length (4.83 cm) was registered under the T_0 (untreated control) treatment.

At 10 DAS, the maximum fruit length (5.59 cm) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax) followed by T_9 - shrink film (15 µ) with 10 % wax (5.49 cm) showed significant differences among the rest of the treatments under the present experiment. The treatments T_5 & T_4 and T_1 & T_6 and T_7, T_2 & T_8 having the average fruit length of 5.32 & 5.28 and 5.22 & 5.18 and 5.11, 5.05 & 5.00 cm, respectively were noticed statistically at par with each other at 5 % level of significance. However, the treatment T_3 having the fruit length of (4.90 cm) found significantly different from rest of the treatment. The minimum fruit length (4.71 cm) was registered under the treatment T_0 (control).

At 15 DAS, significant variations were observed under the different treatments. The data showed that the treatment T_{10} (cling film 15 µ with 10 % wax) registered the highest fruit length (5.37 cm), which was significantly superior than all other treatments under the present study. Furthermore, it was noticed that the treatments T_8 & T_2 and T_1 & T_7 and T_6, T_4 & T_5 with their average fruit length of 4.79 & 4.91 and 4.99 & 5.01 and 5.10, 5.15 & 5.21 cm, respectively were found statistically non-significant differences with each other. However, the treatments T_9 and T_3 having the average fruit length of 5.17 and 4.65 cm was significantly

different than rest of the other treatments. The minimum fruit length (4.12 cm) was recorded under the treatment T_0 (control untreated) during the storage period.

At 20 DAS, significant differences were found among various treatments with respect to the fruit length. Fruit length significantly decreased as the storage days increased. Treatment T_{10} (cling film 15 µ with 10 % wax) retained the highest fruit length (5.23 cm) of kinnow mandarin. However, the lowest fruit length (4.41 cm) was obtained under the treatment T_3-Polypropylene (25 µ), which was confirmed statistically similar with T_8-Polypropylene 25 µ with 10 % wax treatment (4.55 cm), whereas control fruits were discarded at 20^{th} day of storage due to spoilage by micro-organism or over ripening

At 25 days after storage, decreasing trend was observed among various treatments with respect to fruit length. The maximum fruit length (5.03 cm) was registered under the same treatment T_{10} (cling film 15 µ with 10 % wax), which was succeeded by T_9-shrink film 15 µ with 10 % wax (4.91 cm). However, the minimum fruit length (4.25 cm) was noticed under the treatment T_3-Polypropylene, whereas no fruits were retained under control (T_0) for observation, as the fruits were spoiled and discarded.

As per the data obtained, it can be concluded that various packaging materials had significantly affected the diameter of fruit as compared to control. Among the various treatments of packaging material, the maximum length of fruit 5.89 and 5.03 cm was measured under the treatment cling film 15 µ with 10 % wax coated fruit (T_{10}) at 5^{th} and 25^{th} days of storage, while the minimum length of fruit (4.83, 4.71 and 4.12 cm) was recorded under T_0 (control) during 5, 10 and 15 days of observation respective, whereas no fruits were found to be retained under control at 20 and 25 days of observation.

It can be noticed that storage period and packaging material had significantly impacted the fruit length, where the fruit length reduced gradually as the storage period increased. The decrease in fruit length with the increase in storage period might be due to increased moisture loss through respiration and transpiration, which affected the fruit shape and weight resulting in Shrinkage of fruits. The highest reduction of length was measured under control fruits, as the

fruits were treated without polythene wrapped or wax coated and stored under ambient conditions causing absence of barrier enabling to moisture loss, as compared to all other with or without wax coated with wrapped fruit. Whereas, in case of fruits stored under packed condition, the lowest reduction of fruit length might be due to modified atmosphere created inside packaging material, which might also act as physical barrier resulting in reduced respiration and transpiration. In addition, Shrinkage mainly occurs due to water loss by transpiration and loss of carbon reserves due to respiration. The results are in close agreement with the findings of Bhatnagar (2012), Singh *et al.* (2017) and Manisha and Gandhi *et al.* (2019) in kinnow fruits.

Table 4.1.1: Effect of various packaging materials and waxing on fruit diameter (cm) of kinnow mandarin during storage

Notations	Treatments	Fruit diameter (cm)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	5.09^{a}	4.45^{a}	3.39^{a}	0.00*	0.00*	2.59
T_1	LDPE (25 µ)	5.71^{cd}	5.61^{cde}	5.29^{cd}	4.98^{c}	4.66^{bc}	5.25
T_2	HDPE (15 µ)	5.65^{c}	5.49^{c}	5.41^{ef}	5.15^{e}	4.52^{b}	5.04
T_3	Polypropylene (25 µ)	5.48^{b}	5.29^{b}	4.98^{b}	4.58^{a}	4.31^{a}	4.93
T_4	Shrink film (15 µ)	5.69^{cd}	5.59^{cd}	5.19^{c}	4.79^{b}	4.70^{c}	5.19
T_5	Cling film (15 µ)	5.89^{efg}	5.70^{ef}	5.48^{f}	5.30^{f}	5.02^{ef}	5.48
T_6	LDPE (25 µ) + wax (10%)	5.85^{ef}	5.69^{def}	5.34^{de}	5.10^{de}	4.95^{de}	5.39
T_7	HDPE (15 µ) + wax (10%)	5.79^{de}	5.55^{cd}	5.46^{f}	5.05^{cd}	4.81^{cd}	5.33
T_8	Polypropylene (25 µ) + wax (10%)	5.83^{ef}	5.66^{def}	5.39^{def}	5.13^{de}	4.71^{c}	5.34
T_9	Shrink film (15 µ) + wax (10%)	5.90^{efg}	5.78^{fg}	5.60^{g}	5.38^{f}	5.10^{ef}	5.56
T_{10}	Cling film (15 µ) + wax (10%)	5.97^{g}	5.85^{g}	5.73^{h}	5.57^{g}	5.17^{f}	5.65
	SE(m) ±	**0.03**	**0.04**	**0.03**	**0.02**	**0.06**	
	C.D. at 5 %	**0.10**	**0.13**	**0.11**	**0.08**	**0.15**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.1.2: Effect of various packaging materials and waxing on fruit length (cm) of kinnow mandarin during storage

Notations	Treatments	Fruit length (cm)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	4.83^{a}	4.71^{a}	4.12^{a}	0.00*	0.00*	2.73
T_1	LDPE (25 µ)	5.31^{de}	5.22^{fg}	4.99^{de}	4.82^{b}	4.55^{c}	4.97
T_2	HDPE (15 µ)	5.13^{b}	5.05^{cd}	4.91^{cd}	4.78^{b}	4.41^{b}	4.85
T_3	Polypropylene (25 µ)	5.10^{b}	4.90^{b}	4.65^{b}	4.41^{a}	4.25^{a}	4.66
T_4	Shrink film (15 µ)	5.37^{ef}	5.28^{gh}	5.15^{f}	4.90^{bc}	4.60^{cd}	5.06
T_5	Cling film (15 µ)	5.61^{g}	5.32^{h}	5.21^{f}	5.03^{cd}	4.78^{e}	5.19
T_6	LDPE (25 µ) + wax (10%)	5.41^{f}	5.18^{ef}	5.10^{ef}	5.00^{cd}	4.70^{de}	5.07
T_7	HDPE (15 µ) + wax (10%)	5.25^{cd}	5.11^{de}	5.01^{de}	4.91^{bcd}	4.59^{cd}	4.97
T_8	Polypropylene (25 µ) + wax (10%)	5.19^{bc}	5.00^{c}	4.79^{c}	4.55^{a}	4.39^{b}	4.78
T_9	Shrink film (15 µ) + wax (10%)	5.69^{g}	5.49^{i}	5.17^{f}	5.06^{d}	4.91^{f}	5.25
T_{10}	Cling film (15 µ) + wax (10%)	5.89^{h}	5.59^{j}	5.37^{g}	5.23^{e}	5.03^{g}	5.41
SE(m) ±		**0.03**	**0.02**	**0.04**	**0.05**	**0.03**	
C.D. at 5 %		**0.09**	**0.08**	**0.13**	**0.15**	**0.11**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

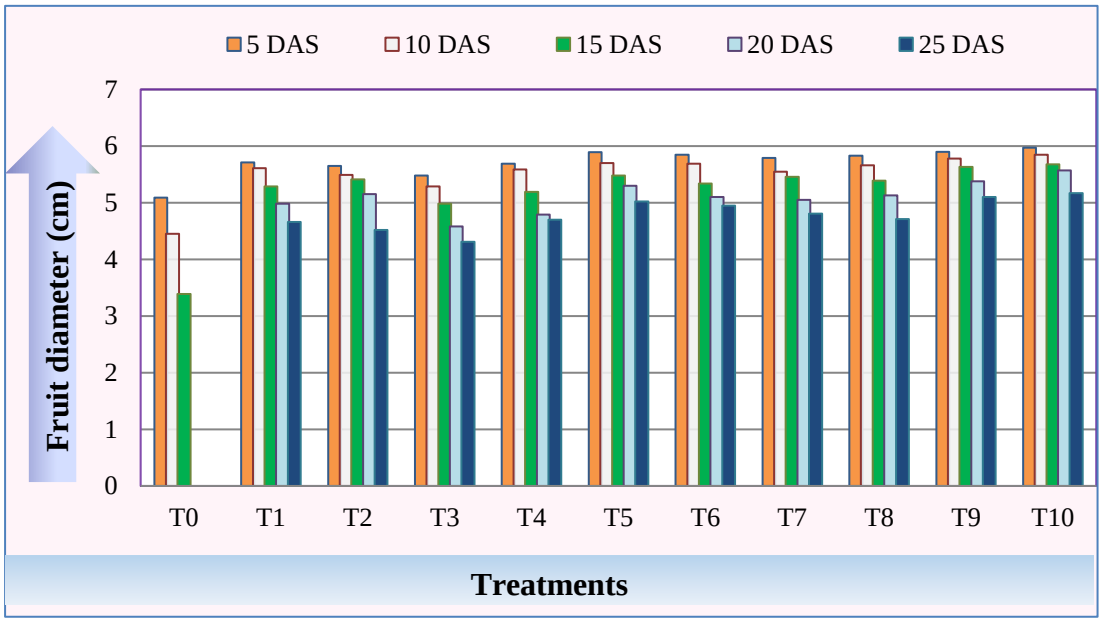


Fig. 4.1.1: Effect of various packaging materials and waxing on fruit diameter (cm) of kinnow mandarin during storage

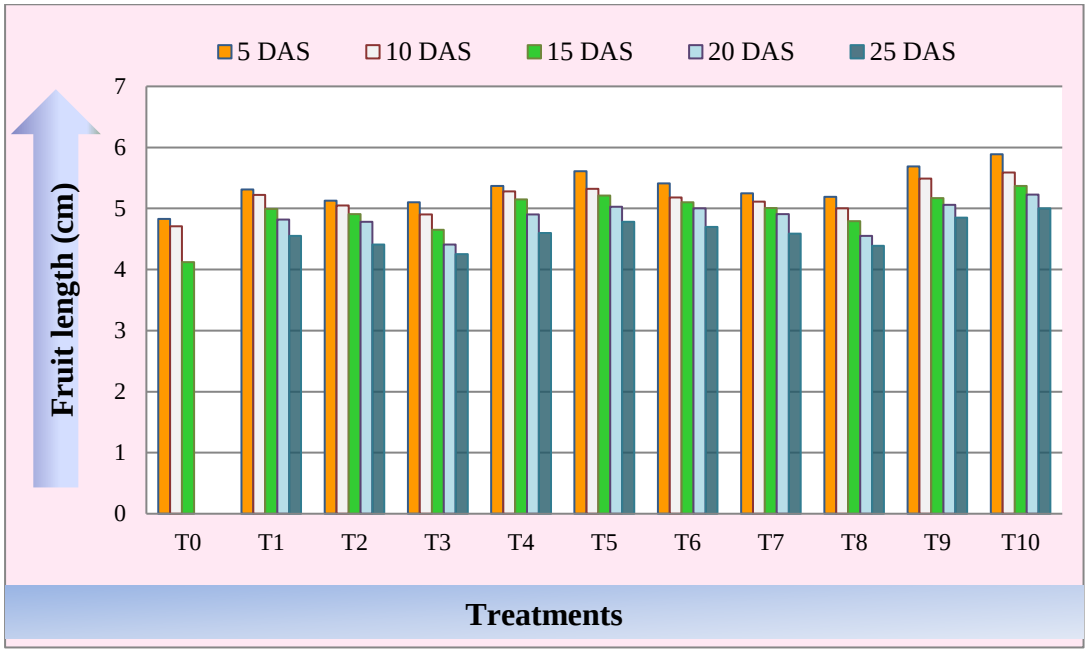


Fig 4.1.2: Effect of various packaging materials and waxing on fruit length (cm) of kinnow mandarin during storage

4.1.3 Total fruit weight (g)

Significant differences were observed with respect to total fruit weight (g) of kinnow mandarin under various packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The data gathered on total fruit weight were tabulated in Table 4.1.3 and exhibited graphically in Fig. 4.1.3. The data clearly indicates that there was decrease in fruit weight with increase in storage days irrespective of different packaging materials.

At 5 days of initial storage of kinnow mandarin, total fruit weight was significantly affected by various packaging material in both wax treated and untreated ones. According to the statistically analyzed data, the treatment T_{10} (cling film 15 µ with 10 % wax) delivered the highest total fruit weight (679.33 g), which was significantly superior from rest of the treatments. Furthermore, the lowest value of total fruit weight (625.12 g) was obtained in T_0-untreated control followed by T_3-Polypropylene (25 µ) having mean total fruit weight of 642.27 g at 5 days of storage period.

At 10 days of storage the treatment T_{10} (cling film 15 µ with 10 % wax) registered maximum total fruit weight (675.42 g), which was followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the average total fruit weight of 666.73 and 663.36 g, respectively. However, the minimum value of total fruit weight (552.54 g) was resulted under the treatment T_0 (untreated control), which was succeeded by T_3-Polypropylene (25 µ) having 636.31 g total fruit weight during 10 days of storage of kinnow mandarin.

At 15 DAS, significant differences among the various packaging treatments with respect to total fruit weight were observed. With the increasing storage period the total fruit weight reduced drastically. Among the different packaging materials, T_{10} (cling film 15 µ with 10 % wax) showed the highest total fruit weight (669.45 g), which expressed statistically superior than all other treatments used under the present study. However, T_0 (untreated) treatment indicated the least value (487.09 g) for total fruit weight during the storage.

After 20 days of storage, the maximum total weight of fruit (661.16 g) was registered under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax).

The treatment T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film15 µ) having the respective total fruit weight 652.89 and 649.10 g were found non-significant differences with each other at 5% level of significance. The minimum total fruit weight (623.13 g) was measured under the treatment T_3 (Polypropylene 25 µ) followed by T_2 HDPE (15 µ) with 634.14 g fruit weight. Whereas no fruits were retained under control (T_0) for recording observation as the fruits were discarded due to spoilage by micro-organism or over ripening.

At 25 DAS, the total fruit weight was found decreased under the various treatments. Treatment T_{10} (cling film 15 µ with 10 % wax) retained the highest total fruit weight 647.34 g and performed better than the other treatments. However, the lowest total fruit weight 591.71 g was recorded under the treatment T_3 (Polypropylene 25 µ), which was followed by T_2 HDPE (15 µ) having average total fruit weight 607.53 g. While, no fruits were found to be retained under T_0 (control untreated) for observations at 25 DAS.

As per the above discussed mean data, various packaging materials had significantly affected the total weight of fruits as compared to control during 5, 10, 15, 20 and 25 days of storage under the present investigation. The data revealed that, there was loss of total fruit weight with the increased storage days. Among the various packaging materials, the maximum total fruit weight 679.33 and 647.34 g was registered under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage respectively, while the minimum total fruit weight 625.12, 552.54 and 487.09 g was recorded under T_0-control at 5, 10 and 15 days of observation. No fruits were found to be retained under control treatment at 20 and 25 days of observation as the fruits were spoiled and completely discarded.

The decrease in total fruit weight with the increase in storage period might be due to increased moisture loss through respiration and transpiration, which directly affects the weight resulting in losses of fruits weight. The fruits stored under packed condition showed the lowest reduction of total fruit weight, which might be due to modified atmosphere created inside packaging material and have acted as a physical barrier resulting in reduced respiration and transpiration. In addition, weight loss during storage occurs because of water loss from the peel and

pulp tissues as the result of transpiration during storage. Packaging treatment restrict the gaseous exchange from fruit skin, which ultimately results in lower respiration and transpiration rates. Furthermore, the decreasing fruit weight may be due to catabolic activities in cell and loss of dry matters in the fruit sac. The atmospheric storage condition lowered the relative humidity, which triggers the pressure difference between fruits and surrounding storage condition. The present results are in similarity with the findings of Bhatnagar *et al.* (2012), Mahajan *et al.* (2016) Singh *et al.* (2017), Miri *et al.* (2018), Sharma *et al.* (2018), and Manisha and Gandhi (2019) in kinnow fruit.

4.1.4 Physiological loss in weight (%)

The data related to PLW (%) of kinnow mandarin showed significant differences among the different packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The observation on PLW (%) are presented in Table 4.1.4 and illustrated in Fig. 4.1.4.

The physiological loss in weight of kinnow mandarin increased significantly with increased storage period.

At 5 days of storage of kinnow mandarin, the minimum PLW (0.87 %) was recorded under the T_{10} (cling film 15 µ with 10 % wax) than other packaging materials. The treatments T_2 & T_8 and T_1 & T_6 and T_4 & T_5 having respective PLW % 1.81 & 1.80 and 1.35 & 1.34 and 1.18 & 1.16 were found non-significant difference with each other at 5 % level of significance. However, the treatment T_7 (1.64 %) and T_9 (1.04 %) recorded significantly differed than rest of the treatment. under the present study. The magnitude of PLW was much higher (10.05 %) obtained in control (T_0) as compared to all other treatments.

At 10 DAS, it was observed that minimum physiological loss in weight of kinnow mandarin (1.45 %) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax). which was found better than rest of the treatments under the present trial. Furthermore, the treatments T_5 & T_4 and T_1 & T_7 having respective physiological loss in weight 1.80 & 1.93 and 2.27 & 2.39 % were found statistically similar with each other. However, the maximum physiological loss in weight (19.68 %) was recorded under the treatment T_0-control.

At 15 DAS, significant variations were recorded under the various treatments. The data showed that the treatment T_{10} (cling film 15 µ with 10 % wax) registered minimum physiological loss in weight per cent (2.13 %) as compared to rest the treatments. Moreover, it was noticed that, the treatments T_2 & T_1 and T_7 & T_6 and T_4, T_5 & T_9 with their respective average PLW percentages 3.19 & 3.05 and 2.99 & 2.90 and 2.74, 2.60 & 2.45 % were statistically at par with each other. The maximum PLW (30.62 %) was observed under the treatment control untreated (T_0) during storage of kinnow mandarin under the present study.

After 20 days of storage, the minimum physiological loss in weight percent (3.20 %) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax), followed by T_9-Shrink film 15 µ with 10 % wax having the physiological loss in weight 3.44 %. Both of these treatments were superior to rest of treatments. The treatments T_5 & T_6 and T_4 & T_7 and T_2 & T_1 having the corresponding PLW (%) 3.58 & 3.71 and 3.86 & 3.95 and 4.04 & 4.20 %, respectively were statistically similar among each other at 5% level of significance. The maximum physiological loss in weight 4.78 % was recorded under the treatment T_3-Polypropylene (25 µ). While, the control fruits were discarded due to fungal spoilage.

At 25 DAS, statistically significant differences were found among various treatments with respect to the physiological loss in weight. The same response was noticed statistically, where treatment T_{10} (cling film 15 µ with 10 % wax) exhibited the lowest physiological loss in weight (4.75 %) of kinnow mandarin. However, the highest physiological loss in weight (9.17 %) was evaluated under the treatment T_3-Polypropylene (25 µ), which was followed by T_8-polypropylne (25 µ) with 10 % wax combination (7.81 %) as compared to rest the treatment under the present experiment. While, no fruit was found to be retained under T_0 (control untreated) for observation.

It can be noticed from the above discussed mean PLW % that various treatments of packaging material gradually increased the mean PLW % with increased storage period. The minimum physiological loss in weight per cent 0.87 and 4.75 % was recorded under the treatment T_{10}-cling film 15 µ with 10 % wax coated fruit at 5 and 25 days of storage, while the maximum physiological loss in

weight per cent 10.05, 19.68 and 30.62 % was recorded under T_0 -control at 5, 10 and 15 days of observation, whereas no fruits were found to be retained in control fruit at 20 and 25 days of observation.

As per the Table 4.1.4, the PLW % increased as the storage period increased. The increased PLW % of fruits in all the treatments with increasing period of storability was due to moisture loss by evapo-transpiration and loss of reserved food material by respiration. During respiration process, various reserved food materials present in fruits are used. In addition, the process of transpiration from fruit surface also continues even after harvest. Hence, due to the respiration and evapo-transpiration, the physiological loss in weight of fruits increased with increasing period of storage.

On the other hand, Dhillon *et.* (2016) reported that PLW is mainly due to the evaporation of water from the fruits, respiration and various degradation processes occurring during storage. This might be due to the restriction on diffusion of gasses and feedback mechanism resulting into slow rate of evapo-transpiration and respiration. These results are in close agreement with the earlier findings by Mandal (2015), Singh and Yadav (2015), Mahajan *et al.* (2016), Sohi *et al.* (2016), Sharma *et al.* (2018), Manisha and Gandhi (2019) and Barsha *et al.* (2021) in kinnow fruit.

Table 4.1.3: Effect of various packaging materials and waxing on total fruit weight (g) of kinnow mandarin during storage

Notations	Treatments	Total fruit weight (g)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	625.12^{a}	552.54^{a}	487.09^{a}	0.00*	0.00*	332.95
T_1	LDPE (25 µ)	656.24^{e}	651.43^{e}	645.48^{d}	639.43^{d}	611.49^{c}	640.81
T_2	HDPE (15 µ)	650.13^{c}	646.49^{c}	641.18^{c}	634.14^{b}	607.53^{b}	635.89
T_3	Polypropylene (25 µ)	642.27^{b}	636.31^{b}	631.21^{b}	623.13^{a}	591.71^{a}	624.92
T_4	Shrink film (15 µ)	659.34^{g}	654.37^{g}	649.29^{f}	643.28^{f}	621.58^{f}	645.57
T_5	Cling film (15 µ)	668.23^{i}	663.36^{i}	656.53^{h}	649.10^{h}	629.16^{h}	653.27
T_6	LDPE (25 µ) + wax (10%)	665.25^{h}	659.78^{h}	654.21^{g}	647.08^{g}	627.35^{g}	650.73
T_7	HDPE (15 µ) + wax (10%)	657.23^{f}	652.46^{f}	648.35^{e}	641.26^{e}	618.48^{e}	643.55
T_8	Polypropylene (25 µ) + wax (10%)	653.16^{d}	647.74^{d}	641.15^{c}	636.41^{c}	613.35^{d}	638.36
T_9	Shrink film (15 µ) + wax (10%)	671.17^{j}	666.73^{j}	659.78^{i}	652.89^{i}	636.88^{i}	657.49
T_{10}	Cling film (15 µ) + wax (10%)	679.33^{k}	675.42^{k}	669.45^{j}	661.16^{j}	647.34^{j}	666.54
	SE(m) ±	**0.23**	**0.23**	**0.17**	**0.20**	**0.15**	
	C.D. at 5 %	**0.67**	**0.70**	**0.54**	**0.61**	**0.45**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.1.4: Effect of various packaging materials and waxing on physiological loss in weight (%) of kinnow mandarin during storage

Notations	Treatments	Physiological loss in weight (%)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	10.05^{h}	19.68^{i}	30.62^{i}	0.00*	0.00*	12.07
T_1	LDPE (25 µ)	1.35^{d}	2.27^{e}	3.05^{ef}	4.20^{f}	7.32^{g}	3.64
T_2	HDPE (15 µ)	1.81^{f}	2.58^{f}	3.19^{f}	4.04^{ef}	7.00^{f}	3.72
T_3	Polypropylene (25 µ)	1.98^{g}	2.96^{h}	3.66^{h}	4.78^{h}	9.17^{i}	4.51
T_4	Shrink film (15 µ)	1.18^{c}	1.93^{c}	2.74^{cd}	3.86^{de}	6.32^{e}	3.21
T_5	Cling film (15 µ)	1.16^{c}	1.80^{c}	2.60^{bc}	3.58^{bc}	5.55^{c}	2.94
T_6	LDPE (25 µ) + wax (10%)	1.34^{d}	2.09^{d}	2.90^{e}	3.71^{cd}	6.13^{d}	3.23
T_7	HDPE (15 µ) + wax (10%)	1.64^{e}	2.39^{e}	2.99^{e}	3.95^{e}	6.28^{e}	3.45
T_8	Polypropylene (25 µ) + wax (10%)	1.80^{f}	2.72^{g}	3.40^{g}	4.46^{g}	7.81^{h}	4.04
T_9	Shrink film (15 µ) + wax (10%)	1.04^{b}	1.62^{b}	2.45^{b}	3.44^{b}	5.35^{b}	2.78
T_{10}	Cling film (15 µ) + wax (10%)	0.87^{a}	1.45^{a}	2.13^{a}	3.20^{a}	4.75^{a}	2.48
	SE(m) ±	**0.03**	**0.04**	**0.05**	**0.07**	**0.03**	
	C.D. at 5 %	**0.10**	**0.13**	**0.15**	**0.22**	**0.10**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

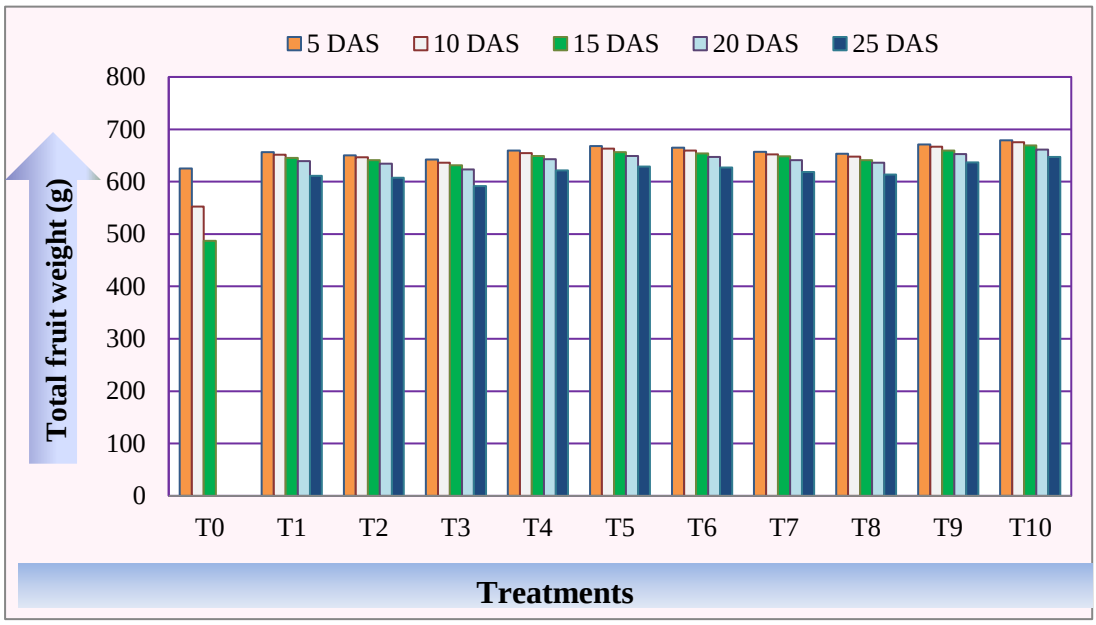


Fig. 4.1.3: Effect of various packaging materials and waxing on total fruit weight (g) of kinnow mandarin during storage

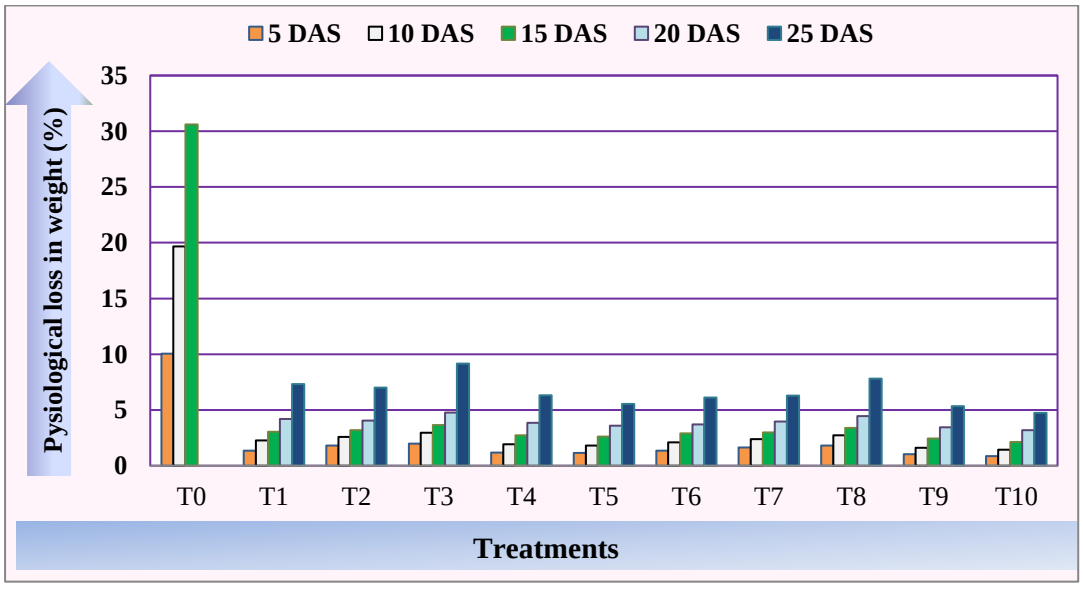


Fig. 4.1.4: Effect of various packaging materials and waxing on physiological loss in weight (%) of kinnow mandarin during storage

4.1.5 Peel per cent

Significant differences among the various packaging materials at 5, 10, 15, 20 and 25 days were observed with respect to peel per cent of kinnow mandarin under ambient storage condition. The data recorded are summarized in Table 4.1.5 and graphically illustrated in Fig. 4.1.5.

At 5 DAS, significant differences were seen among the various treatments. The data revealed that the treatment T_{10} (cling film 15 µ with 10 % wax) recorded significantly highest peel per cent (33.35 %) followed by T_9 (shrink film 15 µ with 10 % wax) with 32.81 % peel and T_5 (cling film 15 µ) having the peel per cent of 32.15. The treatments T_7, T_6, T_4, T_1, T_8 and T_2 with their respective mean fruit peel per cent 31.93, 31.51, 30.85, 29.60, 28.93 and 28.10 % expressed significant differences among each other at 5 % level of significance. While, the treatment T_0 (control untreated) showed the lowest per cent of fruit peel (25.33 %), followed by T_3 (Polypropylene 25 µ) with peel per cent of 26.98 % during the storage period.

At 10 days of storage, the peel per cent of fruit was significant affected by different packaging material. The results obtained for peel content ranged from 24.79 to 32.83 % under the present study. The maximum peel content (32.83 %) was registered under T_{10} (cling film 15 µ with 10 % wax), which was statistically higher than all other treatments. However, the treatments T_9 & T_5 and T_7 & T_4 with corresponding peel content of 32.33 & 31.98 and 30.93 & 30.76 % respectively were statistically at par with each other. Whereas, the least peel content (24.79 %) was recorded under untreated fruits (T_0) followed by T_3-Polypropylene 25 µ (26.89 %) during the storage of kinnow mandarin.

After 15 days of storage, it can be observed that the maximum content of peel per cent (32.65 %) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax) as compared to all other treatments. While, the treatments T_9 & T_5 and T_6, T_7 & T_4 with respective peel percentages 31.84 & 31.58 and 30.92, 30.53 & 30.45 %, was statistically similar with each other at 5 % level of significance. Whereas, T_0 (control) yielded the minimum value (23.75 %) for peel per cent content during the storage.

At 20 DAS, the highest mean peel (32.41 %) was recorded under T_{10} (cling film 15 µ with 10 % wax) and it was significantly higher as compared to all other treatments. The treatment T_9 (shrink film 15 µ with 10 % wax) with 31.87 % peel showed statistically similar with T_5 (cling film 15 µ) having the peel per cent 31.51 %. Moreover, the treatments T_2, T_8, T_1 and T_4 with respective mean peel per cent 27.34, 28.17, 28.94 and 29.71 % expressed significant differences among each other under the present trial. While, the minimum peel per cent (25.59 %) was registered under the treatment T_3 (Polypropylene 25 µ). However, no fruits were noticed to be retained under control untreated treatment (T_0) for observation.

After 25 days of storage of kinnow mandarin, again statistically significant variations were found among the various packaging treatments used under the trial with respect to the peel content. Treatment T_{10} (cling film 15 µ with 10 % wax), confirmed highest peel per cent (31.95 %) as compared to rest of the treatment. Furthermore, the treatments T_2 & T_8 and T_1 & T_4 and T_7 & T_6 and T_5 & T_9 having the respective average value of peel per cent 27.15 & 27.49 and 28.61 & 29.04 and 30.14 & 30.22 and 31.41 %, respectively were statistically at par with each other. Whereas, the treatment T_3 (Polypropylene 25 µ) expressed the lowest peel per cent (24.94 %). No fruits were found to be retained under control (T_0) for observation as fruits were spoiled.

It is evident from the result obtained under the present investigation that various packaging materials had significantly decreased the peel content of fruit (%) with increased storage period. Among the various treatments of packaging material, the maximum peel per cent of fruit (33.35 and 31.95 %) was measured under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage, while the minimum peel per cent was recorded under T_0-control (25.33, 24.79 and 23.75 %) during 5, 10 and 15 days of observation and no fruits were found to be retained under control at 20 and 25 days of observation. The reducing trends in peel per cent of fruit at initial days of observation to last days of observation during the storage might be due to losses of moisture from the peel. Packagings with wax treated fruits showed less reduction in peel per cent during storage as compared to control fruits or without wax coated fruits. This might be due to the fact that wax coated with polythene packaging acted as a barrier, which

had checked the losses of the moisture from the fruit surface. These results are in close agreement with the findings of Sonkar *et al.* (2009), Miri *et al.* (2018), Rashid *et al.* (2019) and Haider *et al*. (2021) in kinnow fruit.

4.1.6 Waste material (%)

The observations relevant to waste material (%) of kinnow mandarin showed that various packaging treatments significantly influenced the waste material per cent at 5, 10, 15, 20 and 25 days of storage under ambient condition are summarized in Table 4.1.6 and graphically illustrated in Fig. 4.1.6. The Table 4.1.6 clearly indicates that the waste material per cent increased with the increased observation period.

At 5 days of initial storage of kinnow mandarin, the minimum waste material (9.64 %) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax), which was significantly superior from rest of the treatments. Similarly, the treatments T_5 & T_7 and T_8 & T_2 having the waste material 11.83 & 12.21 and 17.69 & 18.25 % were also found statistically similar with each other at 5 % level of significance. However, the maximum waste material (35.88 %) was registered under the T_0 (untreated control) treatment.

Significant differences were observed between the treatments at 10 days of storage. The experimental findings revealed that the treatment T_{10} (cling film 15 µ with 10 % wax) showed significantly lowest waste material (10.93 %) than the other treatments. The treatments T_7 & T_6 and T_8 & T_2 having the waste material 14.00 & 14.35 and 19.17 & 19.25 % respectively were found to be at par with respect to waste material (%) at 5 DAS. However, the treatments T_9, T_5 and T_4 with their respective waste material 12.14, 12.99 and 15.39 %, respectively were recorded significantly differed at 5 % level of significance. While, T_0 (control) treatment recorded the highest waste material of fruit (38.76 %) followed by T_3 (20.69 %).

After 15 days storage of kinnow mandarin, the content of waste material was significantly affected by different packaging treatments. Based on the statistically evaluated data, the treatment T_{10} (cling film 15 µ with 10 % wax) showed the minimum waste material (11.35 %), which was followed by T_9-shrink

15 µ with 10 % wax (13.00 %). Both of these treatments were significantly superior as compared to rest of the treatments. Similarly, T_8 (20.37 %) & T_2 (20.16 %) and T_7 (15.05 %) & T_6 (15.03 %) were also found statistically similar among each other. Whereas, T_0 (control) expressed the highest value (39.89 %) for waste material during the storage period.

At 20 DAS, the same increasing trend was observed in respect to waste material of kinnow fruit under the present trial. The minimum 11.86 % waste material of fruit was obtained under T_{10} (cling film 15 µ with 10 % wax), which was followed by T_9-shrink film 15 µ with 10 % wax having the waste material of 13.59 %, however the maximum 21.97 % waste material was achieved under T_3-Polypropylene (25 µ) treatment. Whereas, the fruits kept under the control were discarded due to spoilage at 20 days after storage.

At 25 DAS, statistically significant differences were found among various treatments with respect to the waste material of fruit. The treatment T_{10} (cling film with 10 % wax) responded the same result and delivered the lowest waste material (13.68 %) of kinnow mandarin and performed superior among all other treatments. However, the highest waste material of fruit (25.77 %) was reported under the treatment T_3-Polypropylene (25 µ), whereas no fruits were found to be retained under T_0 (control) for observation.

From the Table 4.1.6, it can be concluded that the various packaging materials had significantly affected the waste material of fruit and there was significant increase in fruit waste material with the increased observation period. Among the various treatments of packaging material, the minimum waste material of fruit 9.64 and 13.68 % was observed under the treatment T_{10} (Cling film 15 µ with 10 % wax) at 5 and 25 days, while the maximum waste material 35.88, 38.76 and 39.89 % was recorded under T_0-control during 5, 10 and 15 days of observation. However, no fruits were found to be retained under control fruit at 20 and 25 days of observation. The increased fruit waste material with the increased storage day might be due to increased moisture loss through respiration and transpiration, which directly affects the fruit pulp resulting in increased the retained of waste material. The highest retention of waste material was obtained

under control fruits, because this fruit was kept without polythene wrapped or wax coated and stored under ambient conditions causing absence of barrier enabling to moisture loss, as compared to all other treatments. Whereas, in case of fruits stored under packed condition, the lowest retention of fruit waste substance might be due to the modified atmosphere created inside packaging material, which might also act as physical barrier resulting in reduced respiration and transpiration. In addition, waste substance mainly occurs due to water loss by transpiration and loss of reserved food material due to respiration or during respiration process, various reserved food materials present in fruits are used. These results corroborated with the findings of Miri *et al.* (2018), Rashid *et al.* (2019) and Haider *et al.* (2021) in kinnow fruit.

Table 4.1.5: Effect of various packaging materials and waxing on peel per cent of kinnow mandarin during storage

Notations	Treatments	Peel per cent					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	25.33^{a}	24.79^{a}	23.75^{a}	0.00*	0.00*	14.77
T_1	LDPE (25 µ)	29.60^{e}	29.38^{e}	29.03^{e}	28.94^{d}	28.61^{c}	29.11
T_2	HDPE (15 µ)	28.10^{c}	27.75^{c}	27.61^{c}	27.34^{b}	27.15^{b}	27.59
T_3	Polypropylene (25 µ)	26.98^{b}	26.89^{b}	26.12^{b}	25.59^{a}	24.94^{a}	26.10
T_4	Shrink film (15 µ)	30.85^{f}	30.76^{f}	30.45^{f}	29.71^{e}	29.04^{c}	30.16
T_5	Cling film (15 µ)	32.15^{i}	31.98^{h}	31.58^{g}	31.51^{g}	31.04^{e}	31.65
T_6	LDPE (25 µ) + wax (10%)	31.51^{g}	31.21^{g}	30.92^{f}	30.85^{f}	30.22^{d}	30.94
T_7	HDPE (15 µ) + wax (10%)	31.93^{h}	30.93^{f}	30.53^{f}	30.31^{ef}	30.14^{d}	30.76
T_8	Polypropylene (25 µ) + wax (10%)	28.93^{d}	28.53^{d}	28.19^{d}	28.17^{c}	27.49^{b}	28.26
T_9	Shrink film (15 µ) + wax (10%)	32.81^{j}	32.33^{h}	31.84^{g}	31.87^{g}	31.41^{ef}	32.05
T_{10}	Cling film (15 µ) + wax (10%)	33.35^{k}	32.83^{i}	32.65^{h}	32.41^{h}	31.95^{f}	32.63
	SE(m) ±	**0.12**	**0.14**	**0.17**	**0.22**	**0.18**	
	C.D. at 5 %	**0.37**	**0.44**	**0.52**	**0.65**	**0.56**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.1.6: Effect of various packaging materials and waxing on waste material (%) of kinnow mandarin during storage

Notations	Treatments	Waste material (%)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	35.88^{i}	38.76^{i}	39.89^{h}	0.00*	0.00*	22.91
T_1	LDPE (25 µ)	16.79^{f}	17.16^{f}	17.75^{e}	19.47^{f}	23.26^{f}	18.88
T_2	HDPE (15 µ)	18.25^{g}	19.25^{g}	20.16^{f}	20.48^{g}	24.87^{g}	20.60
T_3	Polypropylene (25 µ)	19.98^{h}	20.69^{h}	21.48^{g}	21.97^{h}	25.77^{h}	21.97
T_4	Shrink film (15 µ)	14.91^{e}	15.39^{e}	16.16^{d}	17.39^{e}	22.73^{f}	17.31
T_5	Cling film (15 µ)	11.83^{c}	12.99^{c}	13.54^{b}	14.31^{c}	16.73^{c}	13.88
T_6	LDPE (25 µ) + wax (10%)	13.67^{d}	14.35^{d}	15.03^{c}	16.01^{d}	19.16^{d}	15.64
T_7	HDPE (15 µ) + wax (10%)	12.21^{c}	14.00^{d}	15.05^{c}	16.18^{d}	20.24^{e}	15.53
T_8	Polypropylene (25 µ) + wax (10%)	17.69^{g}	19.17^{g}	20.37^{f}	20.83^{g}	22.79^{f}	20.17
T_9	Shrink film (15 µ) + wax (10%)	10.58^{b}	12.14^{b}	13.00^{b}	13.59^{b}	15.57^{b}	12.97
T_{10}	Cling film (15 µ) + wax (10%)	9.64^{a}	10.93^{a}	11.35^{a}	11.86^{a}	13.68^{a}	11.49
	SE(m) ±	**0.21**	**0.15**	**0.19**	**0.13**	**0.18**	
	C.D. at 5 %	**0.65**	**0.46**	**0.60**	**0.41**	**0.56**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

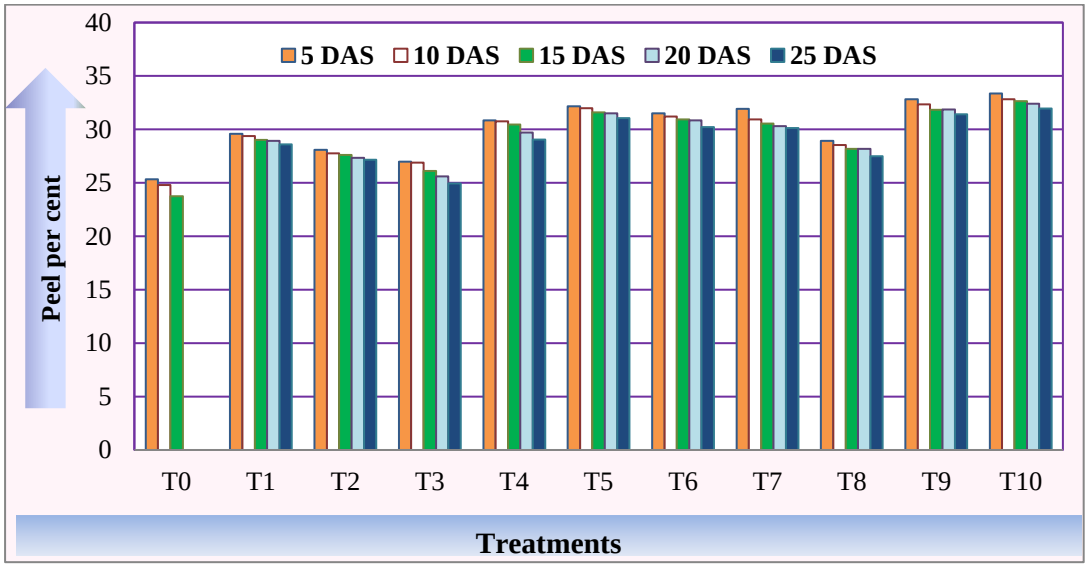


Fig. 4.1.5: Effect of various packaging materials and waxing on peel per cent of kinnow mandarin during storage

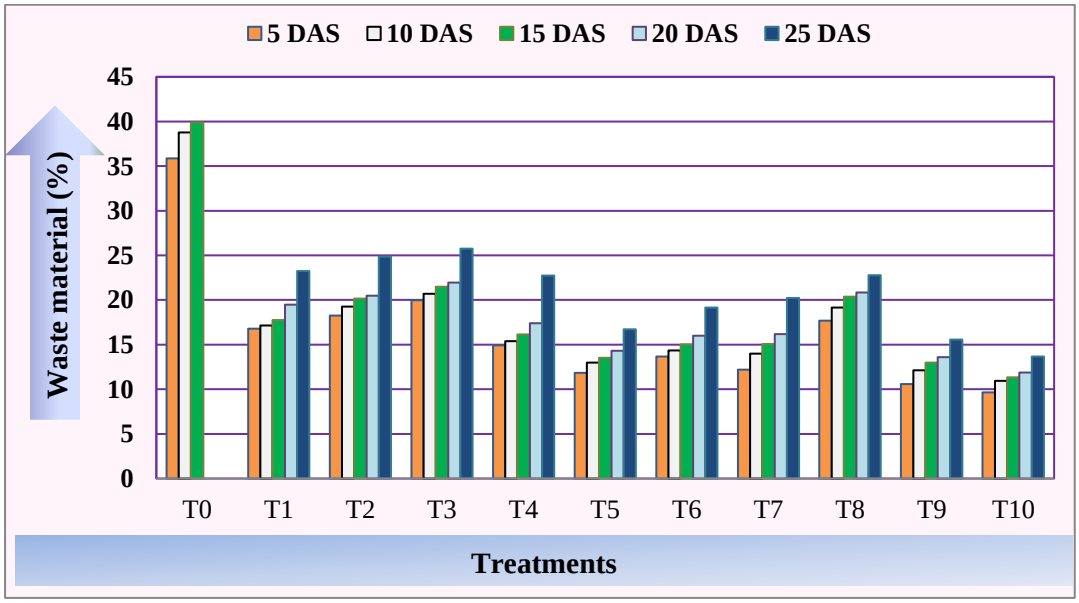


Fig. 4.1.6: Effect of various packaging materials and waxing on waste material (%) of kinnow mandarin during storage

4.1.7 Juice per cent

It is clear from the Table No. 4.1.7 and Fig. 4.1.7 the different packaging materials significantly influenced the juice (%) of kinnow mandarin at 5, 10, 15, 20 and 25 days of storage under ambient condition.

At 5 DAS, significant differences were seen among the treatment means. From the present findings, it was revealed that the treatment T_{10} (cling film 15 µ with 10 % wax) achieved significantly highest juice content (57.05 %), which was found non-significant differences with T_9 (shrink film 15 µ with 10 % wax) having the juice content 56.61 %. Whereas, statistically similar means were observed under T_8 (53.38 %), T_1 (53.61 %) & T_2 (55.86 %) and T_7 (55.86 %) & T_5 (56.02 %) in current study. However, lowest juice content (24.79 %) was noticed under the control (T_0) during the storage period.

At 10 days of storage, the juice per cent was significantly affected by different packaging materials. The results obtained for juice content varied from 36.45 to 56.24 % under different treatments. The maximum juice content (56.24 %) was registered under T_{10} (cling film 15 µ with 10 % wax), which was significantly higher among all the treatments and minimum was noted in T_0-control (36.45 %) at 10 days of storage, which was found non-significant differences with T_3-Polypropylene (25 µ) having the juice per cent of 53.04 % during the present investigation.

At 15 days of storage, it can be observed that the juice content of fruit was significantly influenced by various packaging materials used under the present experiment. The highest content of juice (56.00 %) was registered under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax), which was found superior as compared to all other treatments. While, the treatments T_8, T_3 & T_2 and T_1 & T_4 with respective juice content of 51.44, 52.00 & 52.23 and 53.22 & 53.39 % showed statistically at par with each other at 5 % level of significance. However, the treatment T_0 (control) performed poorest among all the treatments with minimum juice value (35.86 %) during 15^{th} days of storage.

At 20 DAS, as per the Table 4.1.7, it can be observed that the highest mean juice (55.73 %) retained best under the packaging material T_{10} (cling film 15 µ

with 10 % wax), which was followed by T_9 (Shrink film 15 µ with 10 % wax) having 54.54 % juice content. Furthermore, the treatments T_5, T_7, T_2 and T_1 with corresponding juice per cent 54.18, 53.51, 52.18 and 51.59 %, respectively showed significant differences between each other. However, the lowest content of juice per cent (50.74 %) was yielded under the T_3 (Polypropylene 25 µ), which showed statistically at par with T_8 (51.00 %). Whereas, no fruit was found to be retained under control (T_0) for recording observation at 20 DAS.

At 25 DAS, significant differences were found among various treatments with respect to juice per cent of kinnow fruit. The treatment T_{10} (cling film with 10 % wax) maintained the highest juice per cent (54.37 %) of kinnow mandarin, which was significantly superior among all other treatments. However, the lowest juice of fruit (47.29 %) was obtained under the treatment Polypropylene 25 µ (T_3). However, no fruits were found to be retained under T_0 (control) for recording observation at 25 DAS.

It is evident from the result obtained under present investigation that the various packaging materials had significantly affected the juice per cent of fruit as compared to control and there was decreased juice (%) with increased storage days. The maximum fruit juice 57.05 and 54.37 % was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5^{th} and 25^{th} days of storage respectively. The minimum juice per cent (38.79, 36.45 and 35.86 %) was achieved under T_0-control at 5, 10 and 15 days of observation respectively. Similarly no fruits were found to be retained under control at 20 and 25 days of observation.

The juice recovery per cent of fruit reduced drastically from initial days to last days of observation during the storage periods, which might be due to loss of moisture from the peel. The fruits packed with wax treated showed less reduction in juice (%) during the storage as compared to control and unwaxed fruit packed under different packaging materials. This might be due to the fact that wax coated with polythene packaging acted as a barrier, which checked the losses of the moisture from the fruit surface. Similar findings were reported by Sonkar *et al.* (2009), Paudel *et al.* (2019), Baswal *et al.* (2020), Joshi *et al* (2020), Barsha *et al.*

(2021) and Haider *et al.* (2021) in kinnow fruits. Similar result were collaborated with Mir *et al.* (2014) in pear, Gidagiri *et al.* (2020) in acid lime and Thapa *et al.* (2020) also reported in sweet orange.

4.1.8 Juice: peel ratio

The data relevant to juice: peel ratio of kinnow mandarin during storage from 5 to 25 days have been presented in Table 4.1.8 and illustrated graphically in Fig. 4.1.8.

The juice: peel ratio of kinnow mandarin progressively increased during the storage. At 5 DAS, The juice to peel ratio increased up to 1.97 under T_3-Polypropylene (25 µ) and was found highest among the other treatments. In control (T_0), the juice: peel ratio was recorded minimum (1.53) as compared to all other treatments under the present trial.

At 10 DAS, the maximum juice: peel ratio (1.94) was registered under the treatment T_3 (Polypropylene 25 µ), which was significantly higher than rest of the treatment under the present trial. The treatments T_{10}, T_9, T_5, T_4 & T_6 and T_7, T_1 & T_8 having respective juice: peel ratio of 1.71, 1.72, 1.72, 1.75 & 1.74 and 1.78, 1.82 & 1.83, were found statistically at par with each other. The minimum juice: peel ratio (1.47) was obtained under the T_0 (untreated control).

At 15 DAS, juice: peel ratio of kinnow mandarin was influenced by various treatments. The juice: peel ratio increased with increasing storage period. The treatment T_3 (Polypropylene 25 µ), exhibited the highest juice: peel ratio (1.99) of kinnow mandarin. However, the lowest juice: peel ratio of fruit (1.50) was noticed under the T_0-control, which was succeeded by T_{10}-Cling film with 10 % wax (1.72) at 15 days of storage period.

At 20 days of storage, the peak juice: peel (1.98) ratio was recorded under the superiority of treatment T_3 (Polypropylene 25 µ). However, the treatments T_4, T_7 & T_8 having the respective juice: peel ratio of 1.78, 1.77 & 1.81 % respectively, were found statistically similar among each other at 5% level of significance. Whereas, the least juice: peel ratio (1.71 %) was observed under treatment T_9

(Shrink film 15 µ with 10 % wax). No fruits were found to be retained under the treatment T_0 for observation as the fruits were discarded due to microbial spoilage.

At 25 DAS, the juice: peel ratio was significantly affected by different treatments under the present study. The maximum juice: peel ratio of fruit (1.90) was obtained under the superiority of treatment T_3-Polypropylene (25 µ), which was found significantly superior among all other treatments. Among the various treatments, significant differences were recorded under T_2, T_8 and T_3 (1.77 and 1.81, respectively) at 5 % level of significance. However, minimum juice: peel ratio (1.65) was noted under T_7 (HDPE 15 µ with 10 % wax), which was statistically at par with T_4 (1.66), T_1 (1.68), T_9 (1.69) & T_{10} (1.70) between each other. However, fruits kept under control treatment were completely discarded due to microbial spoilage.

It is evident from the result obtained under present study that the various packaging materials had significantly affected the juice to peel ratio as compared to control.

Among the various treatments of packaging materials, the maximum juice: peel ratio (1.97 and 1.90) was observed under treatment T_3 (Polypropylene 25 µ) at 5^{th} and 25^{th} days of storage, while the minimum juice: peel ratio (1.53, 1.47, 1.50) was noticed under untreated control (T_0) at 5, 10 and 15 days of storage respectively. At 20 and 25 days of storage in control, there was no fruits were found to be retained for further observation.

The juice to peel ratio significantly affected as the storage period increased. The increase in juice: peel ratio with the increase in storage day might possible due to higher rate of transpiration from peel over pulp, which attributes to increase of juice: peel ratio. Other causes might also be due to the absorption of moisture in pulp, which was derived from hydrolysis of carbohydrate and the osmotic pressure of water from juice to peel ratio. The results of the present experiment are strongly supported by the findings of Hakim *et al.* (2013) in banana fruit, Srivastava and Said (2019) in pomegranate and Haider *et al.* (2021) in kinnow mandarin.

Table 4.1.7: Effect of various packaging materials and waxing on juice per cent of kinnow mandarin during storage

Notations	Treatments	Juice per cent					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	38.79^{a}	36.45^{a}	35.86^{a}	0.00*	0.00*	22.22
T_1	LDPE (25 µ)	53.61^{c}	53.46^{d}	53.22^{c}	51.59^{b}	48.13^{bc}	52.00
T_2	HDPE (15 µ)	53.65^{c}	53.00^{c}	52.23^{b}	52.18^{c}	47.98^{b}	51.80
T_3	Polypropylene (25 µ)	53.04^{b}	52.12^{b}	52.00^{b}	50.74^{a}	47.29^{a}	51.03
T_4	Shrink film (15 µ)	54.24^{d}	53.84^{e}	53.39^{c}	52.90^{d}	48.23^{c}	52.52
T_5	Cling film (15 µ)	56.02^{f}	55.03^{g}	54.88^{f}	54.18^{f}	52.23^{f}	54.46
T_6	LDPE (25 µ) + wax (10%)	54.82^{e}	54.44^{f}	54.05^{d}	53.11^{d}	50.62^{e}	53.40
T_7	HDPE (15 µ) + wax (10%)	55.86^{f}	55.07^{g}	54.42^{e}	53.51^{e}	49.62^{d}	53.69
T_8	Polypropylene (25 µ) + wax (10%)	53.38^{bc}	52.30^{b}	51.44^{b}	51.00^{a}	49.72^{d}	51.56
T_9	Shrink film (15 µ) + wax (10%)	56.61^{g}	55.53^{h}	55.16^{g}	54.54^{g}	53.02^{g}	54.97
T_{10}	Cling film (15 µ) + wax (10%)	57.05^{h}	56.24^{i}	56.00^{h}	55.73^{h}	54.37^{h}	55.87
	SE(m) ±	**0.13**	**0.06**	**0.07**	**0.09**	**0.08**	
	C.D. at 5 %	**0.41**	**0.19**	**0.23**	**0.29**	**0.24**	

1. Values marked as * indicates fruit gets spoiled.
2. DAS - Days after storage
3. The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.1.8: Effect of various packaging materials and waxing on juice: peel ratio of kinnow mandarin during storage

Notations	Treatments	Juice: peel ratio					
		5 DAS	10 DAS	15 DAS	20 DAS	25 DAS	Mean
T_0	Control (untreated)	1.53^{a}	1.47^{a}	1.50^{a}	0.00*	0.00*	0.90
T_1	LDPE (25 µ)	1.81^{de}	1.82^{d}	1.83^{d}	1.78^{ab}	1.68^{a}	1.79
T_2	HDPE (15 µ)	1.91^{f}	1.91^{e}	1.89^{e}	1.91^{c}	1.77^{b}	1.88
T_3	Polypropylene (25 µ)	1.97^{g}	1.94^{e}	1.99^{f}	1.98^{c}	1.90^{d}	1.95
T_4	Shrink film (15 µ)	1.76^{cd}	1.75^{bc}	1.75^{bc}	1.78^{ab}	1.66^{a}	1.74
T_5	Cling film (15 µ)	1.74^{bc}	1.72^{bc}	1.74^{bc}	1.72^{a}	1.68^{a}	1.75
T_6	LDPE (25 µ) + wax (10%)	1.74^{bc}	1.74^{bc}	1.75^{bc}	1.72^{a}	1.68^{a}	1.73
T_7	HDPE (15 µ) + wax (10%)	1.75^{bc}	1.78^{cd}	1.78^{cd}	1.77^{ab}	1.65^{a}	1.74
T_8	Polypropylene (25 µ) + wax (10%)	1.85^{e}	1.83^{d}	1.82^{d}	1.81^{b}	1.81^{c}	1.82
T_9	Shrink film (15 µ) + wax (10%)	1.73^{bc}	1.72^{b}	1.73^{bc}	1.71^{a}	1.69^{a}	1.72
T_{10}	Cling film (15 µ) + wax (10%)	1.71^{b}	1.71^{b}	1.72^{b}	1.72^{a}	1.70^{a}	1.71
	SE(m) ±	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	
	C.D. at 5 %	**0.05**	**0.06**	**0.05**	**0.07**	**0.06**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

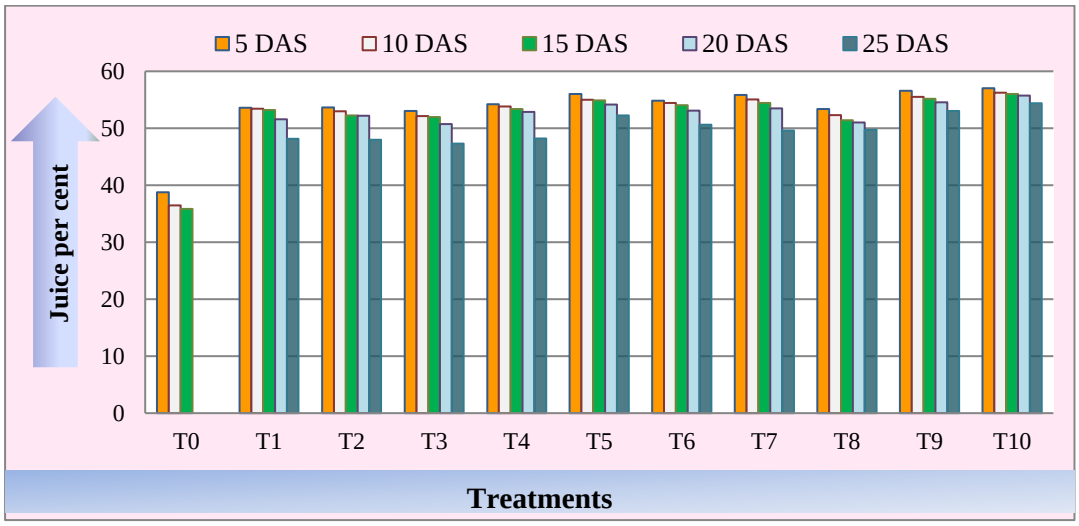


Fig. 4.1.7: Effect of various packaging materials and waxing on juice per cent of kinnow mandarin during storage

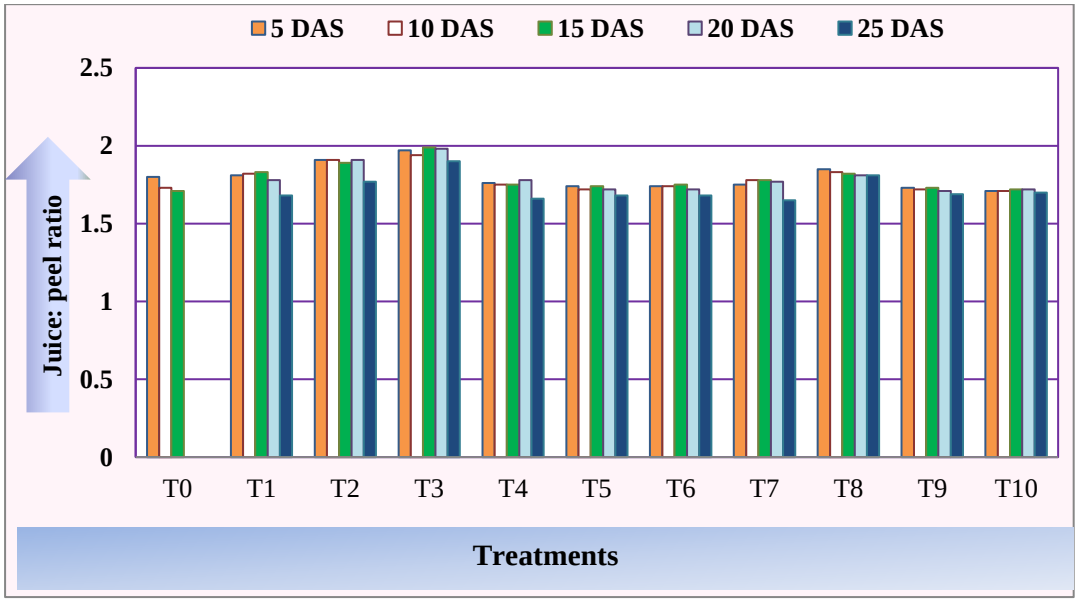


Fig. 4.1.8: Effect of various packaging materials and waxing on juice: peel ratio of kinnow mandarin during storage

4.2 Chemical composition of kinnow mandarin

The chemical composition of kinnow mandarin fruits were recorded for the following variables *i.e.* pH, TSS (%), Acidity (%), TSS: Acid ratio, Total sugar (%), Reducing sugar (%), Non-reducing sugar (%), Sugar: Acid ratio, Ascorbic acid (mg/100 ml) and are presented in Table 4.2.1 to 4.2.9 and graphically depicted from 4.2.1 to 4.2.9.

4.2.1 pH

The data related to pH of kinnow mandarin during storage from 5 to 25 days have been presented in Table 4.2.1 and supported graphically in Fig. 4.2.1.

At 5 days of storage, the maximum pH (3.78) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed significantly superior among all other treatments. The treatments T_2 & T_8 and T_7 & T_6 having respective pH value 3.42 & 3.46 and 3.52 & 3.56 were found non-significant differences with each other at 5% level of significance. However, the treatments T_3 (3.25), T_1 (3.34) and T_5 (3.63) were significantly differed from rest of the treatment. The minimum pH value (3.18) was recorded under T_0 (control).

At 10 days of storage, the highest pH (3.89) was noticed under the treatment T_{10} (Cling film 15 µ with 10 % wax), which was statistically at par with T_9 (shrink film 15 µ with 10 % wax) having the pH value of 3.82. However, the treatments T_2 and T_8 with corresponding pH values 3.44 and 3.61 showed significant differences between each other. Whereas, the lowest pH (3.31) was registered under the treatment T_1 (control untreated), which was followed by T_3 (Polypropylene 25 µ) having the pH value of 3.39.

At 15 days of storage, it was noticed that the maximum mean pH (4.02) was under the treatment T_{10} (cling film 15 µ with 10 % wax), which was found statistically non-significant with T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the pH values 3.91 and 3.85 respectively. The treatments T_6, T_7 & T_4 and T_2 & T_1 with respective pH 3.81, 3.80 & 3.76 and 3.63 & 3.60 were statistically equivalent with each other at 5% level of significance. While, the least

value of pH (3.43) was recorded under T_0 (control), which was found at par with T_3 (3.52) during the storage period

At 20 DAS, the treatment T_{10} (cling film 15 µ with 10 % wax) recorded significantly highest pH (4.09) of kinnow mandarin and performed superior among all other treatments. The lowest pH of fruit (3.61) was registered under the treatment T_3 (Polypropylene 25 µ), whereas no fruits were found to retained under T_0 (control) for observation due to spoilage.

At 25 days after storage, the similar increasing trend was observed among various treatments with respect to pH. The maximum pH value (4.10) was registered under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically at par with the treatment T_9 (shrink film 15 µ with 10 % wax) having the average fruit pH 4.08 under the present experiment. Similarly, the treatments T_2 & T_8 and T_1, T_7 & T_4 and T_6 & T_5 with average pH of 3.80 & 3.82 and 3.87 & 3.90 & 3.91 and 3.97 & 4.01, respectively were found non-significant differences with each other at 5% level of significance. The least fruit pH (3.64) was noticed under the treatment T_3 (Polypropylene 25 µ), whereas fruits kept under control were completely discarded due to spoilage.

It is evident from the result obtained under present investigation that the various packaging materials had significantly increased the pH of fruit with increased storage period. Among the various treatments of packaging material, the maximum fruit pH (3.78 and 4.10) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days, while the minimum pH (3.18, 3.31 and 3.43) was achieved under T_0 (control) during 5, 10 and 15 days of observation respectively, whereas no fruits were found to be retained in control at 20 and 25 days of observation.

The increase in pH values during storage periods might be due to progressed hydrogen ion concentration, bearing moisture evaporation from the kinnow mandarin. The reduction in pH values could be due to retention of higher percentage of acidity during storage period. In addition, this phenomenon of increasing trend of pH during storage might be possible due to the oxidation of acids resulting in higher pH (Acharya *et al.,* 2020). Furthermore, the fluctuations of

pH might be due to the variations in temperature of storage and decline of acidity percentage, which might attributed increased activities of citric acid glyoxylase during ripening. Reduction in acid content may be also due to conversion of starch into sugars in metabolic process during storage. The present findings are in close agreement with the findings recorded by Jadhao *et al.* (2008) in kagzi lime, Singh and Yadav (2015), Singh *et al.* (2017) and Joshi *et al.* (2020) kinnow mandarin.

4.2.2 Total soluble solids (%)

The observations related to total soluble solids (%) of kinnow fruit showed significant differences among various packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The data recorded has been summarized in Table 4.2.2 and graphically illustrated in Fig. 4.2.2.

At 5 days storage of kinnow mandarin, the highest total soluble solids (11.92 %) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax), followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the total soluble solids per cent 10.94 and 10.89, respectively. Similarly, the treatments T_2 & T_1 and T_8, T_7, T_6 & T_4 having the respective total soluble solids 10.47 & 10.53 and 10.63, 10.70, 10.71 & 10.73 % were found statistically similar with each other under the present study. The least total soluble solids (10.21 %) was registered under the control treatment.

At 10 DAS, the data recorded on total soluble solids revealed that the treatments T_{10} (cling film 15 µ with 10 % wax) registered highest total soluble solids (12.00 %) than the fruits treated with other packaging materials. There was significant increase in TSS content with increased storage periods. The treatments T_8, T_1 & T_2 and T_7 & T_6 and T_4 & T_5 having the average total soluble solids percentages 10.86, 10.91 & 10.97 and 11.06 & 11.07 and 11.13 & 11.22 % respectively, were recorded statistically at par with each other at 5 % level of significance. While, the lowest total soluble solids were observed under the treatment T_0 (control) having the TSS content of 10.45 %.

At 15 DAS, significant variations were observed under the various treatments. The data showed that the treatment T_{10} (cling film 15 µ with 10 % wax) registered the maximum total soluble solids (12.67%), which was significantly

superior among all other treatments. The treatments T_3, T_1 and T_6 having the average TSS per cent of 11.32, 11.50 and 12.25, respectively showed significantly differed than rest of other treatments. The minimum TSS (11.15 %) was noticed under the treatment T_0 (control) during 15 days of storage under the ambient condition.

At 20 days of storage, the total soluble solids of kinnow mandarin progressively increased irrespective of packaging materials. The total soluble solids (%) was significantly higher (13.30 %) in T_{10} (cling film 15 µ with 10 % wax) than the fruits treated with other treatments. The treatments T_9 & T_5 and T_4, T_6 & T_7 having the respective average TSS (%) 13.05 & 13.00 and 12.85, 12.81 & 12.79, respectively were statistically at par with each other at 5 % level of significance. The lowest TSS (12.10 per cent) was registered under the treatment T_3 (Polypropylene 25 µ), whereas fruits kept under control treatment were spoiled and completely discarded at 20 DAS.

At 25 days of storage, different types of packaging material significantly affected the total soluble solids. The maximum total soluble solids (14.45 %) was observed under the fruits packed in T_{10}-cling film 15 µ with 10 % wax, which was statistically superior from rest of the treatments under the present trial. The minimum total soluble solids (12.95 %) was registered under T_3 (Polypropylene 25 µ), which was found non-significant differences with T_1 having the TSS value of 13.07 %. However, the fruits kept under control treatments were discarded due to microbial spoilage at 25 days of storage at ambient condition

It is evident from the result obtained under present investigation that the various packaging materials had significantly affected the TSS of fruit as compared to control. Among the various treatments of packaging material, the maximum fruit TSS (11.92 and 14.45 %) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage, while the minimum TSS (10.21, 10.45 and 11.15 %) was achieved under T_0 (control) during 5, 10 and 15 days of observation.

Significant increase in total soluble solids with different packaging materials and storage periods was recorded in the present investigation (Table

4.2.2). The increment of total soluble solids with the extended duration of storage period could be due to the deterioration of complex insoluble compounds, like starch to simple soluble compounds like sugars, which act as the main components of total soluble solids. The present results are similar with the findings of Mahajan and Singh (2014), Sharma *et al*. (2018) and Baswal *et al.* (2020) in kinnow mandarin. Similarly, Thapa *et al* (2020) also found similar results in sweet orange.

Furthermore, the maintenance of superior value for total soluble solids might be attributable to a reduction in water loss through transpiration during storage (Sharma *et al*., 2018). The increasing of higher TSS levels with extended of storage period may also be due to slower respiration, water loss and carbohydrate conversions to disaccharides and monosaccharide (Singh *et al.,* 2017).

Table 4.2.1: Effect of various packaging materials and waxing on pH of kinnow mandarin during storage

Notations	Treatments	pH					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	3.18^{a}	3.31^{a}	3.43^{a}	0.00*	0.00*	1.98
T_1	LDPE (25 µ)	3.34^{c}	3.44^{b}	3.60^{c}	3.69^{b}	3.87^{cd}	3.58
T_2	HDPE (15 µ)	3.42^{d}	3.51^{c}	3.63^{c}	3.79^{c}	3.80^{b}	3.63
T_3	Polypropylene (25 µ)	3.25^{b}	3.39^{b}	3.52^{b}	3.61^{a}	3.64^{a}	3.48
T_4	Shrink film (15 µ)	3.49^{ef}	3.69^{e}	3.76^{de}	3.85^{cd}	3.91^{de}	3.74
T_5	Cling film (15 µ)	3.63^{h}	3.77^{f}	3.85^{fg}	3.99^{e}	4.01^{f}	3.85
T_6	LDPE (25 µ) + wax (10%)	3.56^{g}	3.71^{e}	3.81^{ef}	3.98^{e}	3.97^{ef}	3.80
T_7	HDPE (15 µ) + wax (10%)	3.52^{efg}	3.67^{e}	3.80^{ef}	3.88^{d}	3.90^{d}	3.75
T_8	Polypropylene (25 µ) + wax (10%)	3.46^{de}	3.61^{d}	3.71^{d}	3.78^{c}	3.82^{bc}	3.67
T_9	Shrink film (15 µ) + wax (10%)	3.74^{i}	3.82^{f}	3.88^{g}	4.01^{e}	4.08^{g}	3.90
T_{10}	Cling film (15 µ) + wax (10%)	3.78^{i}	3.89^{g}	3.91^{g}	4.09^{f}	4.10^{g}	3.97
	SE(m) ±	**0.02**	**0.01**	**0.02**	**0.02**	**0.02**	
	C.D. at 5 %	**0.06**	**0.05**	**0.06**	**0.07**	**0.06**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.2.2: Effect of various packaging materials and waxing on total soluble solids (%) of kinnow mandarin during storage

Notations	Treatments	Total soluble solids (%)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	10.21^{a}	10.45^{a}	11.15^{a}	0.00*	0.00*	6.36
T_1	LDPE (25 µ)	10.53^{c}	10.91^{c}	11.50^{c}	12.66^{d}	13.07^{a}	11.73
T_2	HDPE (15 µ)	10.47^{c}	10.97^{cd}	11.80^{d}	12.35^{b}	13.30^{b}	11.77
T_3	Polypropylene (25 µ)	10.37^{b}	10.70^{b}	11.32^{b}	12.10^{a}	12.95^{a}	11.48
T_4	Shrink film (15 µ)	10.73^{e}	11.13^{ef}	11.90^{d}	12.85^{e}	13.95^{de}	12.11
T_5	Cling film (15 µ)	10.89^{f}	11.22^{f}	12.39^{g}	13.00^{f}	14.05^{f}	12.31
T_6	LDPE (25 µ) + wax (10%)	10.71^{de}	11.07^{de}	12.25^{f}	12.81^{e}	13.81^{de}	12.13
T_7	HDPE (15 µ) + wax (10%)	10.70^{de}	11.06^{de}	12.10^{e}	12.79^{e}	13.71^{d}	12.07
T_8	Polypropylene (25 µ) + wax (10%)	10.63^{d}	10.86^{c}	12.06^{e}	12.50^{c}	13.50^{c}	11.91
T_9	Shrink film (15 µ) + wax (10%)	10.94^{f}	11.37^{g}	12.51^{g}	13.05^{f}	14.25^{g}	12.42
T_{10}	Cling film (15 µ) + wax (10%)	11.92^{g}	12.00^{h}	12.67^{h}	13.30^{g}	14.45^{h}	12.86
	SE(m) ±	**0.03**	**0.04**	**0.04**	**0.03**	**0.06**	
	C.D. at 5 %	**0.09**	**0.14**	**0.13**	**0.11**	**0.19**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

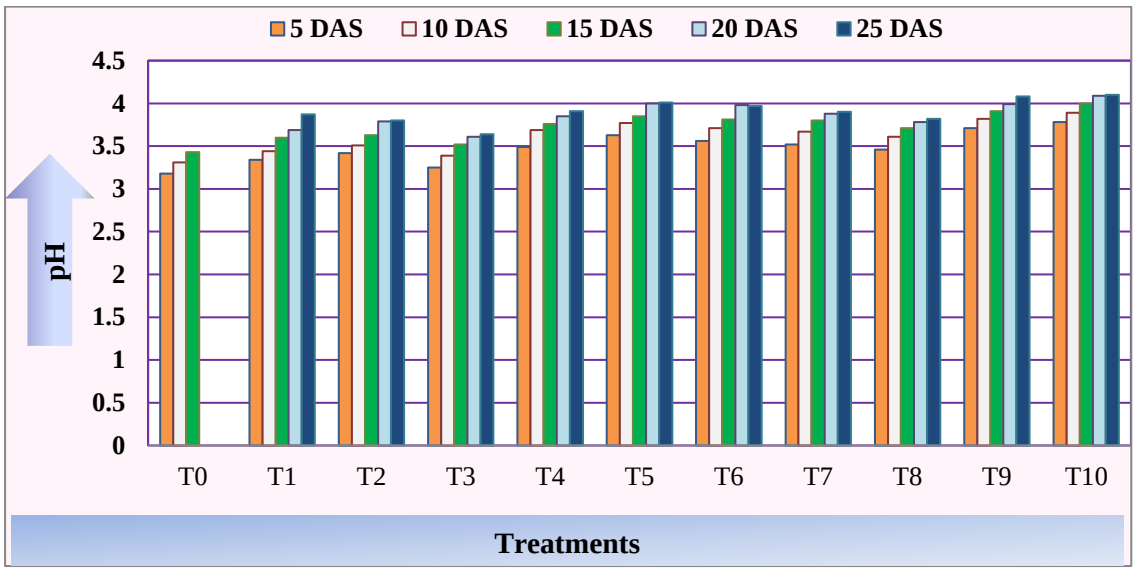


Fig. 4.2.1: Effect of various packaging materials and waxing on pH of kinnow mandarin during storage

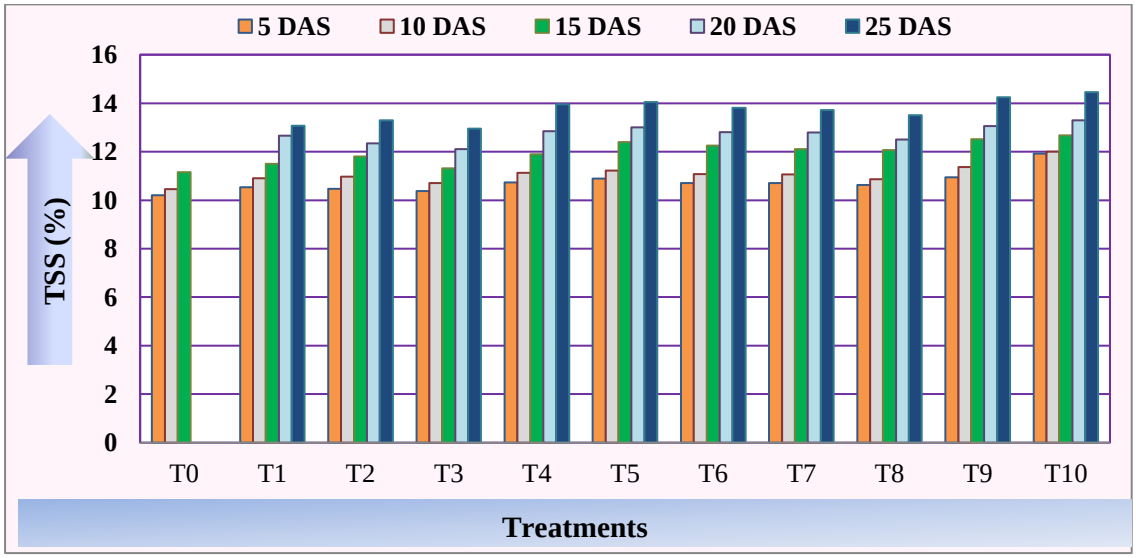


Fig. 4.2.2: Effect of various packaging materials and waxing on total soluble solids (%) of kinnow mandarin during storage

4.2.3 Acidity (%)

The data related to acidity (%) of kinnow fruit presented in Table 4.2.3 and illustrated in Fig 4.2.3, showed significant differences among various packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The data clearly indicates that acidity (%) significantly decreased with increased storage period.

At 5 days of storage of kinnow mandarin, the minimum acidity (1.06 %) was noticed under the treatment T_{10} (cling film 15 µ with 10 % wax) and was superior among all other treatments but showed statistically at par with T_9 (shrink film 15 µ with 10 % wax) having corresponding acidity of 1.09 %. Similarly, the treatments T_3, T_2 & T_1 and T_8 & T_7 and T_6 & T_4 with acidity per cent of 1.37, 1.35 & 1.33 and 1.28 & 1.25 and 1.19 & 1.17 were found non-significant differences with each other at 5% level of significance. However, the maximum acidity (1.40 %) was recorded under the treatment T_0 (control).

After 10 days of storage of kinnow mandarin, the lowest acidity (0.96 %) was noticed under the superiority of treatment T_{10} (cling film15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax) with acidity of 1.02 %. Similarly, the treatments T_3, T_2 & T_1 and T_4 & T_5 having the respective fruit acidity 1.28, 1.26 & 1.24 and 1.07 & 1.04 % were found statistically similar with each other under the present experiment. Whereas, the highest acidity per cent (1.31) was registered under the treatment T_0 (control).

At 15 DAS, it was observed that the minimum acidity per cent (0.79) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax) followed by the treatment T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the respective acidity 0.85 and 0.88 % Similarly the treatments T_1 & T_2 and T_8, T_7 & T_6 with respective acidity of 1.09 & 1.05 and 0.98, 0.93 & 0.91 was statistically equivalent among each other at 5% level of significance. The maximum acidity 1.17 % was recorded in T_0-control followed by T_3-Polypropylene 25 µ (1.11 %) during the storage period

Similarly at 20 DAS, significant differences were also found among various treatments with respect to the acidity (%) of fruit. Treatment T_{10} (cling film

15 µ with 10 % wax) exhibited the minimum acidity per cent (0.72) of kinnow mandarin and significantly superior among all other treatments. However, the maximum acidity of fruit (0.99 %) was noticed under the treatment T_3 (Polypropylene 25 µ), whereas no fruits were found to retained under T_0 (control) for observation as the fruits were spoiled.

At 25 days after storage, similar decreasing trend was observed among various treatments with respect to acidity (%). The minimum acidity of fruit (0.61 %) was obtained under the same treatment T_{10} (cling film 15 µ with 10 % wax). Similarly, the treatments T_9, T_5 & T_7 and T_6, T_4 & T_2 with average acidity of 0.70, 0.72 & 0.75 and 0.79, 0.84 & 0.86 %, respectively were found statistically at par with each other at 5% level of significance. The maximum acidity (0.99 %) was reported under the treatment T_3 (Polypropylene 25 µ), whereas the fruits under control (T_0) were completely spoiled at 25 days of storage.

From the above discussed mean acidity (%) clearly indicates that the various packaging materials had significantly affected the acidity of fruit as compared to control. With the increased storage period acidity (%) of kinnow fruit decreased significantly at ambient condition under different treatments. The minimum acidity of fruit 1.06 and 0.61 % was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage, while the maximum acidity per cent 1.40, 1.31 and 1.17 % was achieved under T_0 (control) at 5, 10 and 15 days of observation, whereas the fruits kept under control was discarded due to spoilage at 20 and 25 days of observation. The decrease in acidity with the increase in storage period might be due to conversion of acids into sugars and its utility in respiration process. The present results are in close agreements with the findings of Shama *et al.* (2012) in kiwi fruit and Mahajan and Singh (2016), Miri *et al*. (2018), Shama *et al*. (2018), Joshi (2020), and Barsha *et al.* (2021) in kinnow mandarin.

4.2.4 TSS: Acid ratio

The data presented in Table 4.2.4 and supported graphically in Fig 4.2.4 clearly indicates that the TSS: Acid ratio of kinnow fruit increased with the advancement of storage period under various packaging materials.

At 5 days of storage of kinnow mandarin, a significant variation on TSS: acid ratio were observed due to different packaging materials in kinnow mandarin. The highest TSS: acid ratio (11.24) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) with average TSS: acid ratio 10.03 and 9.90 respectively, which was significantly superior from rest of the treatments under the present investigation. The treatments T_4, T_6, T_7 and T_8 having respective TSS: acid ratio 9.17, 9.00, 8.56 and 8.30 were found significant differences from each other at 5 % level of significance under the present research. However, the lowest TSS: acid ratio (7.29) was registered under the treatment T_0 (control), followed by T_3 (Polypropylene 25 µ), T_2 (HDPE 15 µ) and T_1 (LDPE 25 µ) having the respective TSS: acid ratio of 7.56, 7.75 and 7.91 at ambient condition.

At 10 DAS, the TSS: Acid ratio of kiinow mandarin was significantly affected by various packaging materials under present investigation. According to the statistically analyzed data the treatment T_{10} (cling film 15 µ with 10 % wax) registered maximum TSS: acid ratio (12.50) and was significantly superior among all other treatments. The treatment T_1 and T_2 having the respective mean TSS: acid ratio of 8.79 and 8.70 were found non-significant differences with each other. Furthermore, the least TSS: acid ratio (7.97) was noticed under T_0 (untreated control), which was confirmed significantly different and minimum from rest of the other treatments under the present study.

At 15 DAS, similar increasing trend with respect to TSS: acid ratio was recorded under the various treatments. The data showed that the superiority of treatment T_{10} (cling film 15 µ with 10 % wax) recorded the maximum TSS: acid ratio (16.03). The treatments T_4 & T_7 with their respective average TSS: acid ratio of 12.93 & 13.01 was found non-significant differences with each other. However, the treatments T_9, T_5, T_6 and T_8 having the mean TSS: acid ratio of 14.71, 14.07, 13.46 and 12.30 TSS: acid ratio showed significant differences among each other at 5 % level of significance. The minimum TSS: acid ratio (9.52) was recorded under the treatment T_0 (control) at 15^{th} days of storage of kinnow mandarin.

At 20 days of storage, significant variations on TSS: acid ratio was observed under the various packaging materials. The mean TSS: acid ratio ranged from (12.22 to 18.47) under the present trial at 20 DAS. Among the various treatments, the highest TSS: acid ratio (18.47) was reported under the treatment T_{10} (cling film 15 µ with 10 % wax) and performed significantly superior than rest of the treatments. The treatments T_9, T_5, T_6 and T_7 having the respective average TSS: acid ratio of 16.51, 16.25, 15.25 and 15.04, which was significantly different with rest of other treatments at 5 % level of significance. However, the lowest TSS: Acid ratio (12.22) was registered under the treatment T_3 (Polypropylene 25 µ), whereas no fruits were found to be retained under T_0 (control) at 20 DAS for observation.

After 25 days of storage, the maximum TSS: acid ratio (23.68) was noticed under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax), which was recorded significantly different and superior among all other treatments under the present study. The minimum TSS: acid ratio of kinnow fruit (13.08) was recorded under the treatment T_3 (Polypropylene 15 µ) which was followed by T_1 (14.52) and T2 (15.34). Whereas no fruits were found to be retained under T_0 (control) for recording observation. The fruits under control were completely discarded due to spoilage.

According to statistically analyzed results obtained under the present investigation, it is clear that storage period and packaging material had significantly affected the TSS: acid ratio of kinnow fruits, which increased gradually as the storage period increased. Among the various treatments of packaging material, the maximum TSS: acid ratio of fruit (11.24 to 23.68) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage, while the minimum TSS: acid ratio (7.29, 7.97 and 9.52) was registered under T_0 (control) at 5, 10 and 15 days of observation respectively, whereas no fruits were found to be retained in control at 20 and 25 days of observation due to spoilage. The higher change in TSS: acid ratio is straightly related to hydrolytic changes in the starch concentration (conversion of starch to sugars). With the passage of time, degradation of ascorbic acid results to more TSS as structural formula of ascorbic acid is similar to glucose, therefore decrease in ascorbic acid

correlated to increased in TSS: acid ratio (Singh *et al*, 2017) reported that valencia oranges fruits harvested, sorted, graded and treated with a wax coating found that TSS: acid ratio was increased with the passage of time. These results are in similar with the finding of jadho *et al.* (2008) in kagzi lime and Gidagiri *et al*. (2020) in acid lime.

4.2.5 Total sugar (%)

The data pertaining to total sugar per cent as affected by different packaging materials is presented in Table 4.2.5 and depicted graphically in Fig. 4.2.5.

Significant differences were observed between the treatments at 5 days of storage. The experimental findings revealed that the treatment T_{10} (cling film 15 µ with 10 % wax) showed significantly highest total sugar (6.51 %) than the other treatments. The treatments T_1, T_8 and T_4 having the total sugars 5.37, 5.38 and 5.43, respectively were found to be at par with respect to total sugar (%) at 5 DAS. However, the treatments T_9, T_5, T_6 and T_7 with their respective total sugars 6.11, 5.98, 5.83 and 5.70 %, respectively were recorded significantly differed at 5 % level of significance. While, T_0 (control) treatment recorded the lowest total sugar of fruit (4.64 %) followed by T_3 (5.11 %) and T_2 (5.29 %).

The total sugar of fruits increased sharply from 5 to 10 days of storage. At 10 DAS the maximum total sugar (6.92 %) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically superior from rest of the treatments. Non-significant differences were noticed among the treatments T_4, T_1 & T_8 having the respective total sugar contents 5.51, 5.56 & 5.58 %, respectively. However, the least value of total sugar (5.12 %) was measured under the treatment T_0 (control).

Table 4.2.3: Effect of various packaging materials and waxing on acidity (%) of kinnow mandarin during storage

Notations	Treatments	Acidity (%)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	1.40^{g}	1.31^{h}	1.17^{g}	0.00*	0.00*	0.78
T_1	LDPE (25 µ)	1.33^{fg}	1.24^{fg}	1.09^{ef}	0.93^{e}	0.90^{e}	1.09
T_2	HDPE (15 µ)	1.35^{fg}	1.26^{g}	1.05^{e}	0.91^{d}	0.86^{de}	1.08
T_3	Polypropylene (25 µ)	1.37^{g}	1.28^{g}	1.11^{f}	0.99^{f}	0.99^{f}	1.14
T_4	Shrink film (15 µ)	1.17^{bc}	1.07^{cd}	0.92^{c}	0.88^{cd}	0.84^{de}	0.97
T_5	Cling film (15 µ)	1.10^{ab}	1.04^{bc}	0.88^{bc}	0.80^{b}	0.72^{bc}	0.90
T_6	LDPE (25 µ) + wax (10%)	1.19^{cd}	1.11^{de}	0.91^{c}	0.84^{bc}	0.79^{cd}	0.96
T_7	HDPE (15 µ) + wax (10%)	1.25^{de}	1.15^{e}	0.93^{cd}	0.85^{c}	0.75^{bc}	0.98
T_8	Polypropylene (25 µ) + wax (10%)	1.28^{ef}	1.20^{f}	0.98^{d}	0.90^{d}	0.88^{e}	1.04
T_9	Shrink film (15 µ) + wax (10%)	1.09^{a}	1.02^{b}	0.85^{b}	0.74^{a}	0.70^{b}	0.89
T_{10}	Cling film (15 µ) + wax (10%)	1.06^{a}	0.96^{a}	0.79^{a}	0.72^{a}	0.61^{a}	0.82
	SE(m) ±	**0.02**	**0.01**	**0.01**	**0.02**	**0.02**	
	C.D. at 5 %	**0.07**	**0.04**	**0.05**	**0.04**	**0.08**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.2.4: Effect of various packaging materials and waxing on TSS: Acid ratio of kinnow mandarin during storage

Notations	Treatments	TSS: Acid ratio					
		5 DAS	10 DAS	15 DAS	20 DAS	25 DAS	Mean
T_0	Control (untreated)	7.29^{a}	7.97^{a}	9.52^{a}	0.00*	0.00*	4.95
T_1	LDPE (25 µ)	7.91^{d}	8.79^{c}	10.55^{c}	13.61^{b}	14.52^{b}	11.07
T_2	HDPE (15 µ)	7.75^{c}	8.70^{c}	11.23^{d}	13.57^{b}	15.34^{c}	11.31
T_3	Polypropylene (25 µ)	7.56^{b}	8.35^{b}	10.19^{b}	12.22^{a}	13.08^{a}	10.28
T_4	Shrink film (15 µ)	9.17^{h}	10.40^{g}	12.93^{f}	14.60^{d}	16.60^{d}	12.74
T_5	Cling film (15 µ)	9.90^{i}	10.78^{h}	14.07^{h}	16.25^{g}	19.51^{g}	14.10
T_6	LDPE (25 µ) + wax (10%)	9.00^{g}	9.97^{f}	13.46^{g}	15.25^{f}	17.48^{e}	13.03
T_7	HDPE (15 µ) + wax (10%)	8.56^{f}	9.61^{e}	13.01^{f}	15.04^{e}	18.28^{f}	12.90
T_8	Polypropylene (25 µ) + wax (10%)	8.30^{e}	9.05^{d}	12.30^{e}	13.88^{c}	15.46^{c}	11.79
T_9	Shrink film (15 µ) + wax (10%)	10.03^{j}	11.14^{i}	14.71^{i}	16.51^{h}	20.35^{h}	14.54
T_{10}	Cling film (15 µ) + wax (10%)	11.24^{k}	12.50^{j}	16.03^{j}	18.47^{i}	23.68^{i}	16.38
SE(m) ±		**0.02**	**0.03**	**0.03**	**0.06**	**0.07**	
C.D. at 5 %		**0.06**	**0.09**	**0.14**	**0.19**	**0.21**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

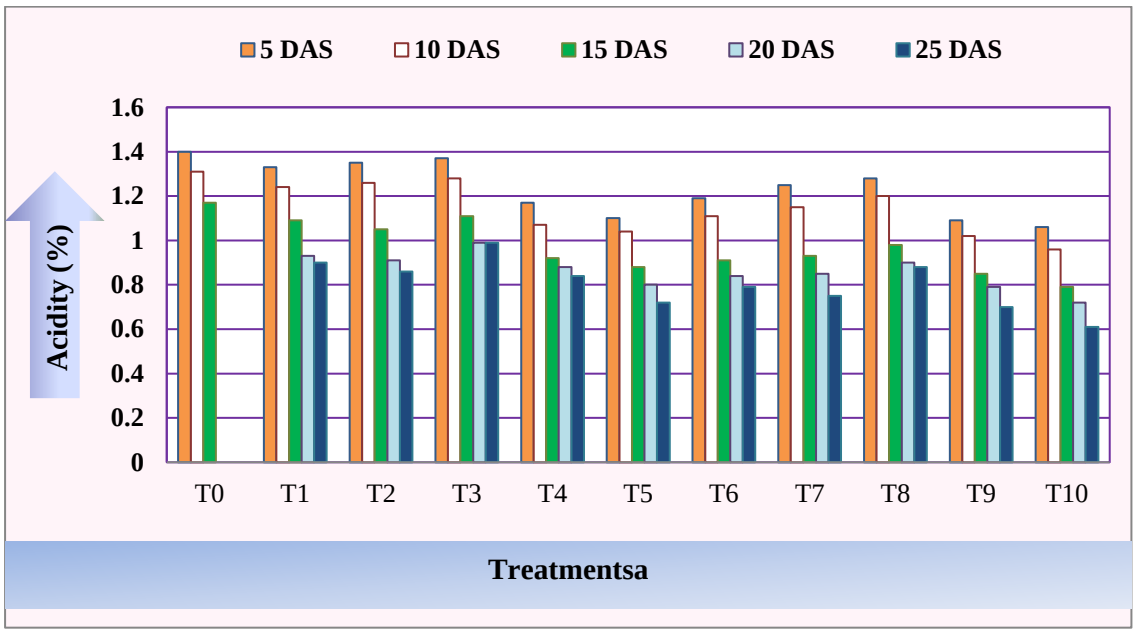


Fig. 4.2.3: Effect of various packaging materials and waxing on Acidity (%) of kinnow mandarin during storage

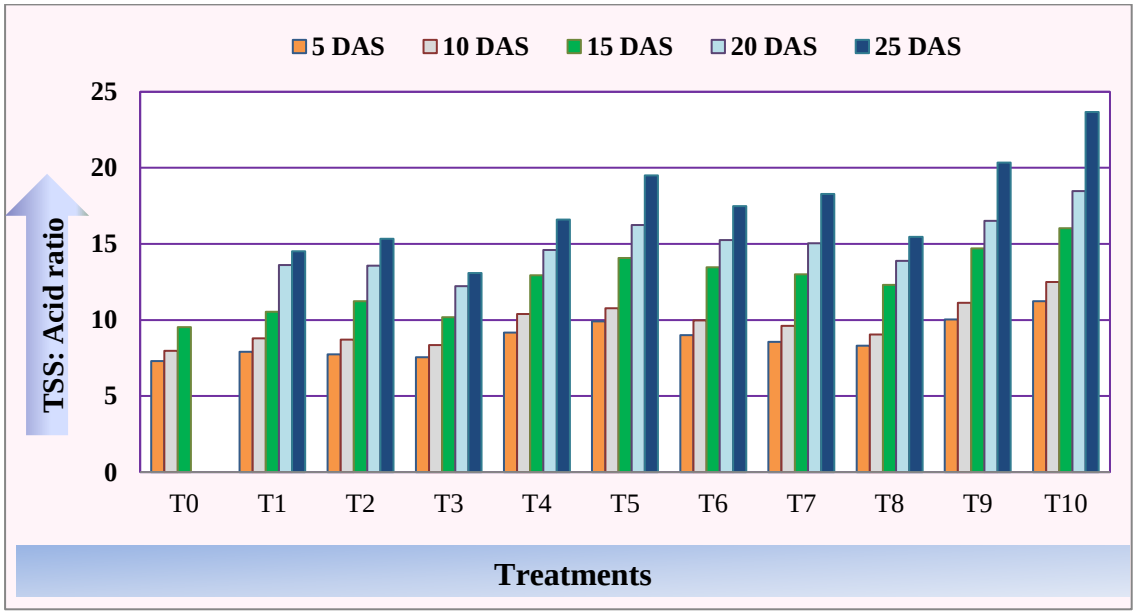


Fig. 4.2.4: Effect of various packaging materials and waxing on TSS: Acid ratio of kinnow mandarin during storage

During 15 days of storage, it can be observed that the total sugar (%) of fruit were significantly influenced by various packaging treatments used under the present experiment. The maximum content of total sugar (7.12 %) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed significant differences among all other treatments. Similarly, the treatments T_9 (6.95 %), T_5 (6.74 %) T_1 (6.02 %) and T_3 (5.71 %) were also found significant differences with each other. Whereas treatment T_0 (control) treatment showed the minimum total sugar content (5.56 %) at 15 days of storage.

At 20 DAS, the same increasing trend was noticed in respect to total sugar content of kinnow fruit under the present trial. The treatment T_{10} (cling film 15 µ with 10 % wax) registered maximum total sugar (7.29 %) followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the respective total sugars 7.04 % and 6.83 %. The treatments T_7, T_6 & T_4 and T_8 & T_2 with respective mean total sugars 6.54, 6.50 & 6.49 and 6.34 & 6.27 % showed non-significant differences with each other at 5 % level of significance. The minimum total sugar content (5.91 %) was registered under T_3 (Polypropylene 25 µ). However, the fruits kept under the control were discarded due to spoilage at 20 days after storage.

At 25 days of storage of kinnow mandarin, significant variations were found among the various packaging treatments used in present investigation. The treatment T_{10} (cling film 15 µ with 10 % wax) registered the maximum total sugar (7.48 %) among all other treatments. Non-significant differences were noticed among the treatments T_8 & T_2 and T_4, T_7 & T_6 and T_5 & T_9 having the respective mean total sugar per cent 6.45 & 6.49 and 6.86, 6.95 & 7.05 and 7.19 & 7.25 % respectively. However, the treatment T_3 (Polypropylene 25 µ) registered the minimum total sugar content (6.09 %). Whereas no fruits were found to be retained under control (T_0) for observation as the fruits were completely discarded due to microbial spoilage.

It is evident from the result obtained under present investigation that the various packaging materials had significantly affected the total sugar (%) of fruit as compared to control. Various packaging materials significantly increased the

total sugar (%) with the increasing storage period. The maximum total sugar of fruit (6.51 and 7.48 %) was obtained under the treatment cling film 15 µ with 10 % wax coated fruit (T_{10}) at 5 and 25 days of storage, while the minimum total sugar per cent (4.64, 5.12 and 5.56) was achieved under T_0 (control) at 5, 10 and 15 days of observation. The increase in Total sugar (%) may be due to the increase in TSS and decrease in acidity in respective treatment. The maximum value for sugars might be due to conversion of polysaccharides into soluble sugars, dehydration and transformation of certain cell wall materials like hemicelluloses and pectin's and also due to decrease in ascorbic acid content. The results are in line with the findings of Sharma *et al.* (2018) in kinnow mandarin. The least total sugar in other treatments might be due to delayed transpiration, respiration and ripening processes and also delayed activity in the conversion of polysaccharides into soluble sugars and ascorbic acid into dehydro ascorbic acid in the fruits. The results are in similar with the findings of Singh and Yadav (2015), Mahajan *et al.* (2016) and Singh *et al.* (2017) in kinnow mandarin and Srivastava and Said (2019) in pomegranate.

4.2.6 Reducing sugar (%)

The observations relevant to reducing sugar (%) of kinnow mandarin showed significant differences among the different packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition and the data pertaining to it is tabulated in Table 4.2.6 and illustrated in Fig. 4.2.6.

At 5 days of initial storage of kinnow mandarin, the maximum reducing sugar (3.52 %) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax), which was significantly higher than all other treatments. The treatments T_1, T_2, & T_8 and T_4 & T_7 and T_6 & T_5 having respective reducing sugar 3.13, 3.17 & 3.21 and 3.28 & 3.31 and 3.35 & 3.37 % were found statistically at par with each other at 5 % level of significance under the present trial. However the minimum reducing sugar content (2.78 %) was registered under the T_0 (control), which was followed by the treatment T_3 (Polypropylene 25 µ) having the mean reducing sugar of 3.06 %.

At 10 DAS, the reducing sugar content of kinnow mandarin was significantly influenced by various treatments. The maximum reducing sugar (3.77%) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed statistically similar with T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the respective average reducing sugars 3.71 and 3.65 %, respectively under the present trial. Similarly, the treatments, T_7, T_4 & T_8 and T_2 & T_1 having the respective mean reducing sugar content of 3.45, 3.42 & 3.41 and 3.38 & 3.29 % showed statistically non-significant differences with each other at 10 days of observation. Whereas, the minimum reducing sugar (3.12 %) was registered under the treatment T_0 (control), which was also found statistically at par with T_3 (Polypropylene 25 µ) having the average reducing sugar content of 3.19 %.

After 15 days of storage, the reducing sugar content was significantly affected by different packaging treatments. Based on the statistically evaluated data, the treatment T_{10} (cling film 15 µ with 10 % wax) registered maximum reducing sugar (4.15 %) as compared to rest of the treatments, followed by T_9 (shrink film 15 µ with 10 % wax) with 4.04 % reducing sugar. However, the minimum reducing sugar (3.25 %) was obtained under control (T_0) treatment.

At 20 DAS, the maximum per cent of reducing sugar (4.32) was recorded under the packaging treatment T_{10} (cling film 15 µ with 10 % wax), which was followed by T_9 (shrink film 15 µ with 10 % wax) with 4.21% reducing sugar. The treatments T_2 & T_8 and T_4, T_7, T_6 & T_5 having the respective mean reducing sugars 3.78 & 3.82 and 3.98, 4.01, 4.04 & 4.09 % were found non-significant differences with each other at 5% level of significance. However, the minimum value of reducing sugar (3.58 %) was obtained under Polypropylene 25 µ (T_3) and was confirmed statistically at par with T_1 (3.67 %). Whereas, no fruits were found to be retained under control (T_0) for observation.

At 25 DAS, different treatments showed significant differences with respect to the reducing sugar content. The reducing sugar (%) was significantly increased in the present trial irrespective of packaging materials. The treatment T_{10} (cling film 15 µ with 10 % wax) exhibited the highest reducing sugar (4.08 %) and was superior among all other treatments but showed non-significant differences

with T_9 (shrink film 15 µ with 10 % wax), having corresponding mean value of 4.01 %. However, the lowest reducing sugar (3.36 %) was obtained under the packaging material T_3 (Polypropylene 25 µ), which was confirmed statistically at par with T_1 (LDPE 25 µ) having reducing sugar percent of 3.44. Whereas, the fruits kept under control were spoiled and discarded at 25 days of storage.

As per the Table 4.2.6, it is clearly observed that the various packaging materials had significantly affected the reducing sugar (%) of fruit as compared to control. Among the various treatments of packaging material, the maximum reducing sugar of fruit (3.52 and 4.08 %) was obtained under the treatment cling film 15 µ with 10 % wax coated fruit (T_{10}) at 5 and 25 days of storage, while the minimum reducing sugar (2.78, 3.12 and 3.25 %) was achieved under T_0 (control) during 5, 10, 15 days of storage period. The significant increased in reducing sugar (%) of kinnow fruit with increased storage period might be due to the hydrolysis of polysaccharides such as starch, pectin and the inversion of non-reducing sugar into reducing sugar as increase in reducing sugar was correlated with the decrease in non-reducing sugar. The increase in reducing sugar corresponded to the increase in total soluble solids and ultimate by decreased in non-reducing sugar during the storage period. The present results corroborates with the findings of Randhawa *et al.* (2009), Mahajan *et al.* (2016), Singh *et al.* (2017) and Sharma *et al.* (2018) in kinnow mandarin. Similar findings were also reported by Patel *et al.* (2009) in passion fruit, Srivastava and Said (2019) in pomegranate.

Table 4.2.5: Effect of various packaging materials and waxing on total sugar (%) of kinnow mandarin during storage

Notations	Treatments	Total sugar (%)					
		5 DAS	10 DAS	15 DAS	20 DAS	25 DAS	Mean
T_0	Control (untreated)	4.64^{a}	5.12^{a}	5.56^{a}	0.00*	0.00*	3.06
T_1	LDPE (25 µ)	5.37^{d}	5.56^{c}	6.02^{c}	6.15^{b}	6.23^{a}	5.87
T_2	HDPE (15 µ)	5.29^{c}	5.68^{d}	6.19^{d}	6.27^{c}	6.49^{b}	5.98
T_3	Polypropylene (25 µ)	5.11^{b}	5.27^{b}	5.71^{b}	5.91^{a}	6.09^{a}	5.62
T_4	Shrink film (15 µ)	5.43^{e}	5.51^{c}	6.41^{e}	6.49^{d}	6.86^{c}	6.14
T_5	Cling film (15 µ)	5.98^{h}	6.42^{g}	6.74^{f}	6.83^{e}	7.19^{ef}	6.63
T_6	LDPE (25 µ) + wax (10%)	5.83^{g}	6.12^{f}	6.45^{e}	6.50^{d}	7.05^{de}	6.39
T_7	HDPE (15 µ) + wax (10%)	5.70^{f}	5.95^{e}	6.20^{d}	6.54^{d}	6.95^{cd}	6.27
T_8	Polypropylene (25 µ) + wax (10%)	5.38^{de}	5.58^{cd}	6.18^{d}	6.34^{c}	6.45^{b}	5.99
T_9	Shrink film (15 µ) + wax (10%)	6.11^{i}	6.57^{h}	6.95^{g}	7.04^{f}	7.25^{f}	6.78
T_{10}	Cling film (15 µ) + wax (10%)	6.51^{j}	6.92^{i}	7.12^{h}	7.29^{g}	7.48^{g}	7.06
SE(m) ±		**0.02**	**0.03**	**0.03**	**0.03**	**0.04**	
C.D. at 5 %		**0.05**	**0.10**	**0.11**	**0.09**	**0.14**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.2.6: Effect of various packaging materials and waxing on reducing sugar (%) of kinnow mandarin during storage

Notations	Treatments	Reducing sugar (%)					
		5 DAS	10 DAS	15 DAS	20 DAS	25 DAS	Mean
T_0	Control (untreated)	2.78^{a}	3.12^{a}	3.25^{a}	0.00*	0.00*	1.83
T_1	LDPE (25 µ)	3.13^{c}	3.29^{b}	3.52^{bc}	3.67^{a}	3.44^{a}	3.41
T_2	HDPE (15 µ)	3.17^{cd}	3.38^{bc}	3.54^{bc}	3.78^{b}	3.55^{b}	3.48
T_3	Polypropylene (25 µ)	3.06^{b}	3.19^{a}	3.47^{b}	3.58^{a}	3.36^{a}	3.33
T_4	Shrink film (15 µ)	3.28^{e}	3.42^{c}	3.70^{d}	3.98^{c}	3.75^{cd}	3.63
T_5	Cling film (15 µ)	3.37^{f}	3.65^{de}	3.94^{e}	4.09^{d}	3.96^{fg}	3.80
T_6	LDPE (25 µ) + wax (10%)	3.35^{f}	3.61^{d}	3.86^{e}	4.04^{cd}	3.88^{ef}	3.75
T_7	HDPE (15 µ) + wax (10%)	3.31^{ef}	3.45^{c}	3.69^{d}	4.01^{cd}	3.81^{de}	3.65
T_8	Polypropylene (25 µ) + wax (10%)	3.21^{d}	3.41^{c}	3.58^{c}	3.82^{b}	3.68^{c}	3.54
T_9	Shrink film (15 µ) + wax (10%)	3.45^{g}	3.71^{ef}	4.04^{f}	4.21^{e}	4.01^{gh}	3.88
T_{10}	Cling film (15 µ) + wax (10%)	3.52^{h}	3.77^{f}	4.15^{g}	4.32^{f}	4.08^{h}	3.97
SE(m) ±		**0.02**	**0.03**	**0.02**	**0.03**	**0.03**	
C.D. at 5 %		**0.06**	**0.09**	**0.08**	**0.10**	**0.09**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

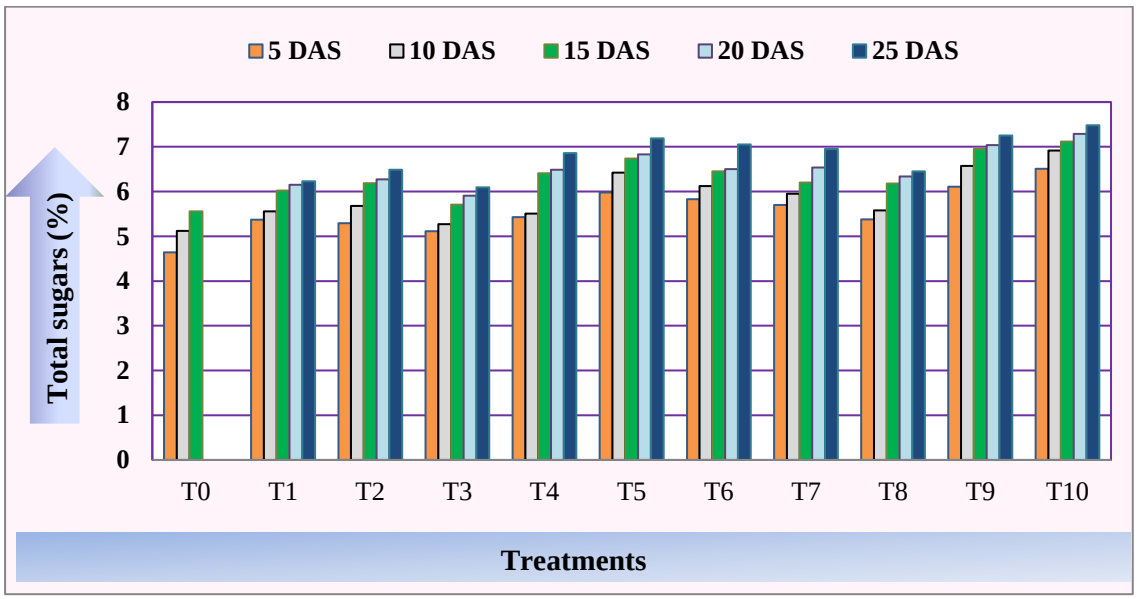


Fig. 4.2.5: Effect of various packaging materials and waxing on total sugar (%) of kinnow mandarin during storage

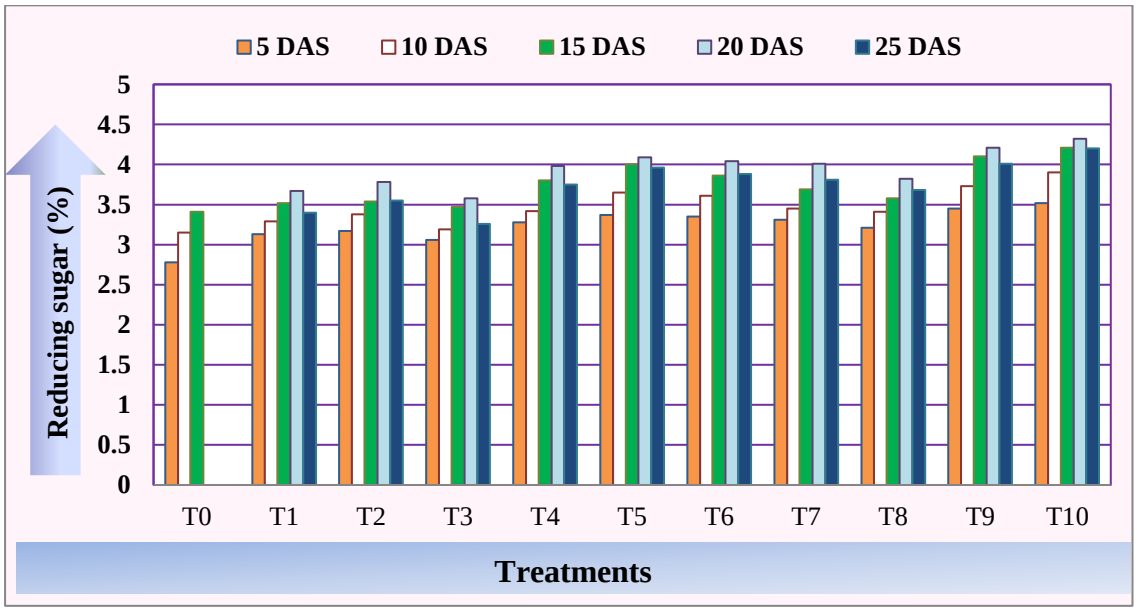


Fig. 4.2.6: Effect of various packaging materials and waxing on reducing sugar (%) of kinnow mandarin during storage

4.2.7 Non-reducing sugar (%)

The data pertaining to non-reducing sugar (%) of kinnow mandarin fruit is tabulated in Table 4.2.7 and illustrated in Fig 4.2.7. The data clearly indicates that various packaging materials had significant influenced the non-reducing sugar (%) of kinnow fruit during different days of storage under ambient condition.

At 5 DAS, significant variations were observed under the various packaging treatments. The data showed that the treatment T_{10} (cling film 15 µ with 10 % wax) recorded the maximum non-reducing sugar (2.99 %) and was superior among all other treatments. Furthermore, it was noticed that, the treatments T_9, T_5 & T_6 and T_7, T_1 & T_8 and T_4 & T_2 with their respective mean non-reducing sugars 2.66, 2.61 & 2.48 and 2.39, 2.24 & 2.17 and 2.15 & 2.12 %, respectively were statistically at par with each other at 5% level of significance. The minimum non-reducing sugar (1.86 %) was observed in T_0 (control).

At 10 DAS, the maximum non-reducing sugar (3.15 %) was registered under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) with non-reducing sugar of 2.86 and 2.77 % showed significantly differed from rest of the other treatments. Similarly, the treatments T_6 & T_7 and T_2 & T_1 and T_8 & T_4 having respective mean non-reducing sugar contents 2.51 & 2.50 and 2.27 & 2.30 and 2.17 & 2.09 %, respectively were statistically non-significant differences with each other at 5 % level of significance. The minimum non-reducing sugar content (2.02 %) was registered under the T_0 (control), which was statistically at par with T_3 (2.08 %) under the present investigation.

Significant differences were observed between treatments for non-reducing sugar of kinnow mandarin fruit recorded at 15 days of storage. The non-reducing sugar (%) increased with increasing storage period in all the treatments. The maximum non-reducing sugar (2.97 %) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), which was significantly superior from rest of the treatments. The treatment T_9 (shrink film 15 µ with 10 % wax) having the non-reducing sugar 2.85 % was found statistically similar with T_5 (cling film 15 µ) with

2.80 % of reducing sugar. The minimum non-reducing sugar (2.31 %) was observed in T_0 (control).

At 20 DAS, the treatment T_{10} (cling film 15 µ with 10 % wax) responded similar results by registering highest non-reducing sugar (2.97 %), which was followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 25 µ) having the respective non-reducing sugars 2.83 and 2.74 %. The treatments T_7, T_8, T_4, T_2, T_1 and T_6 with corresponding mean non-reducing sugars 2.53, 2.52, 2.51, 2.49, 2.48 & 2.46 %, respectively were found non-significant differences with each other at 5% level of significance. However, the lowest value of non-reducing sugar (2.33 %) was obtained in T_3 (Polypropylene 25 µ). Whereas, fruits under control (untreated) were spoiled and discarded at 20 days after storage.

After 25 days of storage of kinnow mandarin, the treatment T_{10} (cling film 15 µ with 10 % wax) was recorded maximum non-reducing sugar (3.40 %). Non-significant differences were noticed among the treatments T_9 & T_5 and T_6, T_7 & T_4 having the respective mean of non-reducing sugar per cent 3.24 & 3.23 and 3.17, 3.14 & 3.11 %, respectively. The treatment T_3 (Polypropylene 25 µ) registered the minimum non-reducing sugars (2.73 %) and it was statistically at par with T_1 LDPE (25 µ) and T_8 (Polypropylene 25 µ with wax 10 %) having the respective non-reducing sugars 2.79 and 2.77 %. Furthermore, no fruits were found to be retained under control untreated (T_0) for recording observation as the fruits were succumbed to spoilage during the storage.

From the present experimental data, it can be observed that various packaging materials had significantly affected the non-reducing sugar (%) of fruit as compared to control. Non-reducing sugar (%) was significantly influenced with increased storage period. The maximum non-reducing sugar of fruit (2.99 and 3.40 %) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage, while the minimum non-reducing sugar (1.86, 2.02 and 2.31 %) was achieved under T_0 (control) at 5, 10 and 15 days of observation. However, fruits under control treatment was spoiled and discarded completely at 20 and 25 days of storage. Significant decrease in non-reducing sugar (%) with the increased storage period might be due to hydrolysis of starch in the early stage and later for

utilization of sugars in respiration. The increase in total sugar and reducing sugar ultimately decreased the non-reducing sugar as they are co-related with each other. These results are in close agreements with the findings of Patel *et al.* (2009) in passion fruit and Randhawa (2009), Mahajan *et al.* (2016), Singh *et al.* (2017) and Sharma *et al.* (2018) in kinnow mandarin.

4.2.8 Sugar: Acid ratio

The data related to sugar: acid ratio of kinnow fruit presented in Table 4.2.8 and illustrated in Fig 4.2.8, showed significant differences among various packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The data clearly indicates that sugar: acid ratio significantly increased with increased storage period.

At 5 days of storage of kinnow mandarin, the highest sugar: acid ratio (6.14) was noticed under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed significantly superior among all other treatments. Similarly, the treatments T_4 & T_7 and T_1 & T_2 with sugars: acid ratio of 4.64 & 4.56 and 4.04 & 3.92 were found non-significant differences with each other at 5% level of significance. However, the treatments T_6 (4.90) and T_8 (4.20) were significantly differed from rest of the treatment. While, the least sugars: acid ratio (3.31) was recorded under the treatment T_0 (control).

After 10 days of storage of kinnow mandarin, the highest sugar: acid ratio (7.21) was noticed under the superiority of treatment T_{10} (cling film15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax) with sugar acid ratio of 6.44. Similarly, the treatments T_7 & T_4 and T_2 & T_1 having the respective fruit sugars: acid ratio 5.17 & 5.15 and 4.51 & 4.48 were found statistically similar with each other under the present experiment. Whereas, the lowest mean value of sugars: acid ratio (3.91) was registered under the treatment T_0 (control), which was followed by T_3 (Polypropylene 25 µ) having sugar acid ratio of 4.12.

At 15 DAS, it was observed that the maximum mean value of sugars: acid ratio (9.01) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax) followed by the treatment T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the respective sugar: acid ratio 8.18 and 7.66. Similarly, the

treatments T_6 & T_4 with respective sugar: acid ratio 7.09 & 6.97 was statistically equivalent between each other at 5% level of significance. The minimum value of sugars: acid ratio (4.75) was recorded in T_0 (control) followed by T_3-Polypropylene 25 µ (5.14) during the storage period

Similarly at 20 DAS, significant differences were also found among various treatments with respect to the sugar: acid ratio of fruit. Treatment T_{10} (cling film 15 µ with 10 % wax) exhibited the highest sugar: acid ratio (10.13) of kinnow mandarin and significantly superior among all other treatments. The lowest sugars: acid ratio of fruit (5.97) was noticed under the treatment T_3 (Polypropylene 25 µ), whereas no fruits were found to be retained under T_0 (control) for observation as the fruits were spoiled.

At 25 days after storage, similar increasing trend was observed among various treatments with respect to sugar: acid ratio. The maximum sugar: acid ratio of fruit (12.26) was obtained under the same treatment T_{10} (cling film 15 µ with 10 % wax). Similarly, the treatments T_2 & T_8 with average sugar: acid ratio of 7.55 & 7.33, respectively were found statistically at par with each other at 5% level of significance. The minimum sugar: acid ratio (6.15) was reported under the treatment T_3 (Polypropylene 25 µ), whereas the fruits under control were completely spoiled at 25 days of storage.

According to statistically analyzed results obtained under present investigation, it is clear that the various packaging materials had significantly affected the sugar: acidity ratio of fruit as compared to control. Among the various treatments of packaging material, the maximum sugar: acid ratio of fruit (6.14 and 12.26) was obtained under the treatment cling film 15 µ with 10 % wax coated fruit at 5 and 25 days of storage, while the minimum sugar: acid ratio (3.31, 3.91 to 4.75) was achieved under T_0 (control) at 5, 10 and 15 days of observation, whereas no fruits were found to be retained in control fruit at 20 and 25 days of observation due to spoilage. It was observed that sugar: acid ratio increased drastically with increased storage period. The increased ratio might be due to the increase in sugar and decrease in acidity in respective treatments. These results are in line with the

finding of jadho *et al.* (2008) in Kagzi lime and Singh *et al*. (2017) in kinnow mandarin.

4.2.9 Ascorbic acid (mg/ 100 ml)

The data pertaining to ascorbic acid (mg/100 ml) of kinnow mandarin is presented in Table 4.2.9 and graphically depicted in Fig. 4.2.9. The data showed that the ascorbic acid decreased with the advancement of storage period.

After 5 days of storage of kinnow mandarin, the highest ascorbic acid (26.73 mg/100 ml juice) was noticed under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed non-significant differences with T_9 (shrink film 15 µ with 10 % wax) having the ascorbic acid content 26.58 mg/100 ml juice. The treatments T_2, T_8, T_7, T_4, T_6 and T_5 with corresponding ascorbic acid content of 23.88, 24.06, 24.53, 25.16, 25.77 and 26.28 mg/100 ml juice, respectively were showed significant differences among each other. Whereas, the lowest value of ascorbic acid (21.34 mg/100 ml juice) was registered under the treatment T_1 (control), which was followed by T_3 (Polypropylene 25 µ) and T_1 (LDPE 25 µ) having the respective fruit ascorbic acid 23.35 and 23.52 mg/100 ml under the present experiment.

At 10 DAS, it was observed that packaging materials and storage period had significantly influenced the ascorbic acid content of kinnow mandarin. The maximum mean value of ascorbic acid (25.21 mg/100 ml) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax) under the present study. Furthermore, it was analyzed that, the treatments T_5, & T_4 and T_7 & T_8 and T_1 & T_2 with their respective ascorbic acid contents of 24.06 & 23.97 and 23.11 & 22.87 and 22.10 & 22.06 mg/100 ml were statistically equivalent with each other at 5% level of significance. The treatments T_9 (24.83 mg/100 ml) and T_6 (23.64 mg/100 ml) were significantly differed from rest of the treatment. The minimum value of ascorbic acid (18.79 mg/100 ml) was recorded under T_0 (control) during 10 days of storage period.

Table 4.2.7: Effect of various packaging materials and waxing on non-reducing sugar (%) of kinnow mandarin during storage

Notations	Treatments	Non-reducing sugar (%)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	1.86^{a}	2.02^{a}	2.31^{b}	0.00*	0.00*	1.25
T_1	LDPE (25 µ)	2.24^{cd}	2.27^{c}	2.50^{c}	2.48^{b}	2.79^{a}	2.46
T_2	HDPE (15 µ)	2.12^{bc}	2.30^{c}	2.65^{e}	2.49^{b}	2.94^{b}	2.50
T_3	Polypropylene (25 µ)	2.05^{b}	2.08^{a}	2.24^{a}	2.33^{a}	2.73^{a}	2.29
T_4	Shrink film (15 µ)	2.15^{bc}	2.09^{ab}	2.71^{f}	2.51^{b}	3.11^{c}	2.51
T_5	Cling film (15 µ)	2.61^{fg}	2.77^{e}	2.80^{g}	2.74^{c}	3.23^{cd}	2.83
T_6	LDPE (25 µ) + wax (10%)	2.48^{ef}	2.51^{d}	2.59^{d}	2.46^{b}	3.17^{cd}	2.64
T_7	HDPE (15 µ) + wax (10%)	2.39^{de}	2.50^{d}	2.51^{c}	2.53^{b}	3.14^{cd}	2.61
T_8	Polypropylene (25 µ) + wax (10%)	2.17^{bc}	2.17^{b}	2.60^{de}	2.52^{b}	2.77^{a}	2.45
T_9	Shrink film (15 µ) + wax (10%)	2.66^{g}	2.86^{e}	2.85^{g}	2.83^{d}	3.24^{d}	2.90
T_{10}	Cling film (15 µ) + wax (10%)	2.99^{h}	3.15^{f}	2.97^{h}	2.97^{e}	3.40^{e}	3.10
	SE(m) ±	**0.05**	**0.03**	**0.02**	**0.03**	**0.04**	
	C.D. at 5 %	**0.16**	**0.09**	**0.05**	**0.08**	**0.12**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.2.8: Effect of various packaging materials and waxing on sugar: acid ratio of kinnow mandarin during storage

Notations	Treatments	Sugar: Acid ratio					
		5 DAS	10 DAS	15 DAS	20 DAS	25 DAS	Mean
T_0	Control (untreated)	3.31^{a}	3.91^{a}	4.75^{a}	0.00*	0.00*	2.39
T_1	LDPE (25 µ)	4.04^{c}	4.48^{c}	5.52^{c}	6.61^{b}	6.92^{b}	5.52
T_2	HDPE (15 µ)	3.92^{c}	4.51^{c}	5.90^{d}	6.89^{bc}	7.55^{c}	5.75
T_3	Polypropylene (25 µ)	3.73^{b}	4.12^{b}	5.14^{b}	5.97^{a}	6.15^{a}	5.02
T_4	Shrink film (15 µ)	4.64^{e}	5.15^{e}	6.97^{g}	7.38^{d}	8.17^{d}	6.46
T_5	Cling film (15 µ)	5.44^{g}	6.17^{g}	7.66^{h}	8.54^{f}	9.99^{g}	7.56
T_6	LDPE (25 µ) + wax (10%)	4.90^{f}	5.51^{f}	7.09^{g}	7.74^{e}	8.92^{e}	6.83
T_7	HDPE (15 µ) + wax (10%)	4.56^{e}	5.17^{e}	6.67^{f}	7.69^{e}	9.27^{f}	6.67
T_8	Polypropylene (25 µ) + wax (10%)	4.20^{d}	4.65^{d}	6.31^{e}	7.04^{c}	7.33^{c}	5.91
T_9	Shrink film (15 µ) + wax (10%)	5.61^{h}	6.44^{h}	8.18^{h}	8.91^{g}	10.36^{h}	7.90
T_{10}	Cling film (15 µ) + wax (10%)	6.14^{i}	7.21^{i}	9.01^{i}	10.13^{h}	12.26^{i}	8.95
	SE(m) ±	**0.04**	**0.03**	**0.05**	**0.09**	**0.08**	
	C.D. at 5 %	**0.13**	**0.11**	**0.16**	**0.28**	**0.25**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

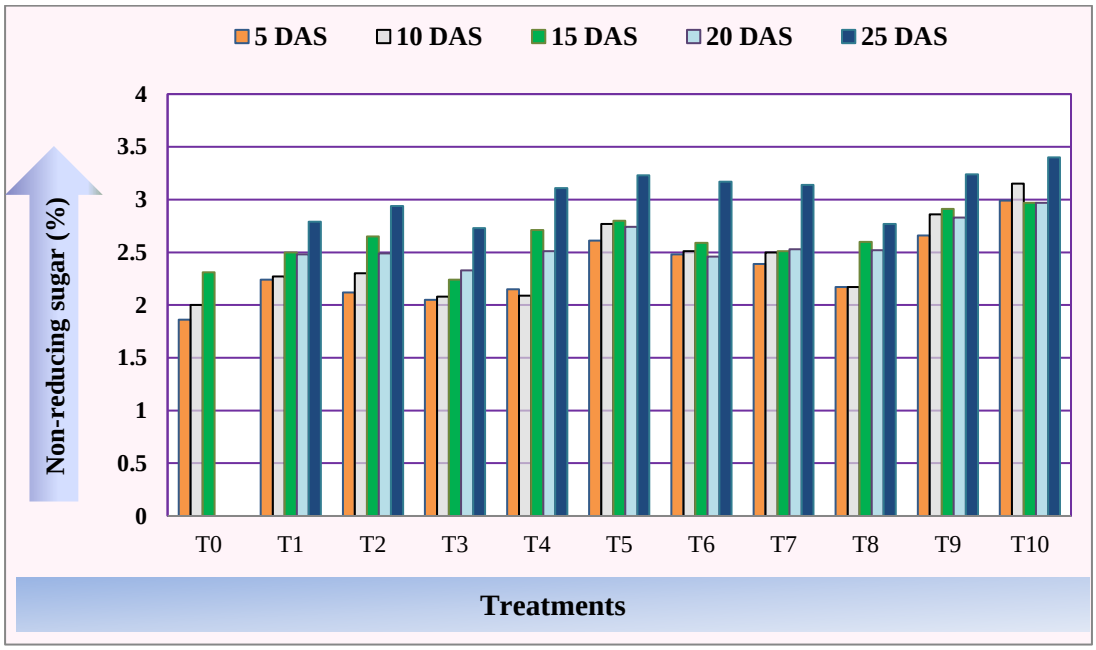


Fig. 4.2.7: Effect of various packaging materials and waxing on non-reducing sugar (%) of kinnow mandarin during storage

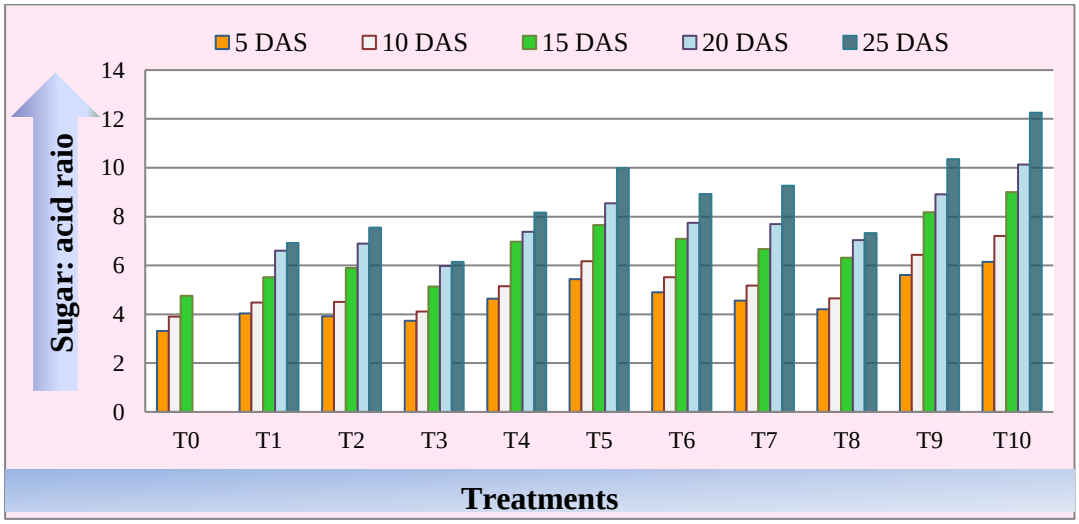


Fig. 4.2.8: Effect of various packaging materials and waxing on sugar: acid ratio of kinnow mandarin during storage

It is evident from the Table 4.2.9, that the different treatments showed significant variations in respect to ascorbic acid content of kinnow fruit at 15 DAS. The treatment cling film 15 µ with 10 % wax (T_{10}) registered the highest average ascorbic acid (23.61 mg/100 ml), which was followed by T_9 (shrink film 15 µ with 10 % wax) having the ascorbic acid 22.19 mg/100 ml under the present investigation. The treatments T_7 & T_8 and T_4 & T_1 with average ascorbic acid content of 21.05 & 21.00 and 20.39 & 20.35 mg/100 ml were statistically similar among each other. Similarly, here it was specified that T_5 and T_6 having the respective average value of ascorbic acid 22.03 and 21.32 mg/100 ml was confirmed significantly different with each other. However, lowest ascorbic acid (14.81 mg/100 ml) was obtained in T_0 (control).

At 20 days after storage, statistically similar decreasing trend was observed among various treatments with respect to ascorbic acid. The highest ascorbic acid of fruit (21.43 mg/100 ml) was reported under the superiority of treatment cling film 15 µ with 10 % wax (T_{10}). The treatments T_9, T_5 and T_6 with mean ascorbic acid of 20.03, 19.71 and 19.32 mg/100 ml, respectively were found significantly differed from rest of the treatment. Moreover, non-significant differences were also recorded among T_7 & T_8 and T_1 & T_2 with corresponding mean ascorbic acid 18.08 & 18.00 and 17.01 & 16.98 mg/100 ml, respectively. However, the lowest fruit ascorbic acid (16.27 mg/100 ml) was noticed under the treatment T_3 (Polypropylene 25 µ), whereas no fruits were found to be retained under control treatment (T_0) for observation as all fruits get spoiled.

At 25 DAS, significant differences were also found among various treatments with respect to the ascorbic acid of fruit. Among the various packaging materials the treatment T_{10} (cling film 15 µ with 10 % wax) exhibited the highest ascorbic acid (19.43 mg/100 ml) of kinnow mandarin. It was showed significantly superior among all other treatments under present trial. The lowest ascorbic acid of fruit (14.78 mg/100 ml) was evaluated under the treatment T_3 (Polypropylene 25 µ). However, fruits kept under T_0 (control) get spoiled at 25 days of storage.

From the statistical analyzed data it can be concluded that storage period and packaging material had significantly affected the ascorbic acid content, which

decreased gradually as the storage period increased. The maximum ascorbic acid of fruit (26.73 and 19.43 mg/100 ml) was obtained under the treatment cling film 15 µ with 10 % wax coated fruit at 5 and 25 days of storage, while the minimum ascorbic acid (21.34, 18.79 and 14.81 mg/100 ml) was achieved under T_0-control at 5, 10, 15 days storage periods. The probable reason for decreased ascorbic acid content during storage might be due to the utilization of organic acids during respiration or their conversion to sugars (Sharma *et al.* 2018). Similar decreasing trend in case of other treatments might be due to the fact that ascorbic acid is very susceptible to oxidative deterioration occurred at accelerated rate due to the presence of higher concentrations of O_2 as compared to polyethylene packages (Singh *et al.* 2017). The results of this study are in close agreement with the findings of Mahajan *et al.* (2016), who reported that ascorbic acid of acid lime and kinnow decreased respectively with the increase storage period because of oxidation of ascorbic acid.

In addition, ascorbic acid content in citrus fruits generally declines with enhanced storability due to increase in the activity of oxidizing enzymes like ascorbic acid oxidase, peroxidase and catalase, which might have converted into dehydro ascorbic acid. The results are also similar with the results of Ahmad *et al.* (2013), Singh *et al.* (2017) and Dhillon (2016) in kinnow mandarin.

4.3 Sensory evaluation of kinnow mandarin

The sensory evaluation of kinnow fruits were recorded for the following variables *i.e.* spoilage (%), color appearance, flavor and taste are presented in Table 4.3.1 to 4.3.4 and graphically depicted from Fig. 4.3.1 to 4.3.4.

4.3.1 Spoilage (%)

The analysis of data from present study showed that different treatments at storage intervals had a significant impact on spoilage percentage of kinnow mandarin. The data related to spoilage per cent has been presented in Table 4.3.1 and graphically illustrated in Fig. 4.3.1.

At 5 days of storage there was no spoilage (%) in any treatment.

At 10 days of storage, similarly no fruits were found to be spoiled under the various packaging materials except T_0 (untreated), which had average spoilage per cent of 19.62 % of kinnow fruit at ambient condition.

At 15 DAS, the minimum spoilage (5.51%) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax), which was found significantly superior as compared to rest of the treatments. Moreover, the treatments T_1, T_2, T_8, T_4, T_7, T_6, T_5 and T_9 having respective spoilage percentage 12.35, 10.60, 9.93, 8.79, 8.00, 7.70, 7.15 and 6.87 were found statistically differed among each other at 5 % level of significance. However, the maximum spoilage (41.12 %) was registered under the treatment T_0 (control).

At 20 DAS, significant differences were found among various treatments with respect to the spoilage percentage. Spoilage (%) increased with the increased storage period irrespective of various packaging materials. Spoilage of kinnow mandarin (10.71 %) was significantly lower under the fruits treated with cling film 15 µ with 10 % wax (T_{10}), whereas the maximum spoilage (69.36 %) was registered under T_0 (control) followed by T_3 (Polypropylene 25 µ) having the spoilage per cent of 25.44.

At 25 days of storage, significant effect of packaging materials on spoilage percentage of kinnow mandarin was observed. The spoilage of fruit significantly increased in all the treatments irrespective of various packaging materials used in present experiment. The minimum spoilage per cent (18.74 %) was registered in fruits packed under T_{10} (cling film 15 µ with 10 % wax) and the maximum spoilage (100 %) was recorded under the treatment T_0 (control), which was followed by T_3 (Polypropylene 25 µ) having the spoilage percentage of 37.21 % at ambient condition.

It is evident from the result obtained under present investigation that the various packaging materials had significantly affected the fruit spoilage as compared to control. Among the various treatments of packaging material, the minimum spoilage percent of kinnow fruit 5.51 and 18.74 % was observed under the treatment T_{10} (cling film 15 µ with 10 % wax) at 15 and 25 days of storage, while the maximum spoilage of fruit 19.62 and 100 % was recorded under T_0

(control) at 5 and 25 days of observation. It can be noticed that significant increase in spoilage (%) of kinnow mandarin under different treatments during the storage period under ambient condition. The increasing of fruit spoilage with the increase in storage period might be due to progress weakening of the defence system against micro-organism or unventilated condition developed inside the fruits atmosphere. The higher spoilage in control might be due to weakening of the defence system against fungal attack with the passage of time and due to higher rates of respiration that leads to shrivelling and wrinkling. The enhanced spoilage (%) was observed under control, because these fruits were treated without polythene wrapped or wax coated and it was stored under ambient condition causing absence of barrier enabling to moisture loss or micro-organism, which are responsible for enhancement of spoilage of fruits as compared to all other treatments. Whereas, in case of fruits stored under packed condition, the lowest spoilage per cent was seen. It might be due to modified atmosphere condition created inside packaging material, which might also act as physical barrier resulting in reduced respiration and transpiration or provided better ventilation against micro-organisms. In addition, spoilage mainly occurs due to the excessive concentration of CO_2 and humidity inside the fruit surface, resulting in rapid deterioration. This result is similar to the findings of Dhiilon *et al.* (2016), Singh *et al.* (2017), Sharma *et al.* (2018), Manisha and Gandhi (2019) and Haider *et al.* (2021) in kinnow fruits.

4.3.2 Color appearance

The data related to color appearance of kinnow fruit presented in Table 4.3.2 and illustrated in Fig. 4.3.2 showed significant variations among various packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The data clearly indicates that color appearance significantly decreased with increased storage period.

Significant differences were observed between the treatments at 5 DAS. The experimental findings revealed that treatment T_{10} (cling film 15 µ with 10 % wax) showed significantly highest score of color appearance (9.00) than the other treatments. The treatments T_2 & T_1 and T_8, T_4 & T_7 and T_5 & T_9 (8.27 & 8.36 and

8.48, 8.52 & 8.61 and 8.82 & 8.90, respectively) were found to be at par with respect to color appearance of kinnow mandarin. While, the control treatment recorded the lowest color appearance of fruit (7.09) followed by T_3 (8.02) during the present investigation of kinnow mandarin.

At 10 DAS, the color appearance of fruit was significantly influenced under different packaging treatments. The maximum score of color appearance (8.91) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed significantly better than all other treatments. Furthermore, the treatments T_8 & T_4 and T_7 & T_6 having average scores of color appearance 8.33 & 8.39 and 8.48 & 8.53, respectively were confirmed significantly similar with each other under the present study. However, the minimum color appearance (6.49) was scored under the untreated control (T_0).

At 15 DAS, again statistically significant differences were found among various treatments with respect to the sensory value of color appearance. Similarly, treatment T_{10} (cling film 15 µ with 10 % wax), exhibited the highest value of color and appearance (8.72) of kinnow mandarin and significantly superior from rest of the treatments. Whereas, the treatment T_1, T_2 & T_8 and T_7 & T_6 and T_4 & T_5 with mean color and appearance of 7.97, 8.04 & 8.06 and 8.10 & 8.19 and 8.25 & 8.34 scores, respectively were found significantly at par with each other at 5% level of significance. However, the lowest value for color and appearance of fruit (4.86) was registered under the T_0 (control), followed by T_3 (Polypropylene 25 µ) having color appearance of 7.50.

After 20 days of storage, the higher score for color and appearance (8.58) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax) and recorded superior among all other treatments. Similarly, the treatment T_9, T_4 and T_8 with mean color appearance scores of 8.34, 7.65 and 7.38, respectively were statistically differed with rest of the treatments. Whereas, the least score for color and appearance **(**7.05) was obtained under the treatment T_3 (Polypropylene 25 µ). However, no fruits were found to be retained under T_0 (control) for observation as the fruits were disposed due to spoilage.

At 25 DAS, statistically similar trend was observed among various treatments with respect to color appearance. The maximum score of colour appearance (8.27) was obtained under T_{10}-Cling film (25 µ) with 10 % wax, which was found significantly better than rest of the treatment. Similarly, significant differences were also recorded among the treatments T_1, T_8, T_4, T_7, T_6 and T_5 with corresponding mean of color and appearance 7.03, 7.18, 7.29, 7.39, 7.77 and 7.86, respectively at 5 % level of significance. However, minimum score of color appearance (6.50) was recorded under T_3 (Polypropylene 25 µ). Furthermore, no fruits were found to be retained under T_0 (control) for observation.

It is evident from the result obtained under present investigation that the various packaging materials had significantly affected the color appearance of fruit as compared to control. Various packaging materials significantly decreased the color appearance with the increasing storage period. The maximum color appearance of fruit (9.00 and 8.27) was obtained under the treatment T_{10}-cling film (15 µ) with 10 % wax coated fruit at 5 and 25 days of storage, while the minimum color appearance (7.09, 6.49 and 4.86) was achieved under T_0 (control) at 5, 10 and 15 days of observation. The retention of maximum color appearance of fruit might be due to the delaying of the senescence process, slow metabolic activity enzymatic reaction and slow chlorophyll pigments degeneration in fruit are responsible. In addition, the decrease in color appearance of the kinnow mandarin could be due to contact air, slight wilting and loss of moisture and natural senescence process. Similar results were also reported by Jadhoa *et al.* (2008) in kagzi lime and Dhillon *et al.* (2016) in kinnow mandarin.

Table 4.2.9: Effect of various packaging materials and waxing on ascorbic acid (mg/100 ml) of kinnow mandarin during storage

Notations	Treatments	Ascorbic acid (mg/100 ml)					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	21.34^{a}	18.79^{a}	14.81^{a}	0.00*	0.00*	10.98
T_1	LDPE (25 µ)	23.52^{b}	22.10^{c}	20.35^{d}	17.01^{b}	15.78^{c}	19.75
T_2	HDPE (15 µ)	23.88^{c}	22.06^{c}	19.73^{c}	16.98^{b}	15.12^{b}	19.55
T_3	Polypropylene (25 µ)	23.35^{b}	21.43^{b}	18.02^{b}	16.27^{a}	14.78^{a}	18.77
T_4	Shrink film (15 µ)	25.16^{f}	23.97^{f}	20.39^{d}	17.71^{c}	16.73^{e}	20.79
T_5	Cling film (15 µ)	26.28^{h}	24.06^{f}	22.03^{g}	19.71^{f}	17.65^{f}	21.94
T_6	LDPE (25 µ) + wax (10%)	25.77^{g}	23.64^{e}	21.32^{f}	19.32^{e}	17.56^{f}	21.52
T_7	HDPE (15 µ) + wax (10%)	24.53^{e}	23.11^{d}	21.05^{e}	18.08^{d}	16.83^{e}	20.72
T_8	Polypropylene (25 µ) + wax (10%)	24.06^{d}	22.87^{d}	21.00^{e}	18.00^{d}	16.04^{d}	20.39
T_9	Shrink film (15 µ) + wax (10%)	26.58^{i}	24.83^{g}	22.19^{h}	20.03^{g}	18.06^{g}	22.33
T_{10}	Cling film (15 µ) + wax (10%)	26.73^{i}	25.21^{h}	23.61^{i}	21.43^{h}	19.43^{h}	23.28
	SE(m) ±	**0.06**	**0.08**	**0.03**	**0.03**	**0.04**	
	C.D. at 5 %	**0.18**	**0.27**	**0.12**	**0.10**	**0.13**	

1. Values marked as * indicates fruit gets spoiled.
2. DAS - Days after storage
3. The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.3.1: Effect of various packaging materials and waxing on spoilage per cent of kinnow mandarin during storage

Notations	Treatments	Spoilage per cent					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	0.00	19.62[a]	41.12[k]	69.36[i]	100[k]	46.02
T_1	LDPE (25 µ)	0.00	0.00	12.35[i]	23.13[g]	32.14[i]	13.52
T_2	HDPE (15 µ)	0.00	0.00	10.60[h]	21.34[f]	30.38[h]	12.46
T_3	Polypropylene (25 µ)	0.00	0.00	15.31[j]	25.44[h]	37.21[j]	15.59
T_4	Shrink film (15 µ)	0.00	0.00	8.79[f]	15.13[d]	26.24[f]	10.03
T_5	Cling film (15 µ)	0.00	0.00	7.15[c]	12.34[b]	21.89[c]	8.27
T_6	LDPE (25 µ) + wax (10%)	0.00	0.00	7.70[d]	13.75[c]	22.68[d]	8.82
T_7	HDPE (15 µ) + wax (10%)	0.00	0.00	8.00[e]	14.91[d]	24.87[e]	9.55
T_8	Polypropylene (25 µ) + wax (10%)	0.00	0.00	9.93[g]	18.17[e]	29.32[g]	11.48
T_9	Shrink film (15 µ) + wax (10%)	0.00	0.00	6.87[b]	11.06[a]	20.17[b]	7.62
T_{10}	Cling film (15 µ) + wax (10%)	0.00	0.00	5.51[a]	10.71[a]	18.74[a]	6.99
SE(m) ±		**NS**	**0.01**	**0.02**	**0.28**	**0.06**	
C.D. at 5 %		**NS**	**0.05**	**0.08**	**0.86**	**0.18**	

1. NS – Non-significant
2. DAS - Days after storage
3. The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.3.2: Effect of various packaging materials and waxing on color appearance of kinnow mandarin during storage

Notations	Treatments	Color appearance					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	7.09^{a}	6.49^{a}	4.86^{a}	0.00*	0.00*	3.68
T_1	LDPE (25 µ)	8.36^{c}	8.24^{d}	7.97^{c}	7.18^{b}	7.03^{c}	7.75
T_2	HDPE (15 µ)	8.27^{c}	8.12^{c}	8.04^{c}	7.16^{b}	6.80^{b}	7.67
T_3	Polypropylene (25 µ)	8.02^{b}	7.84^{b}	7.50^{b}	7.05^{a}	6.50^{a}	7.36
T_4	Shrink film (15 µ)	8.52^{de}	8.39^{e}	8.25^{ef}	7.65^{d}	7.29^{e}	8.02
T_5	Cling film (15 µ)	8.82^{g}	8.70^{g}	8.34^{f}	8.00^{f}	7.86^{h}	8.34
T_6	LDPE (25 µ) + wax (10%)	8.71^{f}	8.53^{f}	8.19^{de}	7.97^{ef}	7.77^{g}	8.23
T_7	HDPE (15 µ) + wax (10%)	8.61^{e}	8.48^{f}	8.10^{cd}	7.90^{e}	7.39^{f}	8.09
T_8	Polypropylene (25 µ) + wax (10%)	8.48^{d}	8.33^{e}	8.06^{c}	7.38^{c}	7.18^{d}	7.88
T_9	Shrink film (15 µ) + wax (10%)	8.90^{g}	8.80^{h}	8.51^{g}	8.34^{g}	8.12^{i}	8.53
T_{10}	Cling film (15 µ) + wax (10%)	9.00^{h}	8.91^{i}	8.72^{h}	8.58^{h}	8.27^{h}	8.69
	SE(m) ±	**0.03**	**0.02**	**0.03**	**0.02**	**0.02**	
	C.D. at 5 %	**0.09**	**0.08**	**0.10**	**0.07**	**0.08**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

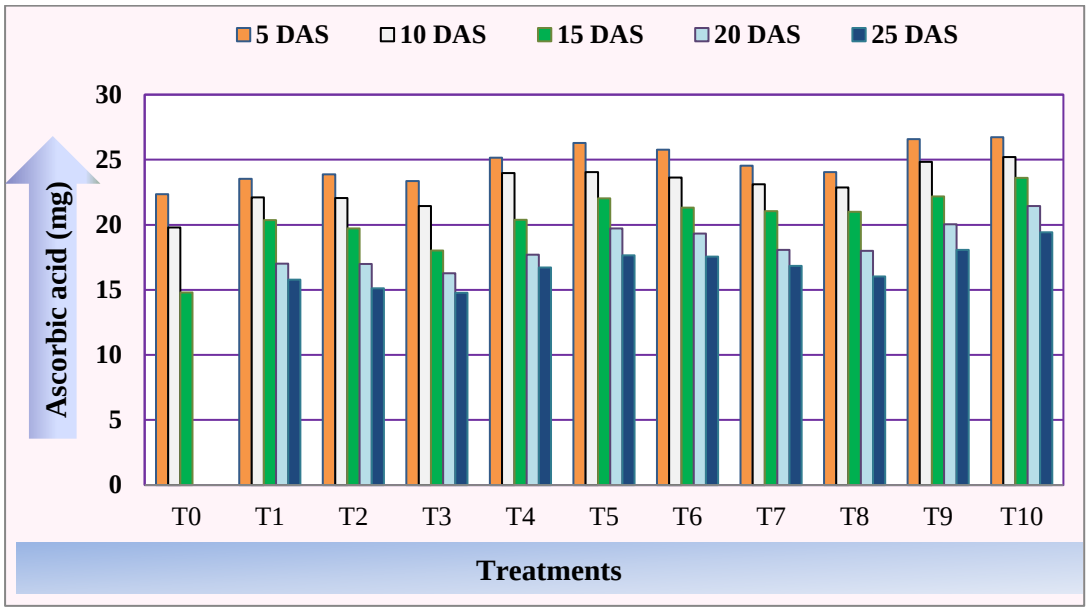


Fig. 4.2.9: Effects of various packaging materials and waxing on ascorbic acid (mg/100 ml) of kinnow mandarin during storage

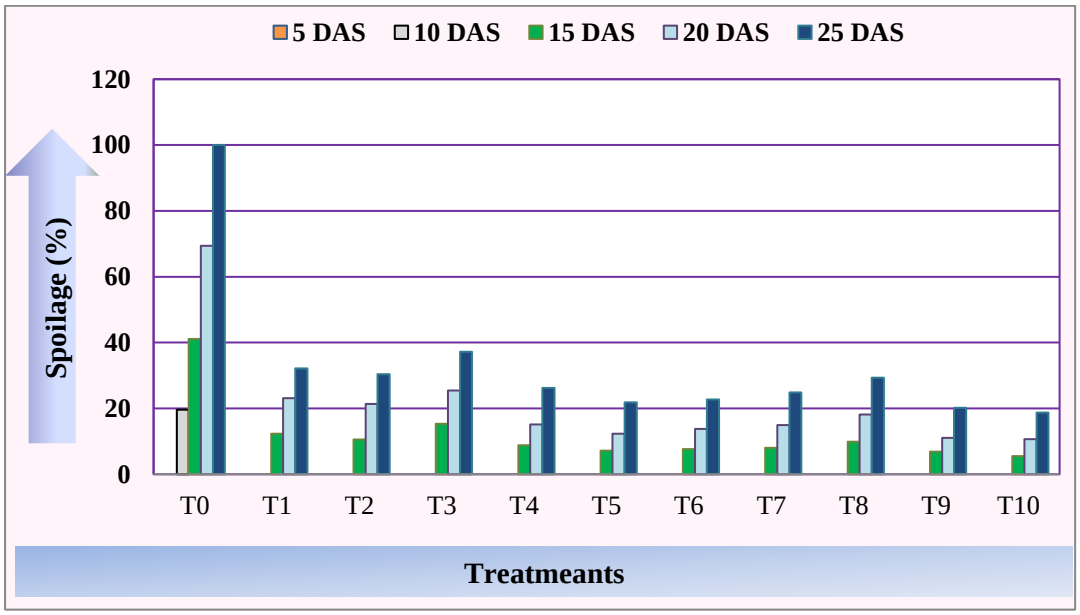


Fig. 4.3.1: Effect of various packaging materials and waxing on spoilage per cent (%) of kinnow mandarin

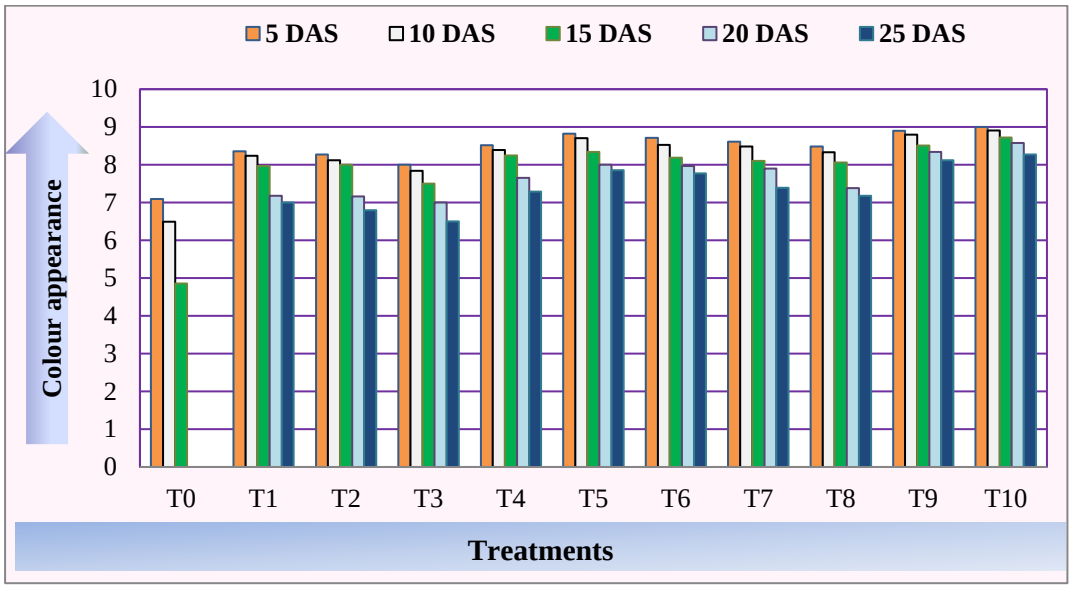


Fig. 4.3.2: Effect of various packaging materials and waxing on color appearance of kinnow mandarin

4.3.3 Flavor

The observations related to flavor of kinnow fruit showed significant differences among various packaging materials at 5, 10, 15, 20 and 25 days of storage under ambient condition. The data recorded has been summarized in Table 4.3.3 and graphically illustrated in Fig. 4.3.3.

At 5 days of storage of kinnow mandarin, the highest sensory score for flavor (8.33) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax), followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) with flavor value of 8.21 and 8.18, respectively. Similarly, the treatments T_6, T_7 & T_8 having respective flavor scores 8.11, 8.07 & 8.00 were found statistically similar with each other under the present study. The lowest flavor score (7.21) was registered under the T_0 (control).

At 10 DAS, the flavor of fruit recorded under different treatments revealed that treatments T_{10} (cling film 15 µ with 10 % wax) scored highest flavor (8.18) than the fruits treated with other packaging materials. There was significant decrease in flavor score with increased storage periods. The treatments T_1 & T_4 having the average flavor score 7.41 & 7.46, respectively were statistically at par with each other at 5 % level of significance. While, the lowest mean sensory score for flavor (6.91) was observed under the treatment T_0 (control) succeeded by T_3 (Polypropylene 25 µ) with flavor value of 7.04.

At 15 DAS, the significant variations were observed under the various treatments. The data showed that the superiority of treatment T_{10} (cling film 15 µ with 10 % wax) registered the maximum organoleptic score for flavor (8.08), which was significantly superior among all other treatments. The treatments T_1, T_4, T_6, T_5, and T_9 having the average flavor scores 7.11, 7.23, 7.66, 7.84 and 7.95 was significantly different than rest of the other treatments. The minimum flavor score (4.97) was recorded under the treatment T_0 (control) during 15 days of storage under the present trial.

At 20 days of storage, the flavor of kinnow mandarin decreased progressively in all the treatments. The sensory score for flavor was significantly higher (7.77) in T_{10} (cling film 15 µ with 10 % wax) than the fruits treated under

other treatments. The treatments T_9 & T_5 and T_6 & T_7 and T_2 & T_1 having respective average value of flavor scores 7.61 & 7.55 and 7.43 & 7.32 and 6.79 & 6.68 were statistically similar with each other at 5 % level of significance. The lowest flavor score (6.55) was registered under the treatment T_3 (Polypropylene 25 µ), whereas the fruits kept under control treatment were spoiled and completely discarded.

At 25 days of storage, different types of packaging materials significantly affected the sensory score for flavor of kinnow mandarin. The maximum organoleptic score for flavor (7.56) was registered under T_{10} (cling film 15 µ with 10 % wax), followed by fruits packed under T_9 (shrink film 15 µ with 10 % wax) having the flavor score of 7.42. The minimum flavor score (6.39) was observed in fruits packed under T_3 (Polypropylene 25 µ), which was statistically at par with T_1 (LDPE 25 µ) with flavor score of 6.51 during the present trial. However, fruits under control treatment were disposed completely due to microbial spoilage.

It is evident from the result obtained under present investigation that the various packaging materials had significantly affected the flavor of fruit as compared to control. The maximum score for flavor of fruit 8.33 and 7.56 was obtained under the treatment cling film 15 µ with 10 % wax coated fruit at 5 and 25 days of storage, while the minimum sensory score for flavor 7.21, 6.91 and 4.97 was achieved under T_0-control during 5, 10 and 15 days of observation, respectively. However, fruits under control treatment was spoiled and discarded completely at 20 and 25 days of storage. As the days of storage extended, the control untreated fruits gradually degraded their flavor and found unaccepted for consumption. The fruit kept under different packaging material maintained their flavor up to the 25^{th} days of storage. It might be due to the delaying of ripening due to the coating with paraffin wax and wrapping of polythene films, which preserve the flavor for longer period of time. In addition, the decrease in flavor of the fruit could be attributed to change in sugar/acid ratio due to increase in ripenin1g and off flavor development due to possible anaerobic respiration under the polythene packaging. These results are similar with the finding of Jadho *et al.* (2008) in kagzi lime and Dhiilon *et al*. (2016), and Pippal *et al.* (2016) in kinnow mandarin and Gidagiri *et al.* (2020) in acid lime.

4.3.4 Taste

The data related to taste of kinnow fruit during storage at 5 to 25 days of storage have been presented in Table 4.3.4 and graphically depicted in Fig. 4.3.4.

At 5 days of storage, the highest sensory score for taste (8.38) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), which showed significantly superior among all other treatments. Similarly, the treatments T_9 & T_5 and T_6, T_7 & T_8 and T_2 & T_1 having respective scores for taste 8.30 & 8.28 and 8.17, 8.11 & 8.09 and 7.86 & 7.77 were found non-significant differences with each other at 5% level of significance. However, the treatments T_4 (7.98) and T_3 (7.51) were significantly differed from rest of the treatment. While, the least taste sensory score (7.29) was recorded under the treatment T_0 (control).

After 10 days of storage of kinnow mandarin, the highest taste score (8.11) was noticed under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically at par with T_9 (shrink film 15 µ with 10 % wax) having the score for taste 8.09. However, the treatments T_2 and T_4 with corresponding taste scores 7.34 and 7.53, respectively were showed significant differences between each other. Whereas, the lowest taste score (6.89) was registered under the treatment T_1 (control), which was followed by T_3 (Polypropylene 25 µ) with taste value of 7.14.

At 15 days of storage, it was observed that the maximum mean taste score (7.92) was observed under the treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically equivalent with T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) having the taste scores 7.81 and 7.74, respectively. The treatments T_6, T_7 & T_8 and T_4 & T_2 and T_1 & T_3 with respective taste scores 7.55, 7.49 & 7.40 and 7.23 & 7.16 and 7.07 & 7.00 were statistically at par with each other at 5% level of significance. While, the minimum taste score (4.86) was noticed under T_0 (control).

At 20 DAS, the fruits treated with T_{10} (cling film 15 µ with 10 % wax) recorded significantly highest score for taste (7.68) of kinnow mandarin. It was found superior among all other treatments under the present investigation. The lowest taste of fruit (6.45) was registered under the treatment T_3 (Polypropylene 25

µ), whereas no fruits were found to be retained under T_0 (control) for observation due to spoilage.

At 25 days of storage, statistically similar trend was observed among various treatments with respect to sensory score of taste. The maximum taste value (7.47) was registered under the same treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically at par with the treatment T_9 (shrink film 15 µ with 10 % wax) having the average fruit taste of 7.42 under the present experiment. Similarly, the treatments T_5, T_6 & T_7 with average taste scores of 7.16, 7.08 & 7.00, respectively were found non-significant differences with each other at 5% level of significance. The least taste score (6.30) was noticed under the treatment T_3 (Polypropylene 25 µ), whereas fruits under control were completely discarded due to spoilage at 25 days after storage.

According to statistically analyzed results obtained under present investigation, it is concluded that the various packaging materials had significantly affected the taste of fruit as compared to control. Among the various treatments of packaging material, the maximum taste score of fruit (8.38 and 7.47) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax) at 5 and 25 days of storage, while the minimum taste scores (7.29, 6.89 and 4.86) were achieved under T_0 (control) during 5, 10 and 15 days of observation, whereas no fruits were found to be retained in control at 20 and 25 days of observation due to spoilage. It can be noticed that the sensory evaluated taste score was decreased gradually as the storage period increased. The taste score was decreased with the increase in storage period might be due to the loss of total soluble solids in fruit and rapid ripening metabolic activity and quality of kinnow fruit during storage period. In addition, taste depends on a delicate balance of sugars, acids, phenolics and aromatic compounds, with a number of additional factors and such as pulp texture also influencing perceived quality. These results are in close agreements with the finding of Jadho *et al.* (2008) in kagzi lime, Dhiilon *et al*. (2016), and Pippal *et al.* (2016) in kinnow mandarin.

Table 4.3.3: Effect of various packaging materials and waxing on flavor of kinnow mandarin during storage

Notations	Treatments	Flavor					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	7.21^{a}	6.91^{a}	4.97^{a}	0.00*	0.00*	3.81
T_1	LDPE (25 µ)	7.66^{d}	7.41^{d}	7.11^{c}	6.68^{b}	6.51^{a}	7.07
T_2	HDPE (15 µ)	7.47^{c}	7.12^{c}	6.97^{b}	6.79^{b}	6.66^{b}	7.00
T_3	Polypropylene (25 µ)	7.31^{b}	7.04^{b}	6.90^{b}	6.55^{a}	6.39^{a}	6.83
T_4	Shrink film (15 µ)	7.78^{e}	7.46^{d}	7.23^{d}	7.19^{d}	6.90^{cd}	7.31
T_5	Cling film (15 µ)	8.18^{hi}	8.02^{h}	7.84^{g}	7.55^{f}	7.21^{e}	7.76
T_6	LDPE (25 µ) + wax (10%)	8.11^{gh}	7.95^{g}	7.66^{f}	7.43^{e}	7.18^{e}	7.66
T_7	HDPE (15 µ) + wax (10%)	8.07^{fg}	7.81^{f}	7.52^{e}	7.32^{e}	7.00^{d}	7.54
T_8	Polypropylene (25 µ) + wax (10%)	8.00^{f}	7.74^{e}	7.51^{e}	7.04^{c}	6.81^{c}	7.42
T_9	Shrink film (15 µ) + wax (10%)	8.21^{i}	8.11^{i}	7.95^{h}	7.61^{f}	7.42^{f}	7.83
T_{10}	Cling film (15 µ) + wax (10%)	8.33^{j}	8.18^{j}	8.08^{i}	7.77^{g}	7.56^{g}	7.96
	SE(m) ±	**0.02**	**0.02**	**0.03**	**0.03**	**0.04**	
	C.D. at 5 %	**0.07**	**0.05**	**0.10**	**0.11**	**0.13**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 4.3.4: Effect of various packaging materials and waxing on taste of kinnow mandarin during storage

Notations	Treatments	Taste					
		5 DAS	**10 DAS**	**15 DAS**	**20 DAS**	**25 DAS**	**Mean**
T_0	Control (untreated)	7.29^{a}	6.89^{a}	4.86^{a}	0.00*	0.00*	3.80
T_1	LDPE (25 µ)	7.77^{c}	7.22^{b}	7.07^{bc}	6.68^{b}	6.51^{b}	7.05
T_2	HDPE (15 µ)	7.86^{c}	7.34^{c}	7.16^{cd}	6.86^{c}	6.66^{c}	7.17
T_3	Polypropylene (25 µ)	7.51^{b}	7.14^{b}	7.00^{b}	6.45^{a}	6.30^{a}	6.88
T_4	Shrink film (15 µ)	7.98^{d}	7.53^{d}	7.23^{d}	7.00^{d}	6.78^{d}	7.30
T_5	Cling film (15 µ)	8.28^{f}	8.00^{fg}	7.74^{g}	7.42^{g}	7.16^{g}	7.72
T_6	LDPE (25 µ) + wax (10%)	8.17^{e}	7.93^{f}	7.55^{f}	7.33^{f}	7.08^{fg}	7.61
T_7	HDPE (15 µ) + wax (10%)	8.11^{e}	7.78^{e}	7.49^{ef}	7.27^{f}	7.00^{f}	7.53
T_8	Polypropylene (25 µ) + wax (10%)	8.09^{e}	7.71^{e}	7.40^{e}	7.09^{e}	6.90^{e}	7.43
T_9	Shrink film (15 µ) + wax (10%)	8.30^{fg}	8.09^{g}	7.81^{gh}	7.51^{h}	7.42^{h}	7.80
T_{10}	Cling film (15 µ) + wax (10%)	8.38^{g}	8.11^{g}	7.92^{h}	7.68^{i}	7.47^{h}	7.91
	SE(m) ±	**0.03**	**0.03**	**0.04**	**0.02**	**0.02**	
	C.D. at 5 %	**0.09**	**0.11**	**0.13**	**0.06**	**0.08**	

(1) Values marked as * indicates fruit gets spoiled.

(2) DAS - Days after storage.

(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

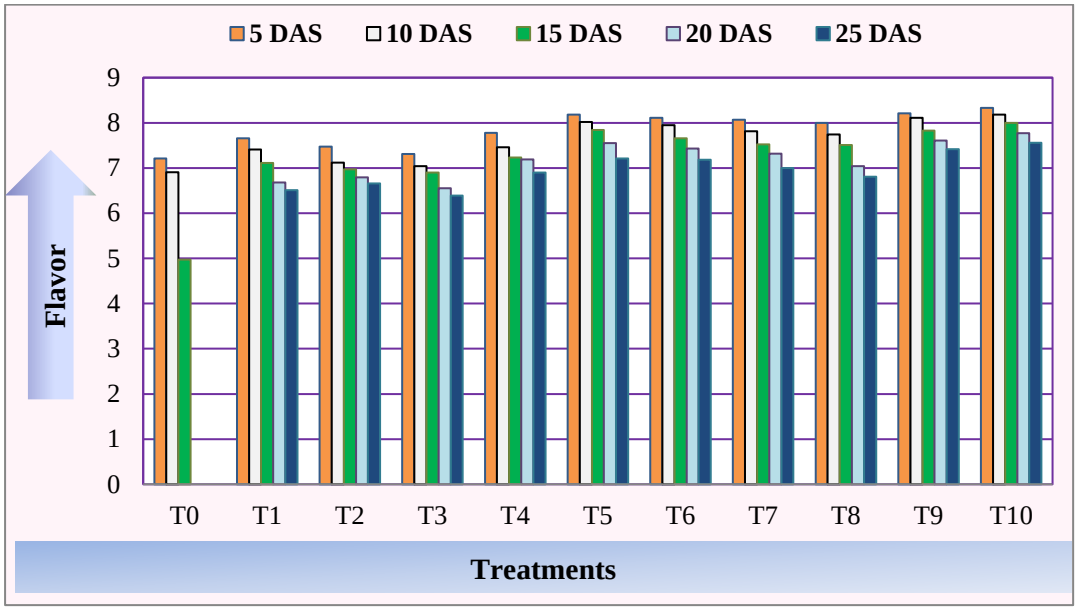


Fig. 4.3.3: Effect of various packaging materials and waxing on flavor of kinnow mandarin during storage

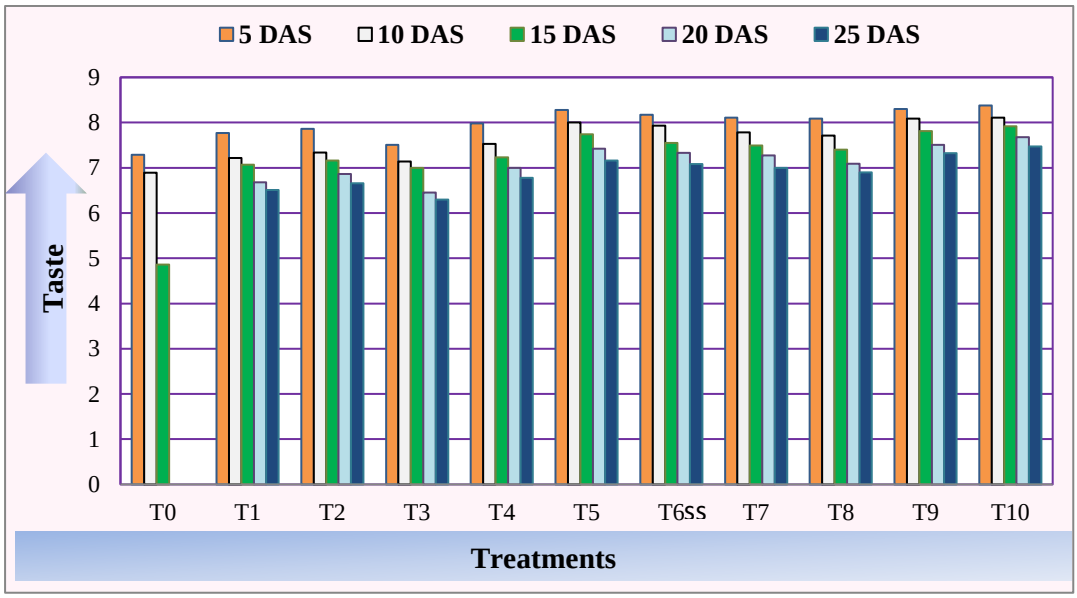


Fig. 4.3.4: Effect of various packaging materials and waxing on taste of kinnow mandarin during storage

CHAPTER-V
SUMMERY AND CONCLUSION

The present investigation entitled “Studies on the effect of various packaging materials and waxing on shelf life and fruit quality of kinnow mandarin (*Citrus reticulata* Blanco)” was carried out during December 2020 at Processing Laboratory, Department of Fruit Science, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G).

The main objective of the experiment was to find out the suitable packaging material for enhancing the shelf-life of kinnow mandarin under ambient condition. The experiment material consisted 11 different packaging materials including control in which the fruits were packed individually as well as in combination with 10 % wax. The experiment was laid out in Completely Randomized Design (CRD) and replicated thrice. Fresh kinnow mandarin fruits were procured from the College of Horticulture and Research Station, Chitrakote Road, Kumharavand, Jagdalpur Dist-Bastar, Chhattisgarh. The fruits were stored under ambient condition up to 25 days of storage for their various physico-chemical analysis. All the data were recorded at every 5 days interval till 25th days of storage. The experimental findings were statistically analyzed and their outcomes are summarized as below:

5.1 Physical parameters of kinnow mandarin

The diameter of the fruit decreased with the prolongation of storage period in all the treatments. However, wrapping of fruits under T_{10} (cling film 15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax) maintained higher average diameter under ambient conditions with fruit diameter of 5.17 and 5.10 cm, respectively as compare to all other treatments. The minimum fruit diameter (4.13 cm) was recorded under T_3-polypropylene 25 µ, whereas no fruit was found to be retained under control (T_0) for recording observation as the fruits were discarded due to spoilage by micro-organism or over ripening during 25 days of storage.

The length of kinnow fruits decreased with increased of storage period under ambient condition. The maximum length (5.03 cm) was observed under the treatment T_{10}-Cling film 15 µ with 10 % wax and the minimum length (4.25 cm) was recorded under T_3 (Polypropylene 25 µ) at 25th days of storage, whereas no fruits were found to be retained under control (T_0) for observation, as the fruits were spoiled and discarded.

At 25 DAS, the total fruit weight was found decreased under the various treatments. Treatment T_{10} (cling film 15 µ with 10 % wax) retained the highest total fruit weight (647.34 g) and performed better than the other treatments. However, the lowest total fruit weight (591.71 g) was recorded under the treatment T_3 (polypropylene 25 µ), which was followed by T_2 HDPE (15 µ) having average total fruit weight of 607.53 g. While, no fruits were found to be retained under T_0 (control) for observations at 25 DAS.

Significant variation was observed in respect to physiological loss in weight under the various treatments. The minimum physiological loss in weight (4.75 %) was registered under the treatment T_{10} (cling film 15 µ with 10 % wax), followed by T_9 (shrink film 15 µ with 10 % wax) having the physiological loss in weight per cent (5.35) at 25th days of storage period. The maximum physiological loss in weight (9.17 %) was noticed under the treatment T_3 (Polypropylene 25 µ), whereas fruits kept under control were completely discarded due to spoilage.

Among the various treatments of packaging material, the maximum peel per cent (31.95) was recorded under the treatment T_{10} (cling film 15 µ with 10 % wax), which was statistically at par with T_9 having the peel per cent of 31.41, while the minimum peel (24.94 %) of fruit was recorded under the treatment Polypropylene 25 µ (T_3) at 25th days of observation.

In case of waste material, there was significant increase in waste material per cent of fruits during the storage period. The fruits packed under T_{10} (cling film 15 µ with 10 % wax) and T_9 (shrink film 15 µ with 10 % wax) recorded the lowest waste materials (13.68 and 15.57 %, respectively) as compared to all other treatment. The highest waste material (25.77 %) was registered under the treatment T_3 (polypropylene 25 µ) at 25 days after storage, while no fruits were found to be retained under T_0 (control) for observation.

With regard to juice (%), the juice per cent was significantly affected by different treatments. The maximum juice (54.37 %) was obtained under the treatment T_{10} (cling film 15 µ with 10 % wax), which was followed by T_9 (shrink film 15 µ with wax 10 %) having the juice content 53.02 %. while the minimum juice per cent (47.29) was observed under the treatment T_3 (polypropylene 25 µ) at 25^{th} days of storage.

The data related to juice: peel ratio of kinnow mandarin fruits were significantly differed under the various treatments. The lowest juice: peel ratio (1.65) was noticed under the treatment HDPE film 15 µ with 10 % wax (T_7), while the highest value for juice: peel ratio (1.90) was observed under polypropylene 25 µ (T_3), however the fruits kept under control treatment were completely discarded due to spoilage at 25 days after storage.

At 25 days of storage, the spoilage (%) of fruits were significantly increased in all the treatments irrespective of various packaging materials and waxing treatments used in present experiment. The minimum spoilage per cent (18.74) was registered under the fruits with cling film 15 µ and 10 % wax (T_{10}) and the maximum spoilage (100 %) was recorded under the treatment T_0 (control) under ambient condition.

5.2 Chemical composition of kinnow mandarin

The data related to pH and total soluble solids of kinnow mandarin fruits were significantly influenced under the various treatments. The highest pH (4.10) and total soluble solids (14.45 %) were noticed under the superiority of treatment cling film 15 µ with 10 % wax (T_{10}), while the lowest values for pH (3.64) and total soluble solids (12.95 %) were observed under polypropylene 25 µ (T_3) at 25^{th} days of storage.

Acidity (%) of kinnow mandarin fruits significantly decreased with increased storage period. The lowest acidity (0.61 %) was reported under the cling film 15 µ with 10 % wax (T_{10}), while the highest acidity (0.99 %) was recorded under the treatment T_3 (polypropylene 25 µ) followed by T_1 and T_8 with acidity percentages of 0.90 and 0.88 %, respectively at 25^{th} days of storage period.

The ascorbic acid (mg/100 ml juice) of kinnow mandarin decreased gradually as the storage period increased, the maximum ascorbic acid (19.43

mg/100 ml juice) was reported under the cling film 15 µ with 10 % wax (T_{10}), while the minimum ascorbic acid of kinnow mandarin fruit (14.78 mg/100 ml juice) was registered under the treatment T_3 (polypropylene 25 µ) followed by T_2 and T_1, however fruits under control were completely discarded due to spoilage.

The TSS: acid ratio and sugar: acid ratio of kinnow fruits showed increasing trend with the advancement of storage period. The fruits kept under the treatment T_{10} (cling film 15 µ with 10 % wax), expressed the highest value for TSS: acid ratio (23.68) as well as sugar: acid ratio (12.26) at 25 days of storage. However, the minimum value for TSS: acid ratio (13.08) and sugar: acid ratio (6.15) was registered under T_3 (polypropylene 25 µ).

Total sugar and non-reducing sugar significantly increased as the storage period increased, but the reducing sugar increased at initial period of storage *i.e.* up to 20^{th} days, which later gradually decreased on 25^{th} days of storage. The maximum total sugar, reducing sugar and non-reducing sugar (7.48, 4.08 and 3.40 %, respectively) were recorded under the T_{10} (cling film 15 µ with 10 % wax), at 25^{th} days of storage. However, minimum values for the same (6.09, 3.36 and 2.73 %, respectively) were observed under the treatment T_3 (polypropylene 25 µ).

5.3 Sensory evaluation of kinnow mandarin

The various sensory parameters like colour appearance, flavour and taste was found decreased progressively during 25 days of storage period. The maximum score for colour appearance, flavour and taste (8.27, 7.56 and 7.47) was recorded under the superiority of treatment T_{10} (cling film 15 µ with 10 % wax), which was followed by T_9 (shrink film 15 µ with 10 % wax) and T_5 (cling film 15 µ) at 25 days of storage. However, the colour appearance, flavour and taste scores (6.50, 6.39 and 7.47) was recorded minimum under the treatment T_3 (polypropylene 25 µ).

CONCLUSION

- From the present experimental findings, it can be concluded that different treatment combinations had significant effect on physico-chemical composition and shelf life of kinnow mandarin during storage period

- The treatment cling film 15 µ with 10 % wax was found most effective for enhancing the physico-chemical composition of kinnow mandarin fruit during storage under ambient condition.
- The superiority of treatment T_{10} (cling film 15 µ with 10 % wax) delayed the ripening process and was suitable for enhancing the shelf-life and storability of kinnow mandarin fruits up to 25 days of storage without severely affecting their physico-chemical properties. Similarly, the physiological loss in weight and spoilage percentage was found minimum under the same treatment at 25 days of storage as compared to rest of the treatments under present investigation.
- Quality attributing parameters like total soluble solids, total sugar, reducing sugar, non-reducing sugar, ascorbic acid, TSS: acid ratio and sugar: acid ratio were significantly influenced under the treatment T_{10} (cling film 15 µ with 10 % wax) followed by T_9 (shrink film 15 µ with 10 % wax), at all the stages of observation, while acidity per cent of kinnow fruit was reduced under the same treatment.
- As regard, sensory parameters, the superiority of treatment T_{10} (cling film 15 µ with 10 % wax) showed excellent result in respect to color appearance, flavor and taste of kinnow mandarin during 25 days of storage at ambient condition.

SUGGESTIONS FOR FUTURE RESEARCH WORK

The experience gained from the present study, the following suggestions can be made for future line of work.

- Intensive experiment should be made on the effect of different packaging materials with or without wax in relation to physico-chemical properties and shelf life of kinnow mandarin fruit.
- Since the results of present study was based on one season of investigation. To achieve definite conclusion, it needs to be repeated during successive seasons.
- Response of fruit to similar set of treatments varies with different cultivar, species and physico-chemical status of kinnow mandarin fruit. Therefore,

the experiment should be tested on other varieties of fruit crops for prolonging their shelf-life and stability the market demand.

- Kinnow mandarin fruit can be further investigated under several agro-climatic conditions for shelf-life stability and quality.
- Different low cost modified atmosphere packaging materials should be tested singly or in combination with wax for better response in kinnow mandarin and other citrus fruits.
- Various thickness of LDPE, HDPE, polypropylene, shrink film, cling film, and CA bags should be tested as packaging material for increasing shelf-life of different citrus fruits without affecting their physic-chemical properties.
- Thorough study should be made on the application of modified atmosphere packaging (MAP) by using inert gases such as CO_2 in relation to increase shelf life and various physico-chemical parameters of kinnow mandarin fruit.

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APPENDIX – A

Meteorological data during experiment period (03/12/2020 to 31/12/2021)

Dates	Max. Temp. (°C)	Min. Temp. (°C)	Rainfall (mm)	Relative humidity I (%)	Relative humidity II (%)	Wind velocity (kmph)	Evaporation (mm)	Sunshine (Hours)
03-09 Dec.	30.7	11.9	0.0	89	33	1.3	22.2	7.3
10-16 Dec.	30.2	15.8	0.0	86	37	2.4	20.1	3.7
17-23 Dec.	27.4	10.03	0.0	87	27	2.5	22.7	5.0
24-31 Dec.	28.4	10.3	0.0	87	28	1.8	24.6	4.8

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Publications (If any):

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