EFFECT OF POSTHARVEST TREATMENTS AND PACKAGINGS ON STORAGE LIFE AND QUALITY OF KINNOW FRUIT

Dissertation

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
in
HORTICULTURE (FRUIT SCIENCE)
(Minor Subject: Biochemistry)

By

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CERTIFICATE I

This is to certify that the dissertation entitled, **"Effect of postharvest treatments and packagings on storage life and quality of Kinnow fruit"** submitted for the degree of **Ph.D.**, in the subject of **Horticulture (Fruit Science)** (Minor subject: **Biochemistry**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Mr. Arvind Kumar Baswal (L-2015-A-31-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the dissertation entitled, **"Effect of postharvest treatments and packagings on storage life and quality of Kinnow fruit"** submitted by **Mr. Arvind Kumar Baswal (L-2015-A-31-D)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Ph.D.**, in the subject of **Horticulture (Fruit Science)** (Minor subject: **Biochemistry**) has been approved by the student's Advisory Committee after an oral examination on the same.

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ABSTRACT

The present investigation entitled, "Effect of postharvest treatments and packagings on storage life and quality of Kinnow fruit" was conducted in Department of Fruit Science and Punjab Horticultural Postharvest Technology Centre, PAU campus, Ludhiana during the years of 2016-17 and 2017-18. Fruits of Kinnow were harvested at physiological maturity and divided into requisite lots for further handling. First lot of fruits were coated with different edible coatings *viz* Carboxy Methylcellulose (1, 1.5 and 2%), chitosan (0.5, 1 and 1.5%) and bees wax (5, 10 and 15%). Second lot of fruits were treated with different anti-senescence compounds *viz.* 1-methylcyclopropane (500, 1000 and 1500 ppb), methyl jasmonates (1, 2 and 3mM) and salicylic acid (1, 2 and 3mM). Third lot of fruits were individually seal packed in commercial available packaging films *viz.* perforated and non-perforated PP 100, PP 150, LDPE 100 and LDPE 150 gauge films. The control fruits were kept uncoated, untreated and unpacked. The fruits were stored under cold storage conditions (5-7^{0}C and 90-95% RH). The observations on various physico-chemical attributes were recorded at different storage intervals i.e. 30, 45, 60 and 75 days. The data revealed that among different edible coatings, anti-senescence compounds and packaging materials, Kinnow fruits coated with CMC (2%), treated with MeJA (1mM) and packed in perforated PP 100 gauge film, respectively can be stored up to 60 days in contrast to control i.e. 45 days with minimum loss in PLW, spoilage, acceptable sensory attributes, higher firmness and juice content also maintained the quality attributes such as TSS, sugars, vitamin C, pectin, carotene and phenolic content and delayed the fruit softening by lowering the activity of cell wall degrading enzymes *viz.* PME and cellulase. These treatments seems to hold promise in extending the shelf-life and marketability of Kinnow fruits during prolonged storage.

Keywords: Edible coatings, anti-senescence compounds, packaging films, Kinnow, quality

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Signature of Major Advisor   **Signature of the Student**

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ਮੌਜੂਦਾ ਅਧਿਐਨ "ਤੁੜਾਈ ਮਗਰੋਂ ਕੀਤੇ ਉਪਚਾਰਾਂ ਅਤੇ ਪੈਕੇਜਿੰਗ ਦਾ ਕਿਨੂੰ ਫ਼ਲ ਦੀ ਮਿਆਦ ਅਤੇ ਗੁਣਵਤਾ ਉਪਰ ਪ੍ਰਭਾਵ" ਸਿਰਲੇਖ ਅਧੀਨ, ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਵਿਖੇ ਸਥਿਤ ਪੰਜਾਬ ਹੋਰਟੀਕਲਚਰਲ ਪੋਸਟ ਹਾਰਵੇਸਟ ਟੈਕਨੋਲੋਜੀ ਸੈਂਟਰ (PHPTC) ਅਤੇ ਫ਼ਲ ਵਿਗਿਆਨ ਵਿਭਾਗ ਵਿਖੇ ਸੰਨ 2016-17 ਅਤੇ 2017-18 ਦੌਰਾਨ ਕੀਤਾ ਗਿਆ। ਕਿਨੂੰ ਦੇ ਪੱਕੇ ਹੋਏ ਫ਼ਲਾਂ ਨੂੰ ਤੋੜਿਆ ਗਿਆ ਅਤੇ ਇਹਨਾਂ ਨੂੰ ਵੱਖੋ-ਵੱਖਰੇ ਲਾਟਾਂ ਵਿੱਚ ਵੰਡਿਆ ਗਿਆ। ਪਹਿਲੇ ਲਾਟ ਦੇ ਫ਼ਲਾਂ ਦੀ ਵੱਖੋ-ਵੱਖਰੀ ਖਾਣਯੋਗ ਕੋਟਿੰਗਸ ਭਾਵ ਕਾਰਬੋਕਸੀ ਮਿਥਾਇਲ ਸੈਲੂਲੋਜ਼ (1, 1.5 ਅਤੇ 2%), ਚਿਟੋਸਿਨ (0.5, 1 ਅਤੇ 1.5%) ਅਤੇ ਬੀ ਵੈਕਸ (5, 10, 15%) ਨਾਲ ਕੋਟਿੰਗ ਕੀਤੀ ਗਈ। ਦੂਜੇ ਲਾਟ ਦੇ ਫ਼ਲਾਂ ਨੂੰ ਉਮਰਦਰਾਜ਼ ਕਰਨ ਵਾਲੇ ਸੰਘਟਕਾਂ ਭਾਵ 1-ਮਿਥਾਇਲਸਾਈਕਲੋਪ੍ਰੋਪੇਨ (500, 1000 ਅਤੇ 1500 ppb), ਮਿਥਾਇਲ ਜੈਸਮੋਨੇਟਸ (1, 2 ਅਤੇ 3 mM) ਅਤੇ ਸੈਲੀਸਾਇਕਲਿਕ ਐਸਿਡ (1, 2 ਅਤੇ 3 mM) ਨਾਲ ਸੋਧਿਆ ਗਿਆ। ਤੀਜੇ ਲਾਟ ਦੇ ਫ਼ਲਾਂ ਨੂੰ ਵਾਪਾਰਕ ਤੌਰ ਤੇ ਉਪਲਬਧ ਪੈਕੇਜਿੰਗ ਸਮੱਗਰੀ ਭਾਵ ਸੁਰਖਾਂ ਵਾਲੇ ਅਤੇ ਬਿਨਾਂ ਸੁਰਖਾਂ ਵਾਲੀਆਂ PP 100, PP 150, LDPE 100 ਅਤੇ LDPE 150 ਗੇਜ਼ ਫਿਲਮਾਂ ਵਿੱਚ ਭੰਡਾਰ ਕੀਤਾ ਗਿਆ। ਬਿਨਾਂ ਕੋਟਿੰਗ ਦੇ, ਬਿਨਾਂ ਉਪਚਾਰਤ ਅਤੇ ਬਿਨਾਂ ਪੈਕ ਕੀਤੇ ਫ਼ਲਾਂ ਨੂੰ ਕੰਟਰੋਲ ਫ਼ਲਾਂ ਵਜੋਂ ਵਰਤਿਆ ਗਿਆ। ਫ਼ਲਾਂ ਨੂੰ ਠੰਡੇ ਹਲਾਤਾਂ (5-7^{0}C ਅਤੇ 90-95% ਨਮੀ) ਅਧੀਨ ਭੰਡਾਰ ਕਰਕੇ ਰੱਖਿਆ ਗਿਆ। ਭੰਡਾਰਨ ਦੇ ਵੱਖੋ-ਵੱਖਰੇ ਅੰਤਰਾਲਾਂ ਭਾਵ 30, 45, 60 ਅਤੇ 75 ਦਿਨਾਂ ਉਪਰ ਫ਼ਲਾਂ ਦੇ ਭੌਤਿਕ-ਰਸਾਇਣਕ ਗੁਣਾਂ ਦਾ ਨਰੀਖਣ ਕੀਤਾ ਗਿਆ। ਅਧਿਐਨ ਦੇ ਨਤੀਜਿਆਂ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਵਖੋ-ਵੱਖਰੀਆਂ ਖਾਣਯੋਗ ਕੋਟਿੰਗਸ, ਉਮਰਦਰਾਜ਼ ਕਰਨ ਵਾਲੇ ਸੰਘਟਕਾਂ ਅਤੇ ਪੈਕੇਜਿੰਗ ਸਮੱਗਰੀ ਵਿੱਚੋਂ, CMC (2%) ਕੋਟਿੰਗ, MeJA (1mM) ਨਾਲ ਉਪਚਾਰਤ ਅਤੇ ਸੁਰਾਖਾਂ ਵਾਲੀਆਂ 100 ਗੇਜ਼ PP ਫਿਲਮਾਂ ਵਿੱਚ ਰੱਖੇ ਗਏ ਫ਼ਲਾਂ ਨੂੰ ਕੰਟਰੋਲ (45 ਦਿਨ) ਦੇ ਮੁਕਾਬਲੇ ਜ਼ਿਆਦਾ ਸਮੇਂ ਲਈ ਭਾਵ 60 ਦਿਨਾਂ ਤੱਕ ਭੰਡਾਰ ਕਰਕੇ ਰੱਖਿਆ ਜਾ ਸਕਦਾ ਹੈ ਅਤੇ ਇਹਨਾਂ ਫ਼ਲਾਂ ਦੇ ਭਾਰ ਵਿੱਚ ਸਭ ਤੋਂ ਘੱਟ ਕਮੀ ਅਤੇ ਖਰਾਬੀ ਆਈ ਅਤੇ ਇਹਨਾਂ ਫ਼ਲਾਂ ਦੇ ਸਵਿਕਾਰਤ ਸੈਂਸਗਰੀ ਗੁਣ, ਠੋਸਤਾ ਅਤੇ ਜੂਸ ਦੀ ਮਾਤਰਾ ਵਧੇਰੇ ਸੀ ਅਤੇ ਇਸਦੇ ਨਾਲ ਹੀ ਗੁਣਵਤਾ ਮਾਪਦੰਡ ਜਿਵੇਂ ਕਿ ਕੁੱਲ ਘੁਲਣਸ਼ੀਲ ਸ਼ੂਗਰ, ਵਿਟਾਮਿਨ ਸੀ, ਪੈਕਟਿਨ, ਕੈਰੋਟਿਨ ਅਤੇ ਫਿਨੋਲਿਕ ਦੀ ਮਾਤਰਾ ਵਧੇਰੇ ਸੀ ਅਤੇ ਸੈੱਲ ਅਤੇ ਡੀਜਨਰੇਟਿਵ ਇੰਜ਼ਾਈਮਾਂ ਜਿਵੇਂ ਕਿ PME ਅਤੇ ਸੈਲੂਲੇਜ਼ ਦੀਆਂ ਗਤੀਵਿਧੀਆਂ ਘੱਟ ਹੋਣ ਕਾਰਨ ਫ਼ਲ ਦੇਰੀ ਨਾਲ ਨਰਮ ਹੋਏ। ਲੰਬੇ ਸਮੇਂ ਦੇ ਭੰਡਾਰਨ ਦੌਰਾਨ ਕਿਨੂੰ ਫ਼ਲਾਂ ਦੀ ਮਿਆਦ ਅਤੇ ਮੰਡੀਯੋਗਤਾ ਨੂੰ ਵਧਾਉਣ ਲਈ ਇਹ ਉਪਚਾਰ ਅਸਰਦਾਰ ਹੋ ਸਕਦੇ ਹਨ।

ਮੁੱਖ ਸ਼ਬਦ: ਖਾਣਯੋਗ ਕੋਟਿੰਗਸ, ਉਮਰਦਾਰਜ਼ ਕਰਨ ਵਾਲੇ ਸੰਘਟਕ, ਪੈਕੇਜਿੰਗ ਫਿਲਮਾਂ, ਕਿਨੂੰ, ਗੁਣਵਤਾ

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

Kinnow mandarin is a hybrid between King (*Citrus nobilis* L.) and Willow Leaf (*Citrus deliciosa* L.) mandarins developed by Dr H.B. Frost in 1935 at University of California, USA. Inspite of being an introduction Kinnow has revolutionized citrus industry in India, Pakistan and Bangladesh. It was introduced in India at Abohar, Punjab during 1959 (Rajput and Haribabu 1995), is enjoying major share in area and production among citrus fruits grown in Punjab, Haryana, south western part of Rajasthan, foot hills of Himachal Pradesh and western Uttar Pradesh. Among citrus fruits grown in Punjab Kinnow mandarin share in area (51637 ha) and production (12.08 lakh MT) (Anonymous 2017-18). Kinnow mandarin is cherished around the globe due to their nutritional value, pleasant flavor and refreshing taste. The natural polyphenols in Kinnow mandarin comprise some bioactive compounds like hesperidins, vitamin C, carotenoid, naringin, ferulic acid, hydrocinnamic acid and cyaniding glucoside. These plant metabolites are effective in boosting the immune system against coronary heart diseases, cancer and various infections and also aid the absorption of iron and zinc. Due to these quality traits, Kinnow is in high demand not only in Indian markets but also in abroad.

Kinnow has a very short harvesting period from December to February and these months often witness arrival of large number truck loads of Kinnow fruits at major wholesale markets of India, which lead to glut and huge post-harvest losses; Even at retail shelf life the losses of this fruit are quite high due to poor post-harvest handling practices followed by farmers and traders, thus increasing the risk of high postharvest losses of about 35-40 per cent (Rajput and Haribabu 1995). In India, infrastructure for cold chain and refrigerated transport are insufficient. Morever, there is an increased inclination of farmers to sell the fruits in open market which further enhance the post-harvest losses. Thus the only viable option to reduce the post-harvest losses under Indian scenario is by extending the marketable period through noble approaches of shelf-life enhancement. Recent research studies suggest that the shelf-life of fruits can be enhanced by post-harvest intervention that can effectively reduce the respiration rate, ripening and senescence changes.

Application of edible coatings and packaging films are effective techniques, which can help in reducing the post-harvest losses and enhancing the shelf life of fruit by reducing the rate of respiration, transpiration and other metabolic processes in the fruit. Similarly, now-a-days noval molecules *viz* 1-MCP, polyamines and brassinosteroids are being used as anti-senescence compound to delay the shelf life of different fruits during marketing will help extending its marketability and shelf life by storing it for that time of the year which help farmers to earn by selling it after the glut.

Kinnow along with a variety of other fruits such as apple and few vegetables are commonly stored after coating. Coating wax can be cheap and easy method for prolonging the shelf life of fruits. Application of wax coating slows down the permeability of water vapour and other gases, which retards the ripening and also checks the storage loss. Role of peel coating for extending the shelf life has been reported by Giri *et al* (2003) in various fruits. These coatings can also enhance the overall appearance and quality of the fruit to by reducing water loss and preventing shrinkage (Moreira *et al* 2011). The use of food grade wax coating on the fruit is safe and approved by Ministry of Health and Family Welfare (FSSAI 2006).

Storage life of fruits can be prolonged by using ethylene inhibitors. AVG (aminoethoxyvinylglycine) and 1-MCP (1-methylcyclopropene) are commonly used for postharvest pre-storage treatments for many fruits (Asrey *et al* 2012). AVG is a human and environmental friendly organic product registered for use for apple, pear, peache, plum, mandarin and nectarine in several countries (Greene and Schupp 2004 and Rath and Prentice 2004).1-Methylcyclopropene (1-MCP), an ethylene action inhibitor, prevents the ripening effects of ethylene in many climacteric and some non-climacteric fruits (Blankenship and Dole 2003). 1-MCP significantly reduces ethylene production and maintains firmness for many days (Fan *et al* 1999, Cin *et al* 2006), mandarins ethylene production and softening are affected and reduced by 1-MCP treatment (Laamim *et al* 2005). In Shamouti oranges, 1-MCP is effective in inhibiting negative effects of ethylene and delays degreening.

Methyl jasmonates (MeJA) is a methyl ester of jasmonic acid (JA) which exists naturally in a wide range of higher plants function as elicitors or signaling agents in many physiological and biochemical processes (Turner *et al* 2002). Exogenous application of MeJA has been demonstrated to enhance the secondary metabolites content to a greater extent (Kim *et al* 2006, Wang *et al* 2009). Fruit treated with MeJA have been reported with improved fruit quality and stimulated host antioxidant systems during postharvest storage in plum, tomato and red raspberry (Zapata *et al* 2014 and Zhu and Tian 2012). Postharvest exposure of MJ on strawberry and raspberry fruits did not affect the flavonols content during storage (De la Pena Moreno *et al* 2010).

Salicylic acid is an endogenous growth regulator from phenolic group which participates in the regulation of several physiological processes such as anti-ripening and anti-senescence (Asghari and Aghdam, 2010). Application of salicylic acid enhanced the fruit weight and fruit quality in different fruit crops *viz;* olive and peach (El-Razek *et al* 2013 and El-Shazly *et al* 2013). Several studies have reported the role of postharvest salicylic acid applications on improving fruit quality parameters*viz;* delay in the reduction of ascorbic acid content of pineapple fruit (Lu *et al* 2011) decreased ethylene production and delayed the ripening process in kiwifruit (Mohammadi and Aminifard 2013).

Packaging of the fresh fruits is essential in the whole distribution cycle, starting from producer to final user. Packaging is an important component of post-harvest handling of produce which not only enhances the shelf life but also maintain quality and add value to the produce during marketing. The basic principle technology is that once produce is placed in a package and hermatically sealed, an environment different from ambient conditions will be established inside the package such as high CO_2 and low oxygen which helps in maintaining the quality and extend the shelf life (Hardenberg 1971). Modified atmospheric packaging has been a proven technology to meet the consumer's demand for more natural and fresh foods, which is increasing day by day.

The information on the effect of edible coatings, anti-senescence compounds and modified atmosphere packaging on storage life and quality of Kinnow fruit is limited and their effects on physical and physico-chemical compounds needs to be investigated. Therefore, in the present study an attempt was made to assess various post-harvest interventions to enhance the shelf-life of Kinnow fruit. The objectives of the present study were as under:

1. To evaluate performance of different edible coatings on enhancing storage life and maintaining fruit quality of Kinnow mandarin.
2. To study effect of different anti-senescence compounds on extension of storage life and quality of Kinnow mandarin fruit.
3. To examine the effect of modified atmospheric packaging with various packing materials of different thicknesses on extension of storage life of Kinnow mandarin.

CHAPTER II

REVIEW OF LITERATURE

The review of relevant research work on various approaches *viz;* "Effect of edible coatings, anti-senescence compounds and packaging materials of different thickness on storage-life and quality of Kinnow" has been discussed under in the light available literature. Edible coatings (Carboxy methylcellulose, Chitosan and Bees wax), anti-senescence compounds (1-methylcyclopropene, methyl jasmonates and salicylic acid) and different packaging materials of variable thickness (low density polyethylene and polypropylene) are promising postharvest interventions that affect the quality of cold stored Kinnow fruit. Therefore, a brief review of literature relevant to the present study for interpretation of results has been described in this chapter under the following sub-headings:

2.1. Effects of edible coatings on storage life and quality of fruits

Use of an edible coating is one of the popular practices in recent years due to its feasibility and ease of application compared to other postharvest treatment methods. It controls the modified internal gas composition and act as protective barrier that retards dehydration, improves textural quality and reduces microbial growth by forming a thin film layer of edible, natural, and biodegradable substances on fruit surface (Amal *et al* 2010). Edible coatings preserve moisture, lowers solute migration, respiration, transpiration rate thereby maintain the fruit firmness and retards senescence (Tezotto *et al* 2014). Chitosan plays an important role in biochemical and molecular activity such as oxidative burst (Paulert *et al* 2010) pathogenesis related genes (Loschke *et al* 1983) hypersensitivity response (Hadwiger and Beckman 1980) by affecting mitochondrial respiration and starch degradation rate (Silva *et al* 2017) and prevents the fruit from microbial attack (Bolwell and Daudi 2009). Chitosan delayed the climacteric peak, water loss, firmness and lowered the rate of respiration in litchi and papaya (Ali *et al* 2011 and Lin *et al* 2011 and) retarded colour development in banana and mango (Kittor *et al* 2001), inhibited the cell wall degrading enzymatic activity in carambola and strawberry (Gol *et al* 2015 and 2013), enhanced the fruit gloss in citrus fruits (Saberi *et al* 2018 and Arnon *et al* 2015), increased superoxide dismutase (SOD) activity and membrane integrity in peaches (Li and Yu 2000), decreased phenylalanine ammonia-lyase and peroxidase activity in apricot (Ghasemnezhad *et al* 2010) in avocado (Bill *et al* 2014) in banana (Suseno *et al* 2014) in guava (Nair *et al* 2018 and Silva *et al* 2018 and Hong *et al* 2012) in red kiwi fruit (Kaya *et al* 2016) in strawberry (Wang and Gao 2013) and malondialdehyde amount and polyphenol oxidase activity in longan (Shi *et al* 2013) and disease incidence in rose apples and strawberry (Valenzuela *et al* 2015; Plainsirichai *et al* 2012 and Perdones *et al* 2012). Carboxy Methylcellulose (CMC) enhanced the activities of scavenger antioxidant and defense enzymes *viz* peroxidase (POD), superoxide dismutase

(SOD), chitinase (CHI) and beta-1,3- glucanase (GLU) (Zeng *et al* 2013) and maintained higher concentration of total phenolics and total anthocyanin content and inhibited cell wall degrading enzymes and in strawberry (Gol *et al* 2013; Sogvar *et al* 2016 and Velickova *et al* 2013) and in peach and plum fruit (Guillen *et al* 2013). Hydroxy propyl methylcellulose (HPMC) film incorporated with essential oil ingredients reduced the texture loss and internal breakdown in plum fruit (Gunaydin *et al* 2017; Choi *et al* 2016; Fagundes *et al* 2013; Navarro-Tarazaga *et al* 2011 and Perez-Gago *et al* 2003) and polyphenol oxidase (PPO) and peroxidase (PO) activity in guava (Vishwasrao and Ananthanarayan 2016). Edible coatings enhanced ascorbic acid, total phenolics and antioxidant activity in the Kinnow (Din *et al* 2015; Ali *et al* 2015; Shah *et al* 2015 and Mahajan *et al* 2013) in mandarins (Rokaya *et al* 2016) in mango (Abbasi *et al* 2009) in strawberries (Dong and Wang 2017) and in avocado (Tesfay and Magwazaa 2017). Combined application of candelilla wax and tarbrush extract maintained appearance, physiological weight, water activity and firmness in apple (De leon-Zapata 2015) prolonged the shelf life of strawberry and avocado (Oregel-Zamudio *et al* 2017; Aguirre-Joya *et al* 2017 and Saucedo-Pompa *et al* 2009). Sodium alginate coating preserved sensory and nutritional attributes and prevented microbial spoilage in berry fruit (Guerreiro *et al* 2015) and enhanced the shelf-life of peach (Maftoonazad *et al* 2008). SamperFresh™ and calcium caseinate treatment reduced the weight loss and delayed the fruit ripening in blueberries cv Duke and Elliot (Duan *et al* 2011). Gum arabic coating protected the ultra structure of mitochondria in mango and enhanced the shelf-life of guava (Khaliq *et al* 2015 and Murmu and Mishra 2017) Combination of beeswax as hydrophobic phase, triethanolamine and oleic acid as emulsifying agent and CMC as hydrophobic polymer extended the shelf-life of peach and pear (Togrul and Arslan 2004) reduced weight loss and maintained rind firmness of mandrins (Valencia-Chamorro *et al* 2010). Coating with pullulan minimized respiration rate, delayed deterioration and controlled microbial growth in the fruits of high bush blueberry (*Vacciniumcorymbosum* L) (Krasniewska *et al* 2017).

2.2 Effects of anti-senescence compounds on storage life and quality of fruits

1-Methylcylcopropane (1-MCP) interacts with ethylene binding receptors and thereby prevent ethylene-dependent responses (Sisler and Blankenship 1996). There can be major differences in response to 1-MCP among cultivars (Dauny and Joyce 2002; Fan *et al* 1999; Rupasinghe *et al* 2000 and Watkins *et al* 2000). The postharvest application of 1-MCP treatment delayed softening, reduced electrolyte leakage without affecting the quality parameters *viz* total soluble solids, phenolic compounds and total antioxidant activity in apple (Gago *et al* 2015;Choi and Jung 2014; Sardabi *et al* 2013; Lu *et al* 2012; Jeziorek *et al* 2010 and Delong *et al* 2004), kiwifruit (Park *et al* 2015) and Kinnow (Tavallali and Moghadam 2015 and Asrey *et al* 2012) and delayed ethylene production in pear (Calvo and Sozi 2009; Arias *et al* 2009; Gamrasni *et al* 2010 and Villalobos-acuna *et al* 2011), prevented lipid peroxidation and chilling injury in plum (Manganaris *et al* 2008 and Singh and Singh 2012), inhibited the activity of cell wall degrading enzyme *viz* pectate lyase (PL), pectin methyl esterase (PME), cellulase (CX) and polygalacturonase (PG) and delayed the peak activity of 1-aminoacyclopropane 1-carboxylate synthase ACC synthase (ACS) and1-aminoacyclopropane 1-carboxylate oxidase (ACO) in banana and peach (Ullah *et al* 2016 and Zhu *et al* 2015).

Methyl jasmonate (MeJA) and salicylic acid (SA) are endogenous signaling molecules that play an essential role in regulating stress responses and plant development (Raskin 1992 and Turner *et al* 2002). MeJA is a naturally occurring plant growth regulator that modulates many physiological processes including responses to environmental stresses (Creelman and Mullet 1995). It is believed that systemic acquired resistance (SAR) is dependent on MeJA-mediated signaling and is associated with some signal transduction systems, which induce particular enzymes catalyzing biosynthetic reactions to form defense compounds such as polyphenols, alkaloids, reactive oxygen species (ROS) or pathogenesis-related (PR) proteins (Harms *et al* 1995). MeJA was reported to maintain postharvest fruit quality in several tropical fruits such as guava (Sayyari *et al* 2011); mango (Gonzalez-Aguilar *et al* 2000); papaya (Gonzalez-Aguilar *et al* 2003) and pomegranates (Jin *et al* 2014) and in temperate fruits such as apple, cherry and peach (Fan *et al* 1998; Yao & Tian 2005; Meng *et al* 2009 and Jin *et al* 2009).

Salicylic acid (SA) has been shown to induce expression of alternative oxidase genes (AOX) and increase the antioxidant capacity of the cells. Yao and Tian (2005) reported that pre-harvest treatment of sweet cherries with salicylic acid induced β -1,3- glucanase, phenylalanine ammonia-lyase (PAL) and peroxidase (POD) activities during the short time storage period and the activity of these enzymes in salicylic acid treated cherries stored at 25°C was higher than in fruits stored at 0°C. Salicylic acid, in a concentration dependent manner from 0 to 2 mmol L^{-1} enhanced the total antioxidant capacity of strawberry fruit. Consecutive application of salicylic acid at three stages *viz* vegetative growth, fruit development and post-harvest stage was the most effective strategy in improving total antioxidant capacity (Asgharia & Babalar 2009). Post -harvest treatment of sweet cherry fruits with salicylic acid significantly inhibited catalase (CAT) activity but stimulated the activity of superoxide dismutase (SOD) and peroxidase (POD). After inoculation with *P. expansum*, CAT activity decreased and SOD activity increased in salicylic acid treated fruits. Salicylic acid treatment also changed the expression of POD isozymes indicating that salicylic acid directly or indirectly activates antioxidant enzymes (Tian *et al* 2007). Pre and post-harvest treatment of salicylic acid maintained fruit firmness and delayed ripening during storage studies in cherry (Gholami *et al* 2010). Similar results were reported in kiwi fruit (Aghdam *et al* 2009) in kiwifruit and banana (Srivastava and Dwivedi 2000). Lu *et al* (2011) reported that pre and post-harvest salicylic acid treatments significantly reduced internal browning incidence and intensity in pineapple. Salicylic acid decreases ethylene production and inhibits cell wall and membrane degrading enzymes such as polygalacturonase (PG), lipoxygenase (LOX), cellulase and pectinemethylesterase (PME) leading to decreasing the fruit softening rate (Srivastava & Dwivedi, 2000, Zhang *et al* 2003). Salicylic acid was observed to inhibit ethylene production in cultured pear cells, mungbean hypocotyls, apple and pear fruit tissue discs, carrot cell suspension cultures and some fruits (Babalar *et al* 2007). In horticultural crops, salicylic acid affects AOX activity leading to decrease in the harmful effects of different post-harvest oxidative stresses such as chilling injury, prevents fermentation, maintains low respiration rates and decreases fruit ripening and senescence rates (Asghari and Aghdam 2010).

2.3 Effects of packaging materials on storage life and quality of fruits

Modified atmosphere packaging (MAP) has a great advantage in developing countries because it is economically feasible, saving the high cost of equipment (Mangaraj and Goswami 2011). In some commodities, the use of modified atmosphere packaging (MAP) has shown positive effects on maintaining produce quality, such as in table grape (Martinez-Romero *et al* 2003), broccoli (Serrano *et al* 2006) and sweet cherry (Serrano *et al* 2005). MAP consists of sealing a certain amount of fruit or vegetable by using plastic films with selective permeability to CO_2, O_2 and water vapour diffusion. The commodity respiration increases CO_2 and decreases O_2 concentrations inside the packages and transpiration rate increases water pressure. These modifications lead to reduction of weight loss, respiration rate and ethylene production, as well as retard changes in properties related to the ripening process, and in turn, postharvest quality can be maintained for longer periods (Artes *et al* 2006).

2.4 Effect of edible coatings, anti-senescence compounds and packaging materials on physical, biochemical and enzymatic parameters

2.4.1 Physiological weight loss (%)

2.4.2 Spoilage (%)

2.4.3 Organoleptic sensory quality (Hedonic scale 1-9)

2.4.4 Firmness (Kg Force)

2.4.5 Juice (%)

2.4.6 Sugars (TSS, Reducing sugars and total sugars (%)

2.4.7 Vitamin C (mg/100g)

2.4.8 Total carotenoids (mg/100g)

2.4.9 Pectin (Calcium pectate %)

2.4.10 Total phenols (mg/100g)

2.4.11 Pectin methyl esterase (PME)

2.4.12 Cellulase

2.4.1 Physiological loss in weight

The influence of polysaccharide based coatings on the weight loss is probably associated with the existence of hydroxyl groups creating hydrogen bonds both inside the coating matrix and with the cuticle on the peel, which mostly consists of cutin, polyester polymerized from hydroxylated fatty acids (Arnon *et al* 2015 and Koch and Ensikat 2008). The post-harvest application of edible coatings *viz* sodium alginate, pectin and combination of sodium alginate and pectin minimized the loss in weight of blueberry in contrast to uncoated fruit (Mannozzi *et al* 2017). CMC singly and in a combination with garlic essential oil (GEO) registered lower weight loss (16.23%) in strawberry as compared to control fruits (24.73%) after six days of cold storage (Dong and Wang 2017). Khorram *et al* (2017) observed that application of commercial wax registered the lower physiological loss in weight (3.2%) in Valencia orange in contrast to control (5.7%). CMC containing moringa leaf extract minimized PLW and maintained the cell turgidity of avocado fruit (Tesfay and Magwazaa 2015). Silva *et al* (2017) reported that mango fruit coated with chitosan registered minimum loss in physiological weight (11.11%) than that of control (19%). Arnon *et al* (2015) reported that both commercial and CMC/chitosan bilayer coatings significantly reduced the weight loss rates from 5.5 per cent in untreated citrus fruit to 4.6 to 4.7 per cent. The post-harvest application of sodium alginate and pectin registered minimum loss in PLW of strawberry fruits after 7 days of storage (Guerrerio *et al* 2015). Pea starch and guar gum based edible coating minimized the loss in fruit weight, due to higher moisture barrier capacity of 'Valencia' oranges (Saberi *et al* 2018). Candelilla wax with and without fermented extract of tarbrush recorded minimum physiological loss in weight in apples in contrast to control (De Leon Zapata *et al* 2015). Navarro-Tarazaga (2011) reported that HPMC containing bees wax registered minimum physiological loss in weight in plum fruit in contrast to HPMC without bee wax. Oregel-Zamudio *et al* (2017) found that candelilla wax registered minimum physiological loss in weight contrast to control fruit in strawberry after 6 days of storage. Duan *et al* (2011) reported that samperfresh coated blueberry cv. Duke registered minimum physiological loss in weight in contrast to control after 6 days of storage at ambient temperature.The postharvest application of CMC treatment recorded the lowest physiological loss in weight (2.91%) in contrast to control (6.33%) fruits of sweet orange cv. Newhall navel after 100 days of storage (Zeng *et al* 2013). Velickova *et al* (2013) reported that chitosan checked the weight loss (11%) in strawberry fruit as compared to control (48%). Gol *et al* (2013) found that combined application of CMC, HPMC and chitosan registered minimum physiological loss in weight in contrast to CMC and HPMC alone. Ali *et al* (2015) reported that Kinnow fruit coated with NFC and Fomesa registered lower physiological loss in weight (6.15 and 6.12%, respectively) in contrast to control (9.71%). The post-harvest application of citrashine coating registered minimum physiological loss in weight (5.40%) than that of control (12.20%) in Kinnow (Mahajan and Singh 2014). Mahajan *et al* (2013) reported that Niprofresh SS 40 T treatment registered lower physiological loss in weight (7.60%) in Kinnow fruit in contrast to uncoated fruit (9.71%) after 60 days of cold storage. Shah *et al* (2015) reported that CMC and guar gum based silver nano particles minimized the physiological loss in weight after 120 days storage of Kinnow fruits. Bisen *et al* (2012) reported that post-harvest application of edible coatings registered lower physiological loss in weight in lime fruit. The post-harvest application of CMC, cellulose and bees wax checked the moisture loss and reduced the physiological loss in weight in Murcott tangor fruits stored at 5^{o}C for 60 days (Samra *et al* 2014). Edible coating prepared from different ingredients reduced the weight loss in Kinnow fruits (Din *et al* 2015).

Massolo *et al* (2011) reported that 1-MCP treatment reduced the rate of dehydration and registered minimum weight loss (6.2%) in eggplant fruit as compared to control (8.6%) after 21 days of cold storage. Manganaris *et al* (2008) demonstrated that the postharvest application of 1-MCP on plum cv. 'Joanna Red' and found that fruits treated with 1-MCP registered lower (2 to 4%) PLW in contrast to control (6%). The postharvest application of 1-MCP registered the minimum PLW (23.5%) in contrast to control (28.9%) in chinese chive after 12 days of storage (Wu *et al* 2009). 1-MCP subjected to 'Medlar' fruits registered minimum loss in PLW (0.71%) than those of control (1.12%) after 60 days of storage (Selcuk and Erkan 2015). Zulferiyenni *et al* (2015) reported that fruits of guava subjected to combined application of 1-MCP and chitosan registered minimum PLW as compared to control during storage. Tavallali and Moghadam (2015) reported that Kinnow fruits subjected to AVG and 1-MCP treatment registered lower PLW (9.83%) in contrast to control (38.46%) fruits during storage. Gonzalez-Aguilar *et al* (2000) reported that MeJA registered minimum PLW in mango cv. 'Kent' as compared to control; this could be attributed with stomatal closure induced by MeJA which reduced the transpiration rate. Fan *et al* (2016) reported that the postharvest treatment of MeJA registered the lower PLW in eggplant fruit as compared to control at the end of the storage. The anti-senescent action and maintenance of cellular integrity by both MeJA and SA registered minimum PLW (2%) in contrast to control where it was 6 per cent (Ezzat *et al* 2017). Fruits of peach treated with SA registered minimum PLW (14.08%) in contrast to control (17.15%) after 42 days of storage (Khademi and Ersadi 2013). Davarynejad *et al* (2015) demonstrated the combined application of SA and putrescine on storage quality and shelf-life of plum cv. 'Santa Rosa' and found that fruits subjected to SA and putrescine resulted minimum PLW as compared to control at the end of the storage.

Ramayya *et al* (2012) evaluated the effect of oriented polypropylene (perforated and non perforated) films with three different level of gas concentration and found that mangoes packed in OPP bags with 50 per cent CO_2 followed by OPP with 25 per cent CO_2 and 75 per cent CO_2 registered the lower average weight loss 11.4, 14.9 and 18.7 per cent, respectively..

Kudachikar *et al* (2011) evaluated the effect of MAP on shelf-life and quality of banana cv. Robusta and observed that MAP and MAP+GK films registered minimum PLW in contrast to unwrapped banana fruits. The maximum weight loss (31.3%) was registered in unwrapped followed by high density polyethylene (HDPE) perforated (22.4%) and linear low density polyethylene (LLDPE) perforated (21.49%) pear fruits after 12 days of storage; this might be due to continuous loss of moisture due to transpiration from the fruit and respiration (Nath *et al* 2012). Kaur *et al* (2013) reported that the maximum PLW (4.8%) was registered in fruits packed in crates, whereas minimum PLW (1.6%) was in fruits packed in CFB boxes with HDPE liners. Sharma *et al* (2013) evaluated the effect of various heat shrinkable films on the shelf-life and quality of apple cv. Royal delicious' and found that cryovac (9 μ) film was the most effective in reducing the PLW (2.3%) in contrast to control (10.7%). Azene *et al* (2014) demonstrated the effect of various packaging material and environmental condition on the shelf-life and quality of papaya fruit and observed that HDPE packed fruits registered lowest loss in PLW (9.14%) than those of unwrapped fruits (14.61%) after 18 days of storage. Fruits of 'peach' wrapped in shrink film registered the lowest average PLW (0.63 %) as compared to control (5.80%) under super market condition during storage (Mahajan *et al* 2015). Rao and Shivshankara (2015) reported that individual shrink wrapping registered 4-5 time lesser PLW than those of unwrapped fruit of mango cv. 'Alphonso' and 'Banganapalli' at the end of the storage. Mahajan and Singh (2014) demonstrated the effect of packaging films on quality and shelf-life of Kinnow fruits and found that shrink film wrapped fruits registered the lower PLW (1.06%) than those of control (12.20%).

2.4.2 Spoilage (%)

The films and coatings can suspend decay by reducing senescence, which causes more susceptibility to pathogenic infection in produce due to damage of cellular or tissue integrity (Tanada-Palmu and Grosso 2005). The post harvest application of chitosan reduced the spoilage and microbial growth in strawberry after 12 days during storage (Wang and Gao 2013). Fruit of blueberry coated sodium alginate and pectin registered lower fruit decay percentage than that of control (Mannozzi *et al* 2017). Dong and Wang (2017) reported that decay percentage was lower in CMC/GEO coated strawberry as compared to control. Mango fruits coated with chitosan (3%) registered lower spoilage percentage than that of control (Silva *et al* 2017). Guerreiro *et al* (2015) reported that strawberry fruit coated with eugenol and citral were effective in reducing decay percentage. Fruits of 'Valencia' coated with different edible coating ingredients did not show any decay incidence during four weeks at 5^{o}C and three weeks at 20^{0}C (Saberi *et al* 2018). Chitosan reduced the percentage of infected strawberries as compared to control after three week of storage (Perdones *et al* 2012). Chitosan registered lower decay rate in strawberry incontrast to control (Duan *et al* 2011). Uncoated fruits of sweet orange cv. 'Newhall navel' infected earlier due to pathogens (50 days after storage) than those with amended coating treatment (70 days after storage) (Zeng *et al* 2013). The signs of decay in control strawberries appeared only after one day of storage while the coated fruits on the other hand exhibited a delay in decay incidence (Velickova *et al* 2013). Gol *et al* (2013) found that after 12 days of storage 95.59 per cent of control strawberries were infected in contrast to coated fruits i.e. 14.45-28.57 per cent. Pectin and alginate based edible coatings delayed the fruit spoilage incidence in raspberries than those of control fruits (Guerreiro *et al* 2015). Krasniewska *et al* (2017) found that pullulan coated blueberry registered lower decay (32.22%) than those of control (52.22%) after 28 days of storage. Vu *et al* (2011) reported that fruits of strawberries resulted lower decay percentage when coated with combined application of MC and limonene based coatings in contrast to MC alone and control. Shah *et al* (2015) reported that CMC and guar gum based silver nano particle coated Kinnow fruits revealed lower decay percentage in contrast to control. Bees wax and carnauba coated avocado and mango fruits registered reduced chilling injury symptoms and decay incidence during storage (Faygenberg *et al* 2005). Chitosan in a combination with irradiation (200kGy) delayed rotting of mango fruit in contrast to control (Abbasi *et al* 2009).

The postharvest application of 1-MCP registered the lowest index for decay in chinesechive than those of untreated ones after 12 days of storage (Wu *et al* 2009). The postharvest application of 1-MCP registered the lower decay percentage (2.5%) in pear fruits as compared to control (0%) after two weeks of storage (Gamrasni *et al* 2010). Kinnow fruits subjected to AVG and 1-MCP treatments registered minimum chilling injury and decay incidence than those of control fruits at the end of the storage (Tavallali and Moghadam 2015). Fruits of kiwi cv.'Hayward' subjected to 1-MCP treatment registered minimum degree of fruit decay in contrast to control (Park *et al* 2015). Cao *et al* (2008) reported that post harvest application MeJA registered the lower disease incidence and lesion diameter (12.2 and 30.6%, respectively) in loquat fruits than those of control (55.1 and 64%, respectively). Fruits of mango cv. 'Kent' subjected to MeJA registered the minimum chilling injury (CI) symptoms at 5^0C in contrast to control fruits during storage (Gonzalez-Aguilar *et al* 2000). The postharvest subjection of MeJA to strawberry fruits registered the minimum incidence of fruit decay than those of control after 12 days of storage (Geransayeh *et al* 2015). Khademi and Ersadi (2013) reported that fruits of peach subjected to SA registered minimum decay percentage (2.44%) as compared to control (4.00%) after 42 days of storage.

Nath *et al* (2012) evaluated the effect of different packaging materials on the shelf-life and quality of pear fruit and found that minimum cumulative decay loss was registered in fruits packed in PP perforated (12.5%) followed by PP non-perforated (16.5%) and LDPE perforated (29%) after 15 days of storage, while, the maximum decay loss was recorded in control (100%). The reduced decay loss might be attributed to limited permeability of gases (CO_2 and O_2) and water vapour, which can interplay with physiological processes of fruit

(Tijskens and Vollebregt 2003 and Soliva and Martin 2003). The spoilage in fruit packed in different packaging materials was maximum in wooden boxes (6.91%) followed by crates (6.3%) and CFB boxes (5.8%), while minimum spoilage (3.1%) was recorded in fruits packed in CFB boxes with HDPE liners (Kaur *et al* 2013). Sharma *et al* (2013) found that apple cv. 'Royal delicious' wrapped in cryovac (9 μ) film registered minimum incidence of decay (2.8%) compared to unwrapped (8.7%). The LDPE film registered even higher spoilage percentage over unwrapped fruit of peach (Mahajan *et al* 2015). The occurrence of higher decay incidence in LDPE film might be due to accumulation of excessive water vapour inside the package, because of restricted movement of water through the film.

2.4.3 Organoleptic sensory quality (Hedonic scale 1-9)

Choi *et al* (2016) reported that essential oil containing HPMC coated plum registered higher average flavour and overall impression scores over control fruit. CMC in a combination with GEO (2%) retained the highest scores for acceptability ofcolor, taste, texture and flavor of strawberry (Dong and Wang 2017). Aroma and flavour of strawberry samples treated with CH coatings containing essential oils registered higher sensory scores as compared to control (Perdones *et al* 2016). Arnon *et al* (2015) reported that CMC/chitosan bilayer edible coating greatly enhanced fruit glossiness and appearance during storage. Fruit of 'Valencia' orange coated with PSGG coatings maintained overall flavor (Saberi *et al* 2018). Ali *et al* (2015) reported that Kinnow fruits coated with NFC and Fomesa retained the maximum score (7.15) for overall acceptability after 63 days of storage. Mahajan and Singh (2014) reported that there was a gradual increase in palatability rating in citrashine coated Kinnow fruit up to 15 days of cold storage. Mahajan *et al* (2005) found that citrashine coating was most effective in improving the overall quality and sensory score of pear fruit without development of off-flavour. The highest mean overall organoleptic rating of 7.4 and 7.2 was registered in Niprofresh SS 40 T and SS 50 T coated Kinnow fruit, respectively (Mahajan *et al* 2013). Wax coatings have been reported to maintain the gloss, flavour and aroma of fruit (Olivas and Barbosa-Canovas, 2005). Mahajan *et al* (2005) and Bishnoi *et al* (2008) noticed that wax coatings helped in retaining highly acceptable organoleptic quality of pear and apple fruit without development of off-flavour.

Gamrasni *et al* (2010) reported that 1-MCP registered the highest score for sensory attributes (9.3) in pear fruit in contrast to control (5.0) after two weeks of storage. Fan *et al* (2016) reported that fruits of eggplant subjected to MeJA registered the maximum score (6.27) for sensory attributes than that of control (4.63) at the end of the storage. Ezzat *et al* (2017) reported that apricot fruits subjected to MeJA and SA treatments registered the highest sensory score i.e. 4.20 and 3.90, respectively than those of control i.e. 1.80 after 21 days of storage.

Ramaya *et al* (2012) evaluated the effect of OPP (perforated and non perforated) and observed that mango fruits packed in unperforated OPP film registered better quality (6.8) as compared to those were packed in perforated OPP film (4.3). Fruits of banana cv. 'Robusta' wrapped in MAP and MAP +GK registered the maximum scores of 7.5 and 7.4, respectivelyfor overall fruit quality in contrast to unwrapped fruits (7.2) at the end of storage (Kudachikar *et al* 2011). The pear fruit packed in CFB boxes with HDPE liners maintained higher mean sensory score of 7.8, followed by fruits packed in CFB boxes with LDPE liners of 7.6, while minimum score of 6.0 was registered in fruits packed in crates (Kaur *et al* 2013). Fruit of apple cv. 'Royal delicious' wrapped in cryovac film registered the highest sensory score (8.3) (Sharma *et al* 2013).The maximum average sensory score of 7.07 was registered in peach fruits wrapped in shrink film(7.07) as compared to control(5.90) under super market conditions at the end of the storage (Mahajan *et al* 2015). Mahajan and Singh (2014) reported that Kinnow fruit wrapped in shrink films registered the maximum score of 7.76 for sensory attributes (7.76) in contrast to control where it was recorded the minimum 6.27).

2.4.4 Firmness

Firmness is one of the critical components in determining the acceptability of fruit crops (Khaliq *et al* 2015). Khorram *et al* (2017) reported that with an advancement in storage period uncoated orange fruit registered maximum loss in firmness in contrast to coated ones may be due to pectin depolymerization, associated with pectin esterase, pectin lyase and polygalactronase activities. Coatings reduce the activities of pectin esterase, pectin lyase and polygalactronase enzymes in the fruit and allows retention of the firmness during storage (Maftoonazad and Ramaswamy 2005). The application of coatings and essential oils alone or in combination can improve the firmness of strawberry fruit (Eshghi *et al* 2014). The post-harvest application of edible coating may affect fruit firmness retention as a result of the high weight loss reduction (Valencia-Chamorro *et al* 2010). Navarro-Tarazaga *et al* (2008) reported a correlation between citrus fruit weight loss and firmness. Firmness of tomato fruit declined with an advancement of storage period in both coated (gum arabic) and uncoated fruit (Ali *et al* 2010). The post-harvest application of CMC combined with moringa leaf extract maintained higher fruit firmness during the storage as the higher firmness retention on coated avocado fruit could be attributed to improved barrier for gaseous and moisture diffusion (Tesfay and Magwazaa 2017). The softening in control fruit is typical of avocado fruit resulting from weakened cell wall structure, loss of membrane integrity, hydrolysis of cellulose and hemicellulose as well as depolymerisation of pectin and starch (Seymour *et al* 1993). Silva *et al* (2017) observed that the firmness loss rate reduced in mango following the increase in chitosan concentration during the storage. Firmness of Kinnow diminished gradually as the storage period progressed however, fruit coated with NFC treatment retained maximum fruit firmness (9.91N) over control fruits where it was recorded as 4.80 N. (Ali *et al* 2015). Mahajan and Singh (2014) observed the highest mean firmness (1085.50 g force) in citrashine coated Kinnow fruits, while the lowest mean firmness (834.85 g force) was recorded in case of control. The post-harvest application of Niprofresh SS 40 T maintained the maximum firmness of 1118 g force) in Kinnow fruits in contrast to 993 g force fruit firmness in uncoated fruits (Mahajan *et al* 2013).

Massolo *et al* (2011) reported that the post-harvest application 1-MCP retained the higher firmness (16.2 N) in eggplant fruit over control (10.2 N) after 21 days of storage. Fruits of plum cv. ‘Joanna Red’ treated with 1-MCP retained the higher firmness than those of control during storage (Manganaris *et al* 2008). Calvo and Sozzi (2009) reported that the postharvest application of 1-MCP registered a progressive effect on maintaining fruit firmness as 1-MCP maintained higher fruit firmness in pear cv. ‘Bartlett’ over control at the end of the storage. Arias *et al* (2009) reported that 1-MCP treated fresh cut pear fruits registered higher fruit firmness (7.9 N) as compared to control (1.9 N) at the end of the storage. Piriyavinit *et al* (2011) reported that the postharvest application of 1-MCP delayed the loss of firmness in mangosteen fruit in contrast to control after 7 days of storage. Medlar fruits subjected to 1-MCP treatment retained higher fruit firmness (8.93 N) than those of control fruits (7.06 N) after 60 days of storage (Selcuk and Erkan 2015). Zulferiyenni *et al* (2015) observed a decrease in firmness throughout the storage period irrespective of treatments in guava fruit. However, fruit of guava subjected to combination of 1-MCP and chitosan registered minimum loss in firmness over control. The post-harvest application of 1-MCP maintained higher firmness (11.57 N) in kiwi fruit as compared to control (7.45 N) fruits after 180 days of storage (Cantin *et al* 2011). Tavallali and Moghadam (2015) reported that Kinnow fruits subjected to AVG and 1-MCP treatments maintained higher fruit firmness and prevented fruit softening in contrast to control during storage. Park *et al* (2015) reported that kiwi fruits treated with 1-MCP delayed the loss in firmness and checked the fruit softening in contrast to control. Han *et al* (2015) reported that 1-MCP treated bitter melon maintained higher firmness over control fruit during cold storage. Zapata *et al* (2014) examined the effect of pre-harvest application of MeJA on plum cultivars and found that fruit subjected to MeJA maintained the maximum firmness (5.15 N) in contrast to control (2.83 N) after nine days of storage. In general, firmness decreased with prolongation of storage period irrespective of the treatment. However, fruit of eggplant subjected to MeJA maintained the higher firmness in contrast to control during cold storage (Fan *et al* 2016). Fruit of apricot subjected to MeJA and SA maintained the higher firmness than that of control after 21 days of cold storage (Ezzat *et al* 2017). Khademi and Ersadi (2013) demonstrated the post-harvest effect of SA and found that fruits of peach subjected to SA maintained higher firmness (4.45 N) over control (3.84 N) after 42 days of storage.

OPP films did not influence fruit firmness as mangoes wrapped in non perforated OPP film registered marginally higher firmness (4.9 N) over perforated film (4.4 N) (Ramayya *et al* 2012). Fruit of banana cv. Robusta wrapped in MAP and MAP+GK registered higher fruit firmness over unwrapped during storage (Kudachikar *et al* 2011). In the pear fruit, the maximum firmness was recorded in PP non perforated (5.18 kg f) followed by LDPE non-perforated (4.76 kg f) and LDPE perforated (4.23 kg f), respectively. However, the lowest firmness was recorded in HDPE perforated (1.8 kg f) after 12 days of storage (Nath *et al* 2012). Sharma *et al* (2013) reported that apples cv. 'Royal Delicious' wrapped in cryovac films recorded higher firmness force (18.6 N) over other films. Fruits of 'papaya' wrapped in HDPE retained the higher firmness (3.5 kg/cm^2) than those of unwrapped ones (1.7 kg/cm^2) after six days of storage (Azene *et al* 2014). Fruits of 'peach' wrapped in shrink packaging film maintained the highest average firmness (9.77 lb force) in contrast to control fruits (6.90 lb force) under super market conditions after nine days of cold storage (Mahajan *et al* 2015). Rao and Shivashankara (2015) demonstrated the effect of various packaging material on the shelf-life and quality of mango cv. 'Alphonso and 'Banganapalli' and found that among different films, fruits of both cultivars wrapped with D-955 film maintained higher firmness over wrapped in LDPE film during storage. Mahajan and Singh (2014) reported that Kinnow fruit wrapped in shrink film registered the maximum firmness (1542.54 g force) than those of control (999.36 g force) at the end of the storage.

2.4.5 Juice (%)

Sharma and Ghooman (2009) reported that the juice content of Kinnow fruits during storage studies followed a declining trend might be due to loss of moisture from the surface of the fruits. Combined application of wax and bavistin maintained maximum (43.45%) juice percentage in mandarin fruit in contrast to control (34.65%) after four weeks of storage (Rokaya *et al* 2016). Mahajan *et al* (2014) reported that Kinnow fruit coated with Niprofresh SS 40 T and SS 50 T registered gradual decrease in juice yield as compared to control. Fruit of 'Kagzi lime' retained the maximum (42.3%) juice content in the fruits coated with pure coconut oil followed by (40.9%) with castor oil and (40.4%) with liquid paraffin wax coating after 18 days of storage (Bisen *et al* (2012). Samra *et al* (2014) reported that CMC (3%) coated Murcott tangor fruits registered maximum juice ratio (40.60%) over control (36.16%) after 60 days of storage.

Sharma *et al* (2013) demonstrated the effect of heat shrink films on shelf-life and quality of apples cv. 'Royal Delicious' and found that fruits wrapped in cryovac films maintained highest juice recovery (65.2%) followed by apples wrapped in polyolefin (63.2%) and LDPE films (63.1%). Heat shrinkable films are known to influence juice recovery in Mosambi and Kinnow, primarily due to curve on PLW over unwrapped fruits (Ladaniya 2003; Ladaniya and Singh 2001). Pandey *et al* (2006) observed a decline in juice recovery following increase in storage period in apples.

2.4.6 Sugars (TSS, Reducing sugars and Total sugars)

The total soluble solids (TSS) and sugars increase during storage; due to during degree of maturity of the fruit; fruit maturity accelerates metabolic reactions that increase the sugar content and sweetness of the fruit (Trevino-Garza *et al* 2015). While studying the shelf-life of blueberry fruit, Krasniewska *et al* (2017) reported that uncoated fruit registered a gradual increase in TSS and decline in reducing sugars *viz* fructose and glucose over fruit coated with pullulan coating; might be due to berrier properties of coating reduces the rate of respiration of fruits and simultaneously the respiration process accelerate the hydrolysis of starch into sugars (Biliaderis *et al* 1985 and Wills *et al* 1980). Total soluble solids (TSS), which is attributed mainly to sugar and organic acids usually increases during ripening (Herrmann 1995). In peaches and plum, the TSS increased gradually during six days of storage period i.e. 6 and 13 g/100g FW from harvest to 9 and 15 g/100g FW, respectively during cold storage (Guillen *et al* 2013). Sogvar *et al* (2016) evaluated the effect of *Aloe vera* and ascorbic acid coatings on storage life in strawberry and found that TSS increased gradually in uncoated fruits, whereas it remained stable in coated fruit up to 12 days of storage. In red kiwifruit, chitosan coated and uncoated fruit did not register any change in TSS content during initial four days but observed a gradual increase thereafter (Kaya *et al* 2016). Ghasmnezhad *et al* (2010) reported that the post-harvest application of chitosan registered a gradual decline in TSS content in apricot during storage; might be due to respiration and conversion of sugar into CO_2 and H_2O (Saira *et al* 2009). Kumar *et al* (2017) reported that chitosan delayed the increase in TSS content in plum fruit; might be due to catabolic process and respiration rate (Rohni *et al* 1997). Ali *et al* (2011) observed that the reduction in TSS was directly proportional to chitosan concentration as lower TSS was registered in chitosan (1.5 and 2%) coated papaya fruits during storage. Mahajan and Singh (2014) investigated the effect of cellulose, terpenoidal, citrashine and stafresh coatings and found that highest mean TSS was registered in citrashine coated Kinnow fruit during 15 days of storage. Ahmed *et al* (2013) reported that under ambient storage condition Sta-Fresh 960 treatment was most effective in delaying the decrease in total sugars up to 60 days of storage in Kinnow. Abbasi *et al* (2009) reported a gradual increase in reducing sugars in coated mango due to slow ripening process. Irrespective of coating application a gradual increase in reducing sugar content in Kinnow fruit was observed during cold storage (Shah *et al* 2015). Shahid and Abbasi (2011) found that uncoated fruits of sweet orange cv. Blood red registered the maximum reducing sugar and non reducing content in contrast to coated fruits.

Massolo *et al* (2011) reported that the post-harvest application of 1-MCP registered the lower sugar percentage (28 g/kg) in pear fruit over control (30 g/kg) after 21 days of cold storage. Fruits of pear cv. 'Bartlett' treated with 1-MCP registered the higher soluble sugars content as compared to control at the end of the cold storage (Calvo and Sozzi 2009). Lu *et al* (2013) demonstrated the effect of 1-MCP on apple cv. 'Cortland' and 'Delicious' and found that 1-MCP treatment did not influence the soluble solids concentration during cold storage. 'Medlar' fruit subjected to 1-MCP treatment registered the minimum soluble soildsconcentration (16.13%) in contrast to control (16.23%) after 60 days of cold storage (Selcuk and Erkan 2015). Kiwi fruit subjected to 1-MCP did not influence the soluble sugar concentration during storage (Park *et al* 2015). The pre-harvest application of MeJA registered lower soluble sugars concentration in plum over control fruits after 50 days of cold storage (Zapata *et al* 2014). Gonzalez-Aguilar *et al* (2000) registered the maximum sugars content in mango cv. 'Kent' subjected to MeJA as compared to control during storage. Amanullah *et al* (2017) demonstrated the effect of SA on shelf-life and quality of guava fruits and found that fruits treated with SA maintained maximum total sugars, reducing sugars and non reducing sugars percentage (20.08, 6.06 and 11.37%, respectively) in contrast to control (14.58, 5.72 and 8.83%, respectively) after 10 days of storage.

'Robusta' banana fruit wrapped in MAP and MAP +GK registered the maximum TSS content (24 and 23.8^0 brix, respectively) and total sugars (12.1 and 11.8%, respectively) as compared to control fruits during storage (Kudachikar *et al* 2011). In pear fruit, the maximum and minimum TSS (12.8 and 10.4° brix, respectively) content was recorded in control and PP non perforated films at the end of storage (Nath *et al* 2012). Kaur *et al* (2013) studied the effect of various packaging materials on shelf-life and quality of pear fruit and found that wooden boxes registered higher total soluble solids content, reducing sugara and total sugara percentage (14.1^o brix, 7.2 and 11.0%, respectively). Cryovac wrapped apple cv. 'Royal Delicious' registered higher TSS i.e. 16.4 per cent over unwrapped fruits i.e. 14.3 per cent (Sharma *et al* 2013). Azene *et al* (2014) evaluated the effects of various packaging materials on shelf-life and quality of papaya fruit and found that fruits wrapped in LDPE registered the maximum TSS, reducing sugar and total sugar percentage (10.70 brix, 7.6 and 14.3%, respectively) content than unwrapped fruits after 18 days of storage. Mahajan *et al* (2015) evaluated the effect of various packaging materials on shelf-life and quality of peach fruit and found that shrink film resulted the maximum TSS content and sugar percentage (10.0 and 5.10%) during storage. Rao and Shivashankara (2015) observed that unwrapped mango fruit registered the higher soluble solids and sugars percentage in contrast to fruits wrapped in LDPE film. Mahajan and Singh (2014) reported that shrink film wrapped Kinnow fruit recorded higher TSS (9.45^o brix) after 5 days of storage which reached to its peak value (12.30^o brix) after 20 days of storage.

2.4.7 Vitamin C

In blueberry fruit, vitamin C content showed a steady decline and the extent of decline was 33.5 per cent in pullulan coated fruit as compared to control (40%) after 28 days of cold storage (Krasniewska *et al* 2017). Possible reasons for vitamin C losses during storage are auto oxidation which occurs spontaneously when the ascorbic acid combine with oxygen in the air (Owusu-Yaw *et al* 1988). Li and Yu (2000) evaluated the post-harvest application of chitosan and retained the maximum ascorbic acid content in chitosan treated peaches. Sogvar *et al* (2016) reported that coating serve as a protective layer and control the permeability of O_2 and CO_2, thus decreasing the auto oxidation of ascorbic acid. *Aloe Vera* (AV) combined with ascorbic acid (AA) treatment was more effective in reducing vitamin C than AV alone in strawberry fruit. The post-harvest application of chitosan enhanced the vitamin C content initially at the beginning of storage and thereafter followed a decline after 25 days of storage in apricot fruit (Ghasemnezhad *et al* 2010). In contrast to uncoated plum, coating with chitosan maintained the maximum vitamin C content throughout the storage period (Kumar *et al* 2017). Ali *et al* (2011) reported that ascorbic acid retention was maximum in chitosan coated papaya fruit in contrast to control. Ali *et al* (2015) recorded a gradual decline in ascorbic acid content during storage. However, natural and synthetic coating registered lesser decline in Kinnow fruit in contrast to control. Mahajan and Singh (2014) found that citrashine coated Kinnow fruits retained maximum (17.38mg/100g) ascorbic acid content in all the treatments during storage. Mahajan *et al* (2013) observed a declining trend in vitamin C content during storage and found that Kinnow fruit coated with Niprofresh SS 50 T retained the maximum (18.81 mg/100g) vitamin C content among all the treatments during storage. Shah *et al* (2015) reported that the post-harvest application of CMC and guar gum based silver nano particles initially enhanced the ascorbic acid content with advancement of storage. However, with prolongation of storage registered a consistent decline in ascorbic acid content in Kinnow fruit. Fruit of lime coated with pure coconut oil maintained maximum (49.9 mg/100 g) ascorbic acid content after 18 days of cold storage (Bisen *et al* 2012).

The post-harvest application of 1-MCP delayed the loss in ascorbic acid content in chinese chive as the fruit treated with 1-MCP registered minimum (24.2 per cent) loss in vitamin C content than those of untreated ones i.e. 62 per cent after 12 days of storage (Wu *et al* 2009). Cao *et al* (2012) reported that the postharvest application of 1-MCP maintained the higher vitamin C content in bell papper in contrast to control after 10 days of storage. Fruit of 'Medlar' subjected to 1-MCP application maintained higher content of ascorbic acid (5.70 mg/100g FW) than those of untreated fruit (4.94 mg/100g FW) (Selcuk and Erkan 2015). Fruit of Kinnow subjected to AVG and 1-MCP maintained the higher ascorbic acid content (6.8 and 4.1 mg/100g, respectively) as compared to control (4.1 and 1.9 mg/100g, respectively) during cold storage (Tavallali and Moghadam 2015). Fruit of strawberry subjected to MeJA maintained the higher ascorbic acid content over control fruits after 12 days of storage (Geransayeh *et al* 2015). Amanullah *et al* (2017) reported that the postharvest application of SA registered the higher ascorbic acid content (7.95%) in guava as compared to control (5.0%) after 10 days of storage. Combined postharvest application of putrescine and SA maintained maximum content of ascorbic acid in plum cv. Santa Rosa' over control during storage (Davarynejad *et al* 2015).

Ramaya *et al* (2012) evaluated the effect of OPP (perforated and non perforated) and observed that fruit of mango packed inOPP with 50% CO_2perforation registered the average lowest decline in ascorbic acid (2.15 mg/100g FW) content followed by OPP with 25% CO_2 perforation (3.6 mg/100g FW). In pear fruit, the maximum retention of ascorbic acid (49.97%) was recorded in PP non-perforated films, while, the lowest ascorbic acid (17.16%) content was retained in control and non-perforated HDPE wrapped fruits at the end of the storage (Nath *et al* 2012). Fruit of apples cv. 'Royal Delicious' wrapped in cryovac films maintained higher content of ascorbic acid (1.28 mg/100 g pulp) over unwrapped (1.19 mg/100 g pulp) fruit at the end of the cold storage (Sharma *et al* 2013). Fruit of 'papaya' wrapped in LDPE retained the maximum ascorbic acid content (45.6 mg/100g) as compared to control (40.60 mg/100 g) after 18 days of cold storage (Azene *et al* 2014). Fruits of 'peach' wrapped in shrink films maintained the maximum vitamin C content as compared to control during storage (Mahajan *et al* 2015). Rao and shivashankara (2015) evaluated the effect different packaging films on the shelf-life and quality of mango cv. 'Alphonso and 'Banganapalli' and found that shrink wrapping alleviated the CI and was effective in preventing the losses in ascorbic acid content during storage. Mahajan and Singh (2014) reported that fruit of Kinnow wrapped in shrink film retained the maximum ascorbic acid (19.18 mg/100g FW) content over control fruit (17.22 mg/100g FW) at the end of the storage.

2.4.8 Total phenols (mg/100g)

Fruits of 'strawberry' coated with *Aloe vera* (5%) and ascorbic acid (3%) initially registered an increase in total phenolics content after 18 days of cold storage (Sogvar *et al* 2016). 'Red kiwifruit' coated with chitosan registered higher phenolics content (102.9 ± 9.04 mg/100) over control fruit (60.6 ± 4.62 mg/100 g) at the end of the cold storage (Kaya *et al* 2016). Ghasemnezhad *et al* (2010) evaluated the effect of post harvest application of chitosan and found that chitosan (0.5%) registered the highest total phenol content in apricot during storage. Kumar *et al* (2017) observed a pronounced decline in total phenolics content in control fruit of plum as compared to the fruit coated with chitosan after 35 days of cold storage; this might be attributed to the delay in fruit senescence in coated fruits than those of non-coated (Sanchez-Gonzalez *et al* 2011). Wang and Gao (2013) studied the effect of postharvest application of chitosan and found that chitosan registered an initial increase in total phenol content in strawberry fruit during the storage. The pre-harvest application chitosan (0.5% and 1.0%) registered 1.4 times and 1.6 times higher phenolics compounds in sponge guard as compared to control fruit during cold storage (Han *et al* 2014). Fruit of carambola treated with chitosan (0.3%), gum arabic (1%) and alginate (2%) retained the maximum amount of total phenolics over control fruits during storage (Gol *et al* 2015). Alginate treatment registered the higher retention of total phenolics content in sweet cherry (Diaz-Mula *et al* 2011). Gol *et al* (2013) reported that combined application of HPMC (1%) +

chitosan (1%) and CMC (1%) + chitosan exhibited higher level of total phenol in strawberry fruit (0.72 mg/g and 0.69 mg/g, respectively); this might be due to coating with chitosan form a protective barrieron the fruit surface and reduce the oxygen supply for enzymatic oxidation of phenolics compound (Zhang and Quantick 1997). Kumari *et al* (2015) reported that combined application of salicylic acid (1mM) and chitosan (2%) retained higher amount of total phenol (440.05 μg GAE g^{-1}FW) in litchi fruit in contrast to control (298.45 μg GAE g^{-1}FW) at the end of the cold storage. Krasniewska *et al* (2017) reported that pullulan coating registered an increase in total phenol content in blueberry fruit as compared to control fruit. Dong and Wang (2017) reported that combined post-harvest application of CMC + GEO (2%) exhibited the highest level of total phenol content in strawberry fruit in contrast to control after six days of storage. Khorram *et al* (2017) observed that shellac, Persian gum and gelatin enhanced the total phenolics content in orange fruit with an advancement in storage period. Nair *et al* (2018) reported that the post-harvest application of chitosan along with pomegranate peel extract retained the higher content of total phenolics (92%) in guava fruit during cold storage. Duan *et al* (2011) demonstrated the effect of post-harvest application of samperfresh, acid soluble chitosan, water soluble chitosan, calcium caseinate and sodium alginate coatings and experienced the lowest loss in total phenolics (7%) content in blueberry fruit as compared to control.

Fruit of eggplant treated with 1-MCP registered no change in phenolics content, while the control fruit registered a gradual increase in phenolics compounds with prolongation in cold storage period (Massolo *et al* 2011). Gago *et al* (2015) demonstrated the effect of harvest date and 1-MCP on apple cv. ‘Golden Delicious’ and observed that 1-MCP did not affect the total phenol content during initial phase of cold storage, however, treated fruits registered a decline in total phenol content with further prolongation in cold storage period. The postharvest application of 1-MCP registered a gradual increase in total phenol content in pear fruit as compared to control at the end of cold storage (Arias *et al* 2009). Singh and Singh (2012) reported that postharvest application of 1-MCP initially did not influence the total phenol concentration in plum fruit but registered a decline with further prolongation in cold storage period. Medlar fruits subjected to 1-MCP treatment registered the maximum content of total phenol (662.82 mg GAE $100g^{-1}$ FW) content in contrast to control (561.01 mg GAE $100g^{-1}$ FW).

Fruits of plum subjected to pre-harvest application of MeJA registered higher total phenolics content than those of control fruit during storage (Zapata *et al* 2014). Amanullah *et al* (2017) evaluated the post-harvest effect of SA on storage life and quality of guava and found that fruits subjected to SA registered the maximum total phenol content (304.82 μgmL^{-1} FW) as compared to control (262.4182 μgmL^{-1} FW) fruit during cold storage. Khademi and Ersadi (2013) reported that postharvest application of SA registered higher phenolics content

(120.67 mg GAE $100g^{-1}$) in peach as compared to control (82.83 mg GAE $100g^{-1}$) after 42 days of storage. Davarynejad *et al* (2015) reported that combined application of putrescine and SA maintained the higher total phenolics content as compared to control fruit during storage. Park *et al* (2015) reported that kiwifruit cv. 'Hayward' subjected to 1-MCP treatment registered the maximum total phenol concentration (24.3±0.3 mg GAE/100 g FW) over control fruits during cold storage. The level of total phenolics decreased in all the fruit regardless of the treatment. However, fruit of eggplant subjected to MeJA maintained higher content of total phenols than those of control at the end of the cold storage (Fan *et al* 2016).

Fruits of mango cv. 'Alphonso' and 'Banganapalli' registered higher content of total phenols under unwrapped conditions (Rao and Shivshankara 2015). Rana *et al* (2015) studied the effect of cling and shrink films packaging on guava fruit and found a gradual decline in total phenol content with prolongation in storage. However, control fruit registered the highest reduction in total phenolics (12.8 mg/100 g) content in contrast to wrapped fruit (24-28 mg/100 g) at the end of storage. Mangaraj *et al* (2012) evaluated the effect of modified atmospheric packaging on litchi fruit and registered a declining trend in total phenolics content during storage. However, the rate of decline was found to behighest in CS-UT, in comparison to the treatment with MAP alone. The increase in total phenolics was delayed with the use of MAP, especially for fruits of cherry cv. Cornelian wrapped in LDPE and PP polymeric films (LDPE and PP), while air LDPE showed the lowest total phenolics accumulation (Mohebbi *et al* 2015).

2.4.9 Total Carotenoids

Saberi *et al* (2018) reported that commercial wax coating preserved total carotenoids content in sweet orange cv. 'Valencia' during storage. The reason of instability and subsequent reduction of carotenoids is because of the vulnerability to oxidation and geometric isomerization of its polyene chain during storage (Sanchez-Moreno *et al* 2003). Ethylene causes the loss of chlorophylls, produces some minor changes in carotenoids, induces carotenoid synthesis and thus has the potential to re-establish the orange colors (El-Zeftawi and Garrett, 1978). Ali *et al* (2013) reported that gum arabic (10%) coating maintained the higher amount of total carotenoids by delaying ripening and respiration process in tomato fruit. Gol *et al* (2015) reported that alginate (1.5%) exhibited maximum (16.48 μg/g) amount of carotenoids while slower carotenoids accumulation was noticed in gum arabic (1 %) and chitosan (0.3%) coated carambola fruit. Li and Barth (1998) reported that edible coating retained the maximum (50%) carotene content over control (33%) in carrot at the end of the storage. Samra *et al* (2014) evaluated the postharvest application of CMC, chitosan and beeswax and registered the maximum carotenoids content in tangor fruit cv. 'Murcott' at the end of storage. Mohamed *et al* (2013) who reported that edible coatings increased the total carotenoids in "Prickly pear" during nine days of storage period and that may be due to that edible coatings serve as carriers of antioxidants and texture enhancers and nutraceuticals which help in decreasing the water vapor and oxygen gas transfer, resulting in the diminished respiration rate and ethylene production (Rojas-Grau *et al* 2008). Ambarsari *et al* (2017) studied the post-harvest effect of cassava starch coating and registered no significant change in carotene content in tomatoes during storage. The post-harvest application of citrashine coating registered the maximum mean carotene content (0.56%) followed by terpenoidal oligomer (0.54 mg %) in Kinnow fruit, whereas the lowest mean carotene content (0.48 mg %) was recorded in control fruit (Mahajan and Singh 2014). Gol and Rao (2013) observed that zein (5%), gelatin (5%) and gelatin (10%) registered delayed carotenoid accumulation in mango fruit whereas uncoated fruit followed a gradual increase in carotenoid content throughout the storage.

Boonyaritthongchai *et al* (2017) reported that fruits of mango cv. Nom Dok Mai subjected to MeJA retained the maximum carotene content over control fruits after 15 days of storage. Sun *et al* (2012) reported that the post harvest application of 1-MCP retained the higher content of total catotenoids in Chinese Kale during storage. Similar findings were also reported in broccoli (Fernandez-Leon *et al* 2013). Pre-harvest application of SA maintained the highest carotene content in the navel orange cv. 'Cara Cara' after 105 days of storage (Huang *et al* 2008).

Total carotenoid content in mango cv. 'Alphonso' and 'Banganapalli' at harvest were 300 and 230 μg/100 g, respectively and increased to 1,671 and 1,049 μg/100 g, respectively when wrapped in shrink film (D-955 film) whereas in non-wrapped fruit, the carotenoids increased to only 1,363 and 614 μg/100 g in these cultivars, respectively.indicated the suppression of the normal ripening process due to CI (Rao and Shivshankara 2015). Ruth *et al* (2014) reported that unpacked fruits registered higher content of carotene than those of ordinary and active bag modified atmospheric packed mango fruit at the end of storage. Kudachikar *et al* (2011) studied the effect of modified atmospheric packaging on quality and shelf-life of banana cv. Robusta and found that control fruit accumulated the higher carotenoid content than those of packed in various packaging material. Mahajan and Singh (2014) reported that shrink wrapped Kinnow fruit showed gradual and steady increase in carotene content (0.63%) up to 15 days of storage whereas, in control fruits carotene content increased (0.54%) only up to 10 days of storage and thereafter declined at faster pace with further prolongation in storage period.

2.4.10 Pectin (Calcium pectate %)

The degree of fruit ripeness particularly affected the pectin contents, which supports the hypothesis that softening is closely related to pectin solubilisation and depolymerization (Kurz *et al* 2008 and Rosli *et al* 2004). Jongsri *et al* (2017) reported that combined application of chitosan (1%) and spermidine (0.1 mgL^{-1}) registered lower soluble pectin content in mango cv. 'Nam Dok Mai' than that of control. Chen *et al* (2011) evaluated the effect of $CaCl_2$ and observed that water soluble (WSP), chelate soluble (CSP) pectin did not change as distintly as did sodium carbonate soluble pectin (SSP) in strawberry during cold storage. Samra *et al* (2014) reported that the highest pectic substances in peel and edible portion of Murcott tangor was registered in uncoated fruit over fruit those were coated with CMC, chitosan and bees wax; this might be due to the role of edible coatings in reducing moisture loss and respiratory activity and thus maintained the turgidity of the cells (Ribeiro *et al* 2007 and Adetunji *et al* 2012).

Neem oil (1.5–2.0%) treatment retained maximum pectin (1.3%) content in apple during storage (Wijewardane and Guleria 2013). Fruit of strawberry subjected to MeJA registered the higher calcium pectate content than control fruit after 12 days of cold storage (Geransayeh *et al* 2015).

Starch coating and OPP-Coex-film packaging (Antifog film) led to a higher content of soluble pectins in comparison to the control in radish (Schreiner *et al* (2003). Mohammed *et al* (1996) reported that fruit of 'sapota' wrapped in LDPE films registered higher insoluble pectin content over those wrapped in shrink film and control. Similar findings were reported in apple (Tavakoli and Wiley 1968).

2.4.11 Pectin methylesterase (PME)

Gol *et al* (2013) evaluated the post-harvest application of CMC, HPMC and their combinations with chitosan coatings and found that HPMC (1%) + CH (1%) coating registered the maximum influence in terms of restriction of PME activity in strawberry fruit at the end of storage. Pectins are the main constituents of the middle lamella and primary cell wall of the fruit, and are hydrolyzed by PME to generate demethylated pectins that can be more easily hydrolyzed by PG and thus causing the depolymerization of pectins (Zhou *et al* 2011); might be due to the relatively lower activities of PME in the coated strawberry fruit contributed to the enhanced retention of brittleness and firmness during storage. Kumar *et al* (2017) demonstrated the post-harvest effect of chitosan on shelf-life and quality of plums and found that the activity of PME in the chitosan coated and non coated plum increased continuously during the storage. However, PME activity for chitosan coated fruit was significantly lower than those of uncoated ones; this might be due to chitosan coating formed a physical barrier around the fruit leading to depletion of oxygen and subsequently decrease in the enzyme activity. Inhibition of carbon dioxide production in chitosan-coated fruit due to suppressed respiration rate during storage can be one of the factors for reduced PME activity in coated fruit (Liu *et al* 2014). Gol *et al* (2015) studied the effect of chitosan, gum arabic and alginate coatings on shelf-life and quality of carambola fruit and found that chitosan (0.35) coating exhibited the lowest PME activity among all other coating treatments. Gonzalez-

Aguilar *et al* (2009) who recorded that the fresh- cut papaya fruit coated with chitosan registered reduced PME activity as compared to the control.

Zhu *et al* (2015) demonstrated the combined effect of 1-MCP and ethylene on banana fruit and found that fruit subjected to 1-MCP treatment registered lower activity of PME with prolongation in storage period. Venkatachalam and Meenune (2015) reported that longkong fruit subjected to MeJA registered the minimum PME activity during storage. Majeed and Jawandha (2016) reported that fruit of 'plum' subjected to salicylic acid treatment registered the lowest PME activity as compared to control fruits after 40 days of storage.

Mahajan *et al* (2015) demonstrated the effect of various packaging films and found that the packaging films influenced the PME activity in peach fruit; this might be attributed to the difference in gaseous conditions generated inside the packages. Kaur *et al* (2014) reported that unwrapped pear fruit registered the maximum PME activity than those of wrapped fruit in different packaging films with an advancement in storage period.

2.4.12 Cellulase

Wang and Gao (2013) evaluated the effect of chitosan based edible coatings on antioxidant enzyme system and found that chitosan treatment registered the higher activity of cellulase in strawberries which reinforced the microbial defense mechanism of the fruit and accentuated the resistance against fungal invasion. Gol *et al* (2013) demonstrated the effect of CMC, HPMC and chitosan and found that combined application of HPMC (1%) + chitosan (1%) and CMC (1%) + chitosan (1%) registered the lowest cellulase activity in strawberry fruit after 12 days of storage. Fruit of pear coated with edible coatings registered inhibition of cellulase activity (Zhou *et al* 2011). Chitosan has the ability to inactivate or inhibit activity of several enzymes which cause deterioration of fruit and vegetables (Bhaskar-Reddy *et al* 2000).

Zhu *et al* (2015) reported that 1-MCP treatment in banana fruit followed slow but steady increase in cellulase activity, while control fruits initially registered a sudden increase thereafter followed a sharp decline in cellulase activity during storage. The similar findings were also reported in avocado fruit (Jeong *et al* 2002).

Fruit of plum cv 'Tegan blue' stored in MAP alone also showed reduction in the activities of exo-PG, endo-PG, PE, and EGase enzymes as compared with control fruit (Khan and Singh 2008). Similar findings were reported in nacterine (Ozkayaa *et al* 2016) pears (Ortiz *et al* 2011 and Pedreschi *et al* 2008) and papaya (Lazan *et al* 1993).

From the review it can be concluded that literature pertaining to effect of different edible coatings, anti-senescence compounds and packaging materials is limited on non-climacteric fruits. Furthermore, investigations are require to study the effect of different edible coatings, anti-senescence compounds and packaging materials in these crops.

CHAPTER III

MATERIALS AND METHODS

The present investigation entitled, "Effect of postharvest treatments and packagings on storage life and quality of Kinnow fruit" was conducted in the Department of Fruit Science, Punjab Agricultural University, Ludhiana during the years of 2016-17 and 2017-18. The details of analytical techniques adopted and materials used in the present investigation are described in this chapter are as under:

3.1 Selection of Plant Material

The storage studies were conducted using Kinnow fruits harvested at optimum maturity in the month of January. The experimental fruits were obtained from uniform and healthy plants selected and maintained under recommended cultural practices at Regional Fruit Research Station, Abohar (30^{o}55'N, 54^{o}30'E) (Anonymous 2017-18).

Uniform sized, disease and bruise free Kinnow fruit were harvested from all four directions of the plants with the help of clipper by retaining a small button of the stalk. The fruits were packed in cushioned crated and transported to the Postharvest laboratory of Department of Fruit Science, PAU, Ludhiana. The fruits were sorted, graded and washed with chlorine solution (100 mgL^{-1}). Thereafter fruit were divided into requisite lots (50 kg per treatment) for further handling.

3.2 Experiment1:

3.2.1 Title :Effect of edible coating on storage life and quality of Kinnow fruit

3.2.2 Treatment Details

S. No	Treatment	Concentration
T_1	Carboxy Methyl Cellulose (CMC)	1%
T_2	Carboxy Methyl Cellulose (CMC)	1.5%
T_3	Carboxy Methyl Cellulose (CMC)	2%
T_4	Chitosan	0.5%
T_5	Chitosan	1%
T_6	Chitosan	1.5%
T_7	Bees Wax	5%
T_8	Bees Wax	10%
T_9	Bees Wax	15%
T_{10}	Control	Water

3.2.3 Methodology

The kinnow fruits were coated with either chitosan (Sigma-Aldrich Corp (St. Louis, MO, USA), CMC (BDH Limited Poole, England) or Bees wax (Grade 1, Fomesa Fruitech S.L., Valencia, Spain). For coating a piece of foam pad was drenched with respective coating material and applied gently on the surface of fruits. Thereafter fruits were air dried, packed in corrugated fiber boxes (CFB) of two kg capacity and kept inside cold rooms maintained at 5-7^{0}C and 90-95% RH for 75 days.

3.3 Experiment2

3.3.1 Title : Effect of anti-senescence compounds on storage life and quality of Kinnow fruit

3.3.2 Treatment Details

S. No	Treatment	Concentration
T_1	1-Methylcyclopropene (1-MCP)	500 ppb
T_2	1-Methylcyclopropene (1-MCP)	1000 ppb
T_3	1-Methylcyclopropene (1-MCP)	1500 ppb
T_4	Methyl jasmonates	1mM
T_5	Methyl jasmonates	2mM
T_6	Methyl jasmonates	3mM
T_7	Salicylic acid	1mM
T_8	Salicylic acid	2mM
T_9	Salicylic acid	3mM
T_{10}	Control	Water

3.3.3Methodology

Selected fruits were treated with different anti-senescence compounds. For 1-MCP (Smartfresh^{TM} Agrofresh Inc., Rohm and Haas, SpringHouse, PA, USA) treatment, fruits were exposed to gaseous vapours of 1-MCP in an air tight chamber maintained at 20^{0}C for 24 hours. For treatment with MeJA, Kinnow fruits were allowed to dip inside an emulsion of MeJA (Sigma Aldrich, Germany) and tween-20 (0.05%) for 5 minutes at room temperature. For treatment with SA (Sigma Aldrich, Germany), Kinnow fruit were dipped in solution for 5 minutes followed by complete drying at room temperature thereafter were packed in corrugated fibre boxes (CFB) of two Kg capacity and kept inside cold rooms maintained at 5-7^{0}C and 90-95% RH for 75 days.

3.4 Experiment 3

3.4.1 Title: Effect of different packaging materials on storage life and quality of Kinnow fruit

3.4.2 Treatment details

S. No	Treatment	Thickness
T_1	Polypropylene (PP)	100 gauge
T_2	Polypropylene (PP)	150 gauge
T_3	Polypropylene (PP)	100 gauge (5% perforation)
T_4	Polypropylene (PP)	150 gauge (5% perforation)
T_5	Low Density Polyethylene (LDPE)	100 gauge
T_6	Low Density Polyethylene (LDPE)	150 gauge
T_7	Low Density Polyethylene (LDPE)	100 gauge (5% perforation)
T_8	Low Density Polyethylene (LDPE)	150 gauge (5% perforation)
T_9	Control	Unpacked

3.4.3Methodology

The experimental fruit were packed inside each individual packging material *i.e* low density polyethylene (Model LD, Sol Pack system) and polypropylene (Model PP, Sol Pack Syestem). Each packaging material was labelled before sealing it with sealing machine and kept inside cold rooms maintained at 5-7^{o}C and 90-95% RH for 75 days.

3.5 Observations recorded

The freshly harvested fruits were analyzed for zero day data. Periodically stored fruits samples were taken out from the cold storage at 30, 45, 60 and 75 days after cold storage and analyzed for various physico-chemical attributes. For all three experiments, three replications and 15 fruits/replication were taken to assess various physical, biochemical and enzymatic assays under cold storage studies.

3.5.1 Physiological loss in weight (%)

On the basis of initial fruit weight, loss in physiological weight (PLW) of fruit was calculated. At the end of each storage interval the weight of the fruit was estimated and per cent loss in physiological weight was calculated by estimating both final weight and initial weight of fruit as per formula given below:

$$\text{Physiological loss in weight (PLW \%)} = \frac{\text{Initial fruit wt.} - \text{final fruit wt.}}{\text{Initial fruit weight}} \times 100$$

3.5.2 Spoilage (%)

Per cent fruit rot was calculated by counting the total number fruits that had rotten at each storage interval. The spoilage (%) was calculated as follows:

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

3.5.3 Organoleptic Sensory attributes (Hedonic scale 1-9)

The fruit were rated for this character by a panel of ten judges on the basis of external appearance of fruit, texture, taste and flavor. A nine point ‘ Hedonic Scale’ described by Amerine *et al* (1965) was used for its inference, as given below:

Score	**Acceptability**
9	Extremely desirable
8	Very much desirable
7	Moderately desirable
6	Slightly desirable
5	Neither desirable nor undesirable
4	Slightly undesirable
3	Moderately undesirable
2	Very much undesirable
1	Extreamly undesirable

3.5.4 Firmness (Kg Force)

Firmness of randomly selected fruit (15 from each replication) was measured with the help of a ‘Penetrometer’ (Tr di turonil Co. Snc. Italy). Fruit were firmly held in the left hand; by holding the fruit tester between thumb and forefinger of right hand, place the plunger (with diameter 7.9 mm) against the fruit press with increasing strength until the plunger tip is penetrated into the Kinnow fruit up to the notch to obtain uniform application of force was recorded in terms Kg force (Kg f).

3.5.5 Juice (%)

The fruit juice was extracted with the help of screw type extractor and was strained through mesh (32 mm) and weighed. The percentage of juice was calculated on fresh weight basis.

$$\text{Juice percentage} = \frac{\text{Juice weight}}{\text{Weight of fruit}} \times 100$$

3.6 Biochemical parameters

3.6.1 Total soluble solids (%)

Total soluble solids (TSS) were determined with the help of Erna Hand Refractometer, Japan and expressed in per cent with the help of temperature correction chart at 20^0C (AOAC 2005).

3.6.2 Reducing sugars (%)

To determine the reducing sugars, the aliquot was titrated against boiling solution mixture containing 5 ml of each Fehling solution A and B using methylene blue as indicator. Titration was continued until appearance of brick red color. The results were expressed in percentage (AOAC 2005).

3.6.3 Total sugars (%)

Total sugars were estimated by taking 25 ml of above filtrate in 100 ml volumetric flask. To this solution 5 ml of 60% HCL and 25 ml distilled water was added and allowed to stand overnight for hydrolysis. The excess HCL was neutralized with saturated NaOH solution and volume was made up to 100 ml with distilled water. Total sugars were then estimated by titrating the boiling mixture containing 5 ml of each of Fehling A and B against hydrolyzed aliquot, using methylene blue as an indicator. The unloading of titration was stopped on the appearance of brick red colour. The obtained results were expressed in percentage (AOAC 2005).

3.6.4 Vitamin C (mg/100g)

Ascorbic acid content of the fruit flesh was estimated using 2, 6-dichlorophenol indophenols dye (DCPIP) visual titration method (Ranganna 1994).

Standardization of Dye: 25 mg of the standard ascorbic acid was dissolved in 100 ml oxalic acid (0.4%). This was titrated with 0.04% DCPIP dye solution to the pink colour, which persistedfor 15 sec. Dye factor is determined by the formula:

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

Estimation: To 10 ml of each sample, 90ml of 0.4% oxalic acid was added. Out of this prepared sample, 10 ml was taken and titrated against 0.04% DCPIP dye solution till the pink end point obtained which persisted for at least 15sec. The results were expressed in mg/100g of sample (AOAC 2005).

$$\text{Vitamin C} = \frac{\text{titre x volume made x dye factor x 100}}{\text{wt. of sample x aliquot made}}$$

3.6.5 Total carotenoids (mg/100g)

Total carotenoids was determined as described by Gao and Wu (2005). Fruit juice was pulverized in glass mortar, 2 ml of fruit juice was taken in a 25 ml test tube then 7ml solution (petroleum ether : acetone, 1:1) was added , with shaking (100rpm) test tube was soaked in dark for 6 hours. Then absorbance was measured at 445 nm by discarding the lower layer of extract. Carotenoid content was estimated by using following formula.

$$\text{Total carotenoids (mg/100g)} = \frac{A.y(ml) \times 10^{6}}{A^{\%}_{1cm} \times 1000 \times g}$$

A- The highest absorbency value of 445nm

y - Quantity of extracting solution

$A^{\%}_{1\,cm}$- Average absorption coefficient 2500 of carotenoid molecule

g- Weight of sample

3.6.6 Pectin (Ca pectate %)

For estimation of pectin content 50 g of sample was taken in 1 litre beaker and 400 ml distilled water was added to it. Boiled the content for 1 hour at slow heat while maintaining the level of water by addition of extra distilled water. Then cooled the content and made volume to 500 ml with distilled water in volumetric flask. Filtered through Whatman's filter paper no. 4 and 100 ml filtrate was taken from filtrated in 1 litre beaker, 300 ml distilled water was added to it. After this added 10 ml N NaOH, mixed and allowed it to stand overnight Next day added 50 ml 1 N acetic acid, mixed well and allowed it to stand for 5 minutes. Added 25 ml 1 N $CaCl_2$ solution, stirred and allowed it to stand for 1 hour. Boiled the content for 1 minute, precipitated of calcium pectate was formed. Filterated the precipitate through Whatman's filter no. 41 which was previously washed with hot water and dried in oven at 100◦ C for 2 hour to constant weight and weighed in a covered dish. After this, washed the precipitate repeatedly with hot water to make it chloride free. Dried the precipitate on filter paper in oven at $100^{\circ C}$ to constant weight and placed it overnight. Then, placed the filter paper containing precipitate in covered moisture dish and cooled it in dessicator and then weight of precipitate (wt. of filter paper + dish + wt. of precipitate – wt. of filter paper + dish). The reading was expressed as per cent of calcium pectate per 100 g of sample (Ruck 1961).

3.6.7 Total phenols (mg/100g)

Total phenols were determined by Folin-Ciocalteu (FC) reagent as described by Bray and Thorpe (1954). FC reagent was diluted to 1N with 2 volumes of distilled water before use. 2 ml of fresh fruit juice was macerated with 10 ml of ethanol (80%) and filtered through muslin cloth. The residue was washed with 5 ml of ethanol (80%). 0.2 ml of the filtrate was taken in 25 ml test tube and 1ml of FC reagent (1N) was added followed by 2 ml of sodium carbonate

(20%). The contents were thoroughly shaken and heated for 1 minute in boiling water to evaporate the ethanol bath for 1 minute and then test tubes were cooled under running tap water. After incubating test tubes at room temperature for 30 minutes the absorbance was recorded at 650 nm by adjusting blank to zero. Total phenols were calculated against a standard curve of gallic acid. The results were expressed as mg total phenols per 100 g pulp.

3.7 Enzymatic parameters

3.7.1 Pectin Methyl Esterase (PME)

Enzyme extraction: For enzyme extraction, 10 ml fruit juice of Kinnow was blended in 60–100 ml 0.15M NaCl solution, filtered through two layers of cheese-cloth, centrifuged at 2,000 *g* for 30 min at 4°C. The pH of the medium was constantly maintained at 7.0 for 0.15 M of NaCl solution to get maximum PME activity as previously detailed by Castaldo *et al* (1989) and Denes *et al* (2000) as there is a direct correlation between pH and salt concentration used. The supernatant was used as an enzyme source.

Enzyme assay:

For PME essay 10 ml of the per cent solution was taken in 50 ml beaker, pH was adjusted to 7.0 by adding 0.02N NaOH. This was the zero time. Then, the beaker was placed in a water bath at 30 °C for 15 min and pH was checked and adjusted up to 7.0 after every 15 min by using 0.02 N NaOH, while stirring the contents and noted the volume of NaOH used at each interval (Mahadevan and Sridhar 1982).

Pectin methyl esterase activity was expressed as units/ml juice. One unit is defined as the amount of PME required to hydrolyze 1 milli equivalent of ester per min per ml of juice.

3.7.2 Cellulase (mg glucose^{-1} mg protein^{-1})

Enzyme extraction: Fruit juice (2 ml) was obtained and homogenized in 20 mL of sodium citrate buffer (0.05 mM, pH 4.8). The homogenate was filtered and centrifuged at 15,000×g for 30 min at 4^{0}C in a refrigerated centrifuge (Model: EPPENDORF, 5430R). The clear supernatant was used as enzyme extracts for assaying cellulase enzyme activity (Denison and Koehn 1977).

Enzyme assay: Cellulase activity was measured by following the method of (Denison and Koehn 1977). 0.5 ml of enzyme extract was added in test tube containing 0.5 ml of substrate (CMC 2%). The mixture was incubated at 55^{o}C for 20 minutes. 3ml of DNS reagent was added and heated in a boiling water bath for 5 min. 0.1 ml of 40% potassium sodium tarterate was added and make the volume 5 ml with distilled water. The absorbance was recorded at 540 nm. The enzyme activity expressed in international units (IU) or mg glucose released per min^{-1} mg of protein^{-1}.

3.8 Statistical Analysis

The results obtained during both the years of study (2016-17 and 2017-18) and pooled data of both the years were subjected to analysis of variance. The treatment means were compared using the least significant difference (LSD) values at a significance level of $P < 0.05$. The data are analyzed statistically according to two way ANOVA using procedures of the Statistical Analysis System 9.3 (S.A.S. Institute Inc., Cary, NC, USA).

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted to investigate the "Effect of post-harvest treatments and packaging on storage-life and quality of Kinnow fruit" at the Department of Fruit Science, Punjab Agricultural University, Ludhiana during the year 2016-17 and 2017-18. The results obtained from the laboratory studies are presented and discussed in the light of available literature as follows:

4.1 Effect of edible coatings on physical, biochemical and enzymatic parameters of Kinnow fruit

4.1.1 Physiological loss in weight (%)

The data pertaining to the effect of edible coatings on physiological loss in weight (PLW) of Kinnow fruits kept under cold storage, during 2016-17 and 2017-18 revealed that there was significant difference among the treatments with regard to PLW during both the years of study (Table 1). The per cent PLW, in general increased with the advancement of storage period rather slowly in the beginning but at a faster pace as the storage period advanced. In 2016-17, CMC 2 per cent coated fruits registered the lowest average PLW (2.98%) followed by CMC 1.5 per cent concentration (3.29%). However, the control fruits showed the highest mean PLW (7.57%). The PLW in CMC (2 and 1.5 %) coated fruits ranged from 1.68 to 6.35 and 1.43 to 7.88 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits registered the highest PLW ranged between 4.66 to 15.55 per cent from 30 days to 75 days of storage. Similar trend was also noticed in 2017-18 where, CMC 1.5 per cent was found statistically at par with CMC 2 per cent and emerged as second best in terms of reducing the PLW. The average minimum PLW (2.68%) was noticed in fruits coated with CMC 2 per cent followed by its 1.5 per cent concentration (2.91 %) whereas, the control fruits registered the highest average weight loss (6.43%). The PLW in CMC (2 and 1.5%) coated fruits ranged from 1.65 to 5.41 and 1.23 to 6.65 per cent, respectively from 30 days to 75 days of storage as compared to control fruits where, PLW was found to be the highest and ranged from 4.06 to 12.49 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed thorugh the pooled analysis of both years (Table 1a and Fig 1). CMC 2 per cent proved best in terms of reducing the loss in physiological weight (2.94%) followed by its 1.5 concentration (2.98%). However, control fruits registered the maximum meanPLW (7.00%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.The increase in PLW of fruits during storage might be due to transpiration and respiration thereby leading to higher physiological loss in weight (Robertson *et al* 1990). The reduced PLW in wax coated fruits might be due to role of waxes in slowing down the

Table 1: Effect of edible coatings and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

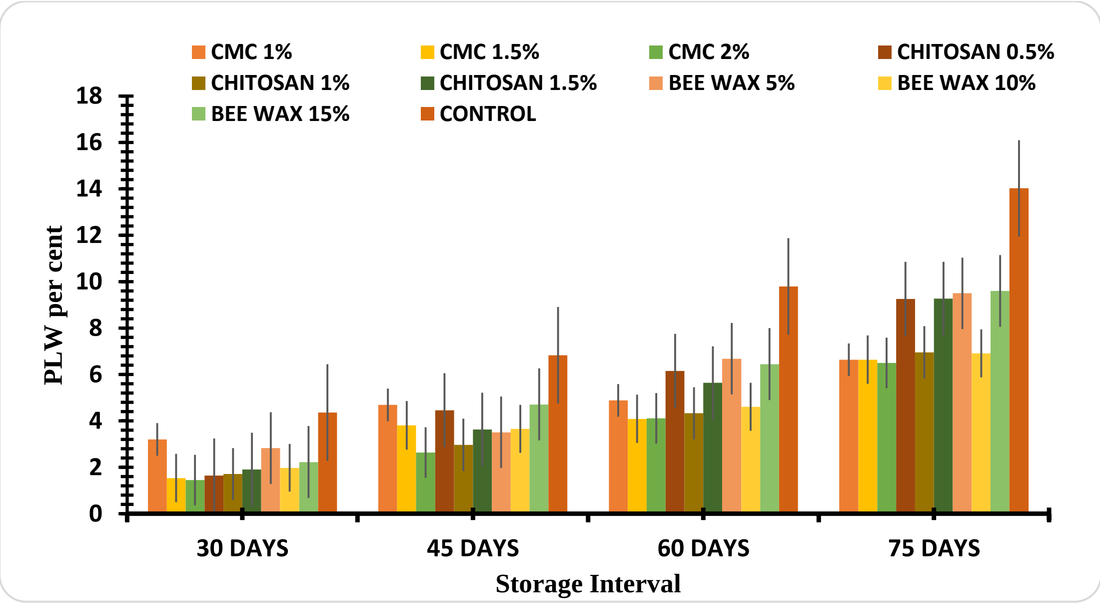
TREATMENT		Physiological loss in weight (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	**1%**	0.00	1.83	4.95	5.12	7.09	**3.80[e]**	0.00	1.55	4.42	4.65	6.19	**3.36[e]**
	1.5%	0.00	1.43	2.94	4.19	7.88	**3.29[f]**	0.00	1.23	2.71	3.94	6.65	**2.91[fg]**
	2%	0.00	1.68	2.58	4.28	6.35	**2.98[g]**	0.00	1.65	2.35	4.00	5.41	**2.68[g]**
Chitosan	**0.5%**	0.00	2.00	4.23	5.79	9.39	**4.28[d]**	0.00	1.31	4.70	6.53	9.14	**4.33[c]**
	1%	0.00	1.58	2.96	4.54	7.73	**3.36[f]**	0.00	1.83	2.98	4.13	6.19	**3.03[f]**
	1.5%	0.00	1.99	4.23	5.77	9.58	**4.23[d]**	0.00	1.84	3.45	5.52	8.97	**3.95[d]**
Bee wax	**5%**	0.00	3.61	5.73	6.80	9.82	**5.19[b]**	0.00	3.41	5.51	6.56	9.19	**4.93[b]**
	10%	0.00	2.11	3.81	4.87	7.83	**3.72[e]**	0.00	1.86	3.52	4.35	6.00	**3.14[ef]**
	15%	0.00	1.71	4.91	6.88	10.41	**4.78[c]**	0.00	2.76	2.35	4.52	8.79	**4.42[c]**
Control		0.00	4.66	7.22	10.44	15.55	**7.57[a]**	0.00	4.06	6.44	9.15	12.49	**6.43[a]**
Mean		**0.00[e]**	**2.26[d]**	**4.31[c]**	**5.87[b]**	**9.16[a]**		**0.00[e]**	**2.15[d]**	**4.06[c]**	**5.48[b]**	**7.90[a]**	
LSD (P≤0.05)		**Treatment (T)** = 0.24 **Days (D)** = 0.17 **D x T** = 0.53						**Treatment (T)** = 0.29 **Days (D)** = 0.20 **D x T** = 0.64					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 1a: Effect of different edible coatings and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Physiological loss in weight (%)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.00	3.21	4.69	4.88	6.64	**3.58^{e}**
	1.5%	0.00	1.54	3.81	4.09	6.64	**2.98^{g}**
	2%	0.00	1.45	2.64	4.11	6.50	**2.94^{g}**
Chitosan	**0.5%**	0.00	1.65	4.46	6.16	9.26	**4.31^{d}**
	1%	0.00	1.71	2.97	4.33	6.96	**3.19^{fg}**
	1.5%	0.00	1.91	3.63	5.64	9.27	**4.09^{d}**
Bee Wax	**5%**	0.00	2.83	3.51	6.68	9.50	**5.06^{b}**
	10%	0.00	1.98	3.66	4.61	6.91	**3.43^{ef}**
	15%	0.00	2.23	4.71	6.45	9.60	**4.60^{c}**
Control		0.00	4.36	6.83	9.79	14.02	**7.00^{a}**
Mean		**0.00^{e}**	**2.20^{d}**	**4.19^{c}**	**5.68^{b}**	**8.53^{a}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.26 **Days (D)** = 0.18 **D x T** = 0.58					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.1: Effect of different edible coatings and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

respiratory activity of fruits because we have used modified atmosphere storage conditions. The post-harvest application of CMC reduced weight loss in Kinnow (Shah *et al* 2015) Mandarin (Arnon *et al* 2014) tangor (Samra *et al* 2014) sweet oranges (Zeng *et al* 2013) acid lime (Bisen *et al* 2012) strawberry (Dong and Wang 2017) and avocado (Tesfay and Magwazza 2017).

4.1.2 Spoilage (%)

All the treatments registered significant decrease in the average cumulative spoilage per cent as compared to control (Table 2). In 2016-17, the lowest average spoilage (1.67 %) was recorded in fruits coated with CMC 2 per cent and 1.5 per cent concentration (1.67 %). However, highest average spoilage (18.33 %) was observed in control fruits. The spoilage percentage in CMC (2 and 1.5%) ranged from 0 to 8.33 per cent from 30 days to 75 days of storage as compared to control where it was ranged from 0 to 50 per cent from 30 days to 75 days of storage. Similar results were obtained during 2017-18, however, interestigaly, till the end of the storage; no spoilage was registered in the fruits coated with both CMC 2 per cent and 1.5 per cent, whereas, the control fruits registered the maximum mean decay (10.00%) and ranged 0 to 33.33 per cent from 30 days to 75 days of storage. Overall, during both the season of investigation, the effectiveness in lowest spoilage per cent among all the treatments followed as: CMC (2%) > CMC (1.5%) > chitosan (1%) > bees-wax (10%). The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were further confirmed through pooled mean analysis of both the years (Table 2a and Fig 2). CMC 2 per cent and 1.5 per cent registered the lowest (0.83%) spoilage percentage in contrast to control (14.16%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.Interestingly, In the present study, a concomitant increase in fruit spoilage was noticed at faster rate with lowest concentration of all coating treatments which might be due to the fact that coatings can suspend decay by delaying senescence, which causes more susceptibility to pathogenic infection in produce due to damage of cellular or tissue integrity (Tanada-Palmu and Grosso 2005). Coatings have been reported to reduce PLW thereby delayed senescence of fruits and thus minimized the decay.

The post harvest application of CMC checked the growth of microorganisms and delayed the spoilage in case of Kinnow fruit (Shah *et al* 2015), oranges (Zeng *et al* 2013) strawberry (Dang and Wang 2017 and Gol *et al* 2013). Chitosan reduced the spoilage and microbial growth in strawberry (Wang and Gao2013 and Perdones *et al* 2012), blueberry (Duan *et al* 2011) and mango (Silva *et al* 2017 and Abbasi *et al* 2009). Faygenberg *et al* (2005) observed that bees wax and carnauba coated avocado and mango fruits registered reduced chilling injury symptoms and decay incidence during storage.

Table 2: Effect of different edible coatings and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

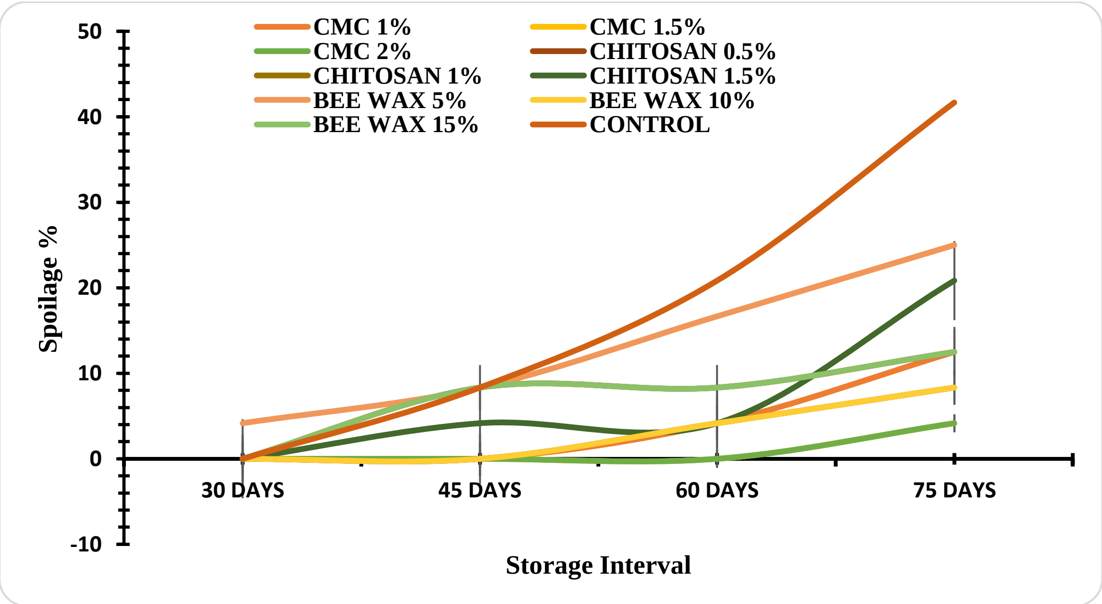
TREATMENT		Spoilage (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	1%	0.00	0.00	0.00	8.33	16.66	**5.00[d]**	0.00	0.00	0.00	0.00	8.33	**1.67[c]**
	1.5%	0.00	0.00	0.00	0.00	8.33	**1.67[f]**	0.00	0.00	0.00	0.00	0.00	**0.00[d]**
	2%	0.00	0.00	0.00	0.00	8.33	**1.67[f]**	0.00	0.00	0.00	0.00	0.00	**0.00[d]**
Chitosan	0.5%	0.00	0.00	8.33	8.33	16.66	**6.66[c]**	0.00	0.00	8.33	8.33	8.33	**5.00[b]**
	1%	0.00	0.00	0.00	8.33	8.33	**3.33[3]**	0.00	0.00	0.00	0.00	8.33	**1.67[c]**
	1.5%	0.00	0.00	8.33	8.33	16.66	**6.66[c]**	0.00	0.00	0.00	0.00	25.00	**5.00[b]**
Bee wax	5%	0.00	0.00	8.33	16.66	33.33	**11.66[b]**	0.00	8.33	8.33	16.66	16.66	**10.00[a]**
	10%	0.00	0.00	0.00	8.33	8.33	**3.33[e]**	0.00	0.00	0.00	0.00	8.33	**1.67[c]**
	15%	0.00	0.00	8.33	8.33	16.66	**6.66[c]**	0.00	0.00	8.33	8.33	8.33	**5.00[b]**
Control		0.00	0.00	16.66	25.00	50.00	**18.33[a]**	0.00	0.00	0.00	16.66	33.33	**10.00[a]**
Mean		**0.00[d]**	**0.00[d]**	**5.00[c]**	**9.16[b]**	**18.33[a]**		**0.00[e]**	**0.83[d]**	**2.50[c]**	**5.00[b]**	**11.66[a]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.76 **Days (D)** = 0.54 **D x T** = 1.70						**Treatment (T)** = 0.49 **Days (D)** = 0.35 **D x T** = 1.11					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 2a: Effect of different edible coatings and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Spoilage (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.00	0.00	0.00	4.16	12.49	**3.33[d]**
	1.5%	0.00	0.00	0.00	0.00	4.16	**0.83[e]**
	2%	0.00	0.00	0.00	0.00	4.16	**0.83[e]**
Chitosan	**0.5%**	0.00	0.00	8.33	8.33	12.49	**5.83[c]**
	1%	0.00	0.00	0.00	4.16	8.33	**2.50[d]**
	1.5%	0.00	0.00	4.16	4.16	20.83	**5.83[c]**
Bee Wax	**5%**	0.00	4.16	8.33	16.66	24.99	**10.83[b]**
	10%	0.00	0.00	0.00	4.16	8.33	**2.50[d]**
	15%	0.00	0.00	8.33	8.33	12.49	**5.83[c]**
Control		0.00	0.00	8.33	20.83	41.66	**14.16[a]**
Mean		**0.00[d]**	**0.42[d]**	**3.75[c]**	**7.08[b]**	**15.00[a]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 1.54 **Days (D)** = 1.09 **D x T** = 3.45					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.2: Effect of different edible coatings and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

4.1.3 Organoleptic sensory attributes (Hedonic scale 1-9)

Organoleptic rating depicts the consumer acceptability, which a function of taste, colour, texture, aroma and appearance of fruits. The data pertaining to effect of edible coatings on organoleptic sensory quality (out of 9) of Kinnow fruit revealed an increasing-decreasing trend during storage (Table 3). CMC 2 per cent coated fruits registered the highest mean sensory score of 7.53 and 8.37 followed by 7.49 and 8.37 with CMC 1.5 per cent, during 2016-17 and 2017-18, respectively and was adjudged the best treatment in retaining the palatability in the stored fruits. However, the lowest average sensory score of 6.76 and 7.15 was recorded in uncoated fruits during both the years of investigation. Interestingly, fruits coated with different wax formulations registered a gradual increase in sensory attributes after 30 days of storage; thereby registered the highest sensory score (7.90 and 8.69); then thereafter followed a steady and sharp decline in sensory score till the end of the storage (6.87 and 7.41) in 2016-17 and 2017-18, respectively. However, control fruits revealed a decline at faster pace in palatability with further prolongation in storage period. The control fruits registered the maximum sensory score after 30 days of storage (7.50 and 7.90), whereas, the minimum sensory attributes were recorded after 75 days of storage (5.90 and 6.20) in 2016-17 and 2017-18, respectively. The interaction between treatments and storage intervals was found to be significant during both the seasons of study. The findings were confirmed through pooled mean analysis of both the years (Table 3a and Fig 3). The maximum mean sensory score (7.95) was recorded when fruits were coated with CMC 2 percent followed by its 1.5% concentration (7.93) while, control fruits registered the lowest mean sensory score (6.96). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present investigation it was noticed that Kinnow fruits coated with CMC (2 and 1.5 per cent) coatings developed better sensory quality, which may be due to the role of coatings in partial modifications of internal atmosphere of fruits resulting in the development of acceptable flavor.

The post-harvest application of CMC retained the highest scores for acceptability. color, taste, texture and flavor of oranges (Arnon *et al* 2014) and strawberry (Dong and Wang 2017). Ali *et al* (2015) observed that NFC and Fomesa retained the maximum score (7.15) for overall acceptability after 63 days of storage in Kinnow. The post harvest application of citrashine improved the overall quality of Kinnow (Mahajan and Singh 2014) and pear (Mahajan *et al* (2005).

Table 3: Effect of different edible coatings and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

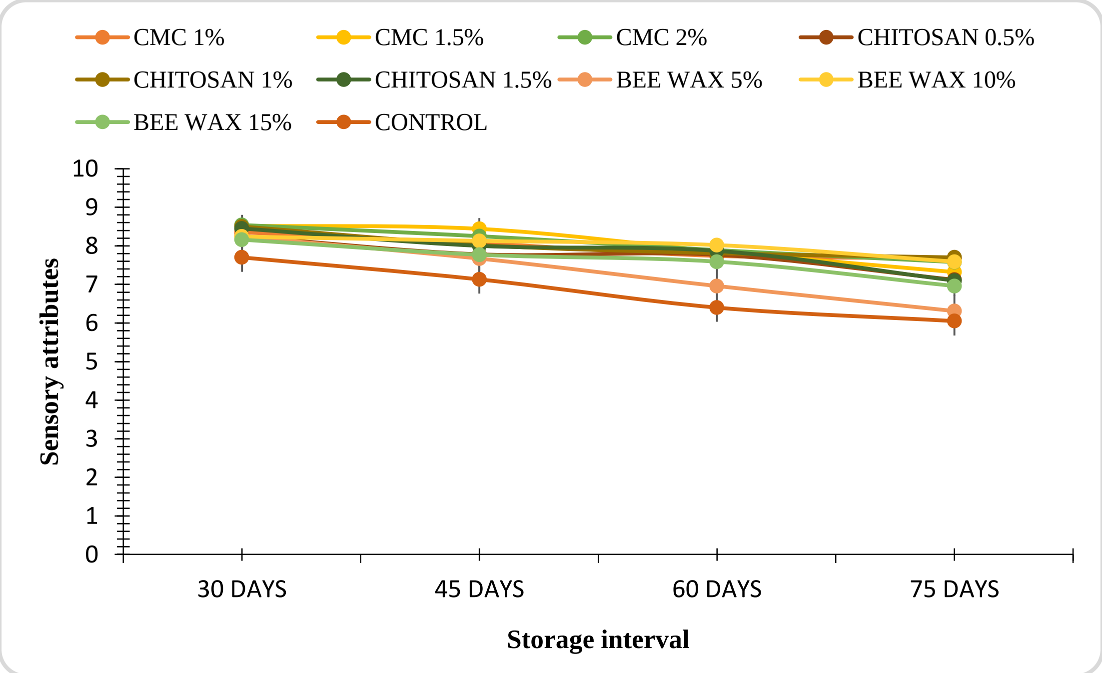
TREATMENT		Organoleptic sensory attributes (Hedonic scale 1-9)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	7.00	7.91	7.60	7.38	7.28	**7.43[a]**	8.00	8.79	8.55	8.10	8.08	**8.30[a]**
	1.5%	7.00	8.09	8.08	7.23	7.06	**7.49[a]**	8.00	8.95	8.80	8.50	7.58	**8.37[a]**
	2%	7.00	8.27	7.90	7.50	7.00	**7.53[a]**	8.00	8.81	8.60	8.29	8.17	**8.37[a]**
Chitosan	**0.5%**	7.00	7.75	7.45	7.45	7.00	**7.33[a]**	8.00	8.75	8.11	8.10	7.25	**8.04[bc]**
	1%	7.00	8.00	7.55	7.41	7.33	**7.46[a]**	8.00	9.00	8.50	8.21	8.08	**8.36[a]**
	1.5%	7.00	8.10	7.70	7.45	6.78	**7.41[a]**	8.00	8.80	8.30	8.30	7.42	**8.16[ab]**
Bee wax	**5%**	7.00	7.68	7.59	6.73	6.30	**7.06[b]**	8.00	8.80	7.75	7.20	6.33	**7.62[d]**
	10%	7.00	7.77	7.70	7.55	7.25	**7.45[a]**	8.00	8.72	8.57	8.50	7.94	**8.35[a]**
	15%	7.00	7.90	7.55	7.28	6.83	**7.31[ab]**	8.00	8.43	8.00	7.90	7.10	**7.89[c]**
Control		7.00	7.50	7.09	6.30	5.90	**6.76[c]**	8.00	7.90	7.17	6.50	6.20	**7.15[e]**
Mean		**7.00[d]**	**7.90[a]**	**7.62[b]**	**7.23[c]**	**6.87[d]**		**8.00[c]**	**8.69[a]**	**8.23[b]**	**7.96[c]**	**7.41[d]**	
LSD (P≤0.05)		**Treatment (T)** = 0.26 **Days (D)** = 0.18 **D x T** = 0.58						**Treatment (T)** = 0.25 **Days (D)** = 0.17 **D x T** = 0.55					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 3a: Effect of different edible coatings and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

Organoleptic sensory attributes (Hedonic scale 1-9)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	7.50	8.35	8.07	7.74	7.68	**7.87[a]**
	1.5%	7.50	8.52	8.44	7.86	7.32	**7.93[a]**
	2%	7.50	8.54	8.25	7.89	7.58	**7.95[a]**
Chitosan	**0.5%**	7.50	8.25	7.78	7.77	7.12	**7.67[bc]**
	1%	7.50	8.50	8.02	7.81	7.70	**7.91[a]**
	1.5%	7.50	8.45	8.00	7.87	7.10	**7.78[ab]**
Bee Wax	**5%**	7.50	8.24	7.67	6.96	6.31	**7.34[d]**
	10%	7.50	8.24	8.13	8.02	7.59	**7.90[a]**
	15%	7.50	8.16	7.77	7.59	6.96	**7.60[c]**
Control		7.50	7.70	7.13	6.40	6.05	**6.96[e]**
Mean		**7.50[c]**	**8.30[a]**	**7.93[b]**	**7.59[c]**	**7.14[d]**	
LSD (**P≤0.05**)		**Treatment (T)** = 0.18 **Days (D)** = 0.13 **D x T** = 0.40					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 3: Effect of different edible coatings and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

4.1.4 Firmness (Kg Force)

The data pertaining to the effect of edible coating on the firmness of Kinnow fruit in general followed a declining trend commensurate with advancement in storage period (Table 4). In the year 2016-17, the average maximum firmness (4.94 kg f) maintained by CMC 2 per cent followed by its 1.5 per cent concentration (4.63 kg f). However, the control fruits registered the lowest average firmness (4.06 kg f). The firmness of fruits coated with CMC (2 and 1.5%) ranged from 5.08 to 4.07 and 4.73 to 3.71 kg force, respectrively from 30 days to 75 days of storage period. On the other hand, control fruits registered an abrupt and sharp decline ranged between 4.40 to 2.80 kg force. Similar results were recorded in the year 2017-18 where, CMC 2 per cent was found superior to all the other coating treatments with respect to retaining and maintaining the highest average firmness (5.29 kg f) and was statistically at par with CMC 1.5 per cent (5.28 kg f). The firmness in fruits coated with CMC (2 and 1.5%) ranged from 5.86 to 3.86 and 5.98 to 3.72 kg force, respectively. On the other hand, the control fruits registered a continuous decline in firmness at faster pace thus ranged from 4.69 to 3.23 kg force from 30 days to 75 days of storage period. The interaction between treatments and storage interval was found to be statistically significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 4a and Fig 4). CMC 2 per cent was most effective in retaining and maintaining highest average firmness (5.12 kg f) followed by its 1.5 per cent concentration (4.96 kg f), whereas, control fruits retained the lowest average firmness (4.21 kg f). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.The softening in fruit during storage resulting due to weakened cell wall structure, loss of membrane integrity, hydrolysis of cellulose and hemi-cellulose as well as depolymerisation of pectin and starch (Seymour *et al* 1993; Matto *et al* 1975 and Solomos and Laties 1973). The coating of fruits with CMC resulted in higher fruit firmness which might be due to reduction in moisture loss and respiratory activity and thus maintained turgidity of the cells. This is evident in avocado (Tesfay and Magwazza 2017). Ali *et al* (2015) observed that coating with NFC maintained the maximum fruit firmness in Kinnow than that of control. Mahajan and Singh (2014) and Mahajan *et al* (2013) observed the highest mean fruit firmness in Citrashine and Niprofresh SS 40 T coated Kinnow fruit.

Table 4: Effect of different edible coatings and storage interval on the firmness (Kg force) in Kinnow fruit stored at 5-7°C and 90-95% RH

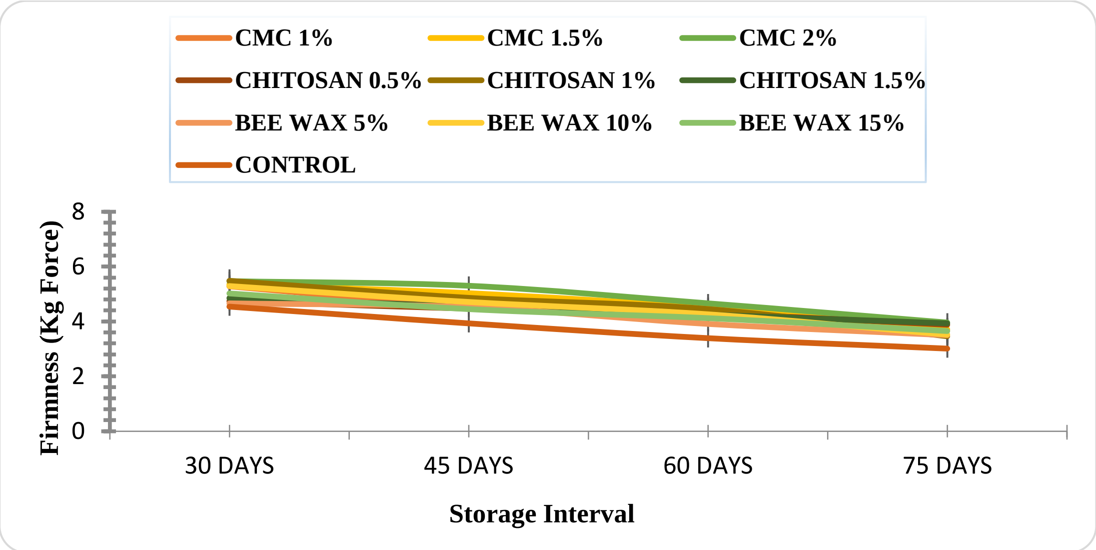
TREATMENT		Firmness (Kg Force)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	1%	6.13	5.09	4.26	4.12	3.34	**4.59^{bc}**	6.25	5.47	4.82	4.00	4.07	**4.95^{cd}**
	1.5%	6.13	4.73	4.52	4.07	3.71	**4.63^{b}**	6.25	5.98	5.54	4.92	3.72	**5.28^{a}**
	2%	6.13	5.08	4.89	4.07	4.07	**4.94^{a}**	6.25	5.86	5.72	4.77	3.86	**5.29^{a}**
Chitosan	0.5%	6.13	4.48	4.32	4.15	3.58	**4.53^{bc}**	6.25	5.01	4.63	4.44	4.25	**4.91^{d}**
	1%	6.13	5.24	4.21	3.84	3.60	**4.60^{b}**	6.25	5.73	5.51	5.06	3.33	**5.18^{b}**
	1.5%	6.13	4.40	4.32	4.16	3.80	**4.56^{bc}**	6.25	5.30	4.78	4.34	4.00	**4.95^{cd}**
Bee wax	5%	6.13	4.25	4.12	3.56	3.44	**4.30^{d}**	6.25	5.08	4.92	4.26	3.57	**4.81^{e}**
	10%	6.13	4.82	4.43	4.00	3.60	**4.59^{b}**	6.25	5.77	5.00	4.53	3.45	**5.00^{c}**
	15%	6.13	5.03	4.36	3.75	3.05	**4.46^{c}**	6.25	5.02	4.53	4.49	4.25	**4.90^{d}**
Control		6.13	4.40	3.70	3.30	2.80	**4.06^{e}**	6.25	4.69	4.17	3.48	3.23	**4.36^{f}**
Mean		**6.13^{a}**	**4.75^{b}**	**4.31^{c}**	**3.95^{d}**	**3.50^{e}**		**6.25^{a}**	**5.39^{b}**	**4.96^{c}**	**4.45^{d}**	**3.77^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** =0.13 **Days (D)** =0.091 **D x T** = 0.29						**Treatment (T)** = 0.12 **Days (D)** = 0.086 **D x T** = 0.27					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 4a: Effect of different edible coatings and storage interval on the firmness (Kg force) in Kinnow fruit stored at 5-7°C and 90-95% RH

Firmness (Kg Force)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	6.19	5.28	4.54	4.17	3.67	**4.77^{cd}**
	1.5%	6.19	5.35	5.03	4.49	3.71	**4.96^{b}**
	2%	6.19	5.47	5.30	4.66	3.96	**5.12^{a}**
Chitosan	**0.5%**	6.19	4.74	4.47	4.29	3.88	**4.72^{d}**
	1%	6.19	5.48	4.86	4.45	3.46	**4.89^{bc}**
	1.5%	6.19	4.85	4.55	4.25	3.93	**4.75^{d}**
Bee Wax	**5%**	6.19	4.66	4.52	3.91	3.50	**4.56^{e}**
	10%	6.19	5.29	4.71	4.26	3.52	**4.80^{cd}**
	15%	6.19	5.02	4.45	4.12	3.65	**4.68^{de}**
Control		6.19	4.54	3.93	3.39	3.01	**4.21^{f}**
Mean		**6.19^{a}**	**5.07^{b}**	**4.64^{c}**	**4.20^{d}**	**3.63^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.13 **Days (D)** = 0.09 **D x T** = 0.30					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 4: Effect of different edible coatings and storage interval on the firmness (Kgf) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

4.1.5 Juice (%)

The data pertaining to effect of edible coating on juice percentage revealed a decreasing trend during storage; might be due to loss of moisture from the surface of the fruits (Table 5). In both the seasons of investigation, CMC 2 per cent, registered the highest average juice content (38.48 and 46.45 %) followed by its 1.5 per cent concentration (38.27 and 45.76 %). However, control fruits registered the lowest average juice content where the mean lowest juice content of 33.98 and 43.14 per cent was recorded during 2016-17 and 2017-18, respectively. The juice percentage in the fruits coated with CMC (2 and 1.5%) ranged from 40.93 to 30.85 and 45.09 to 28.51 per cent, respectively from 30 days to 75 days of storage in first season and 48.75 to 43.61 and 47.45 to 41.96 per cent, respectively from 30 days to 75 days in second season of investigation. On the other hand, the control fruits shown a sharper decline at faster pace in juice content and ranged from 41.81 to 20.80 per cent in 2016-17 and 46.98 to 34.65 per cent during 2017-18. The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were also confirmed through pooled mean analysis of both the years (Table 5a and Fig 5). Fruits coated with CMC 2 per cent retained the highest average juice (42.47%) content followed by its 1.5 per cent concentration (42.02%) while, the lowest average juice content was recorded in the control fruits (38.56%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, control fruits registered the maximum loss in juice content; might be due to dry atmosphere around the fruits leading to faster respiration and transpiration causing drying of the juicy vesicles.

These results are in corroboration with the findings of Samra *et al* (2014) who reported that CMC coated tangor fruits cv. murcott retained the maximum juice ratio than those of control fruits after 60 days of storage. Fruits of ‘Kagzi lime’ retained the maximum juice content under coating with pure coconut oil after 18 days of storage (Bisen *et al* (2012). Mahajan *et al* (2013) reported that Kinnow fruits coated Niprofresh SS 40 T and SS 50 T maintained the maximum yield in juice content in contrast to to control. Rokayya *et al* (2016) reported that combined application of wax and bavistin maintained both better firmness and low PLW thereby resulted higher juice content in mandarin fruit in contrast to control after four weeks of storage period.

Table 5: Effect of different edible coatings and storage interval on the juice per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

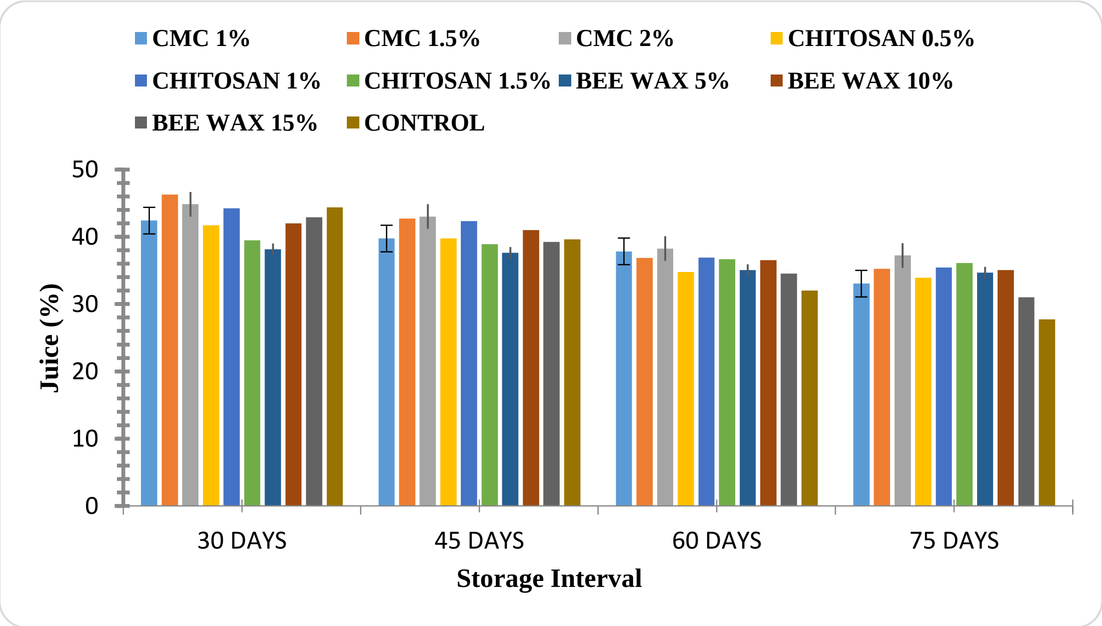
TREATMENT		Juice (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	48.50	36.85	34.84	31.45	26.57	**35.64[b]**	49.50	48.00	44.67	44.20	39.54	**45.18[abc]**
	1.5%	48.50	45.09	39.75	29.52	28.51	**38.27[ab]**	49.50	47.45	45.69	44.21	41.96	**45.76[ab]**
	2%	48.50	40.93	40.80	31.33	30.85	**38.48[a]**	49.50	48.75	45.21	45.20	43.61	**46.45[a]**
Chitosan	**0.5%**	48.50	36.94	36.70	27.23	26.45	**35.16[bc]**	49.50	46.51	42.79	42.33	41.42	**44.51[bcde]**
	1%	48.50	40.91	40.40	29.72	28.83	**37.67[a]**	49.50	47.60	44.30	44.13	42.06	**45.52[ab]**
	1.5%	48.50	34.92	33.92	29.90	28.75	**35.20[bc]**	49.50	44.00	43.87	43.48	43.43	**44.86[bcd]**
Bee wax	**5%**	48.50	32.94	32.71	28.64	28.07	**34.17[ef]**	49.50	43.31	42.49	41.45	41.27	**43.60[de]**
	10%	48.50	38.95	37.03	29.32	26.47	**36.05[c]**	49.50	45.05	44.94	43.75	43.63	**45.37[ab]**
	15%	48.50	40.00	35.42	26.93	23.57	**34.88[bc]**	49.50	45.78	43.11	42.11	38.46	**43.79[cde]**
Control		48.50	41.81	33.55	25.22	20.80	**33.98[c]**	49.50	46.98	45.67	38.88	34.65	**43.14[e]**
Mean		**48.50[a]**	**38.93[b]**	**36.51[c]**	**28.93[d]**	**26.89[e]**		**49.50[a]**	**46.34[b]**	**44.27[c]**	**42.97[d]**	**41.00[e]**	
LSD (P≤0.05)		**Treatment (T)** = 1.30 **Days (D)** = 0.92 **D x T** = 2.91						**Treatment (T)** = 1.51 **Days (D)** = 1.07 **D x T** = 3.38					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 5a: Effect of different edible coatings and storage interval on the juice per cent (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Juice (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	49.00	42.42	39.75	37.82	33.05	**40.41^{bcde}**
	1.5%	49.00	46.27	42.72	36.86	35.23	**42.02^{ab}**
	2%	49.00	44.84	43.00	38.26	37.23	**42.47^{a}**
Chitosan	**0.5%**	49.00	41.72	39.74	34.78	33.93	**39.84^{def}**
	1%	49.00	44.25	42.35	36.93	35.45	**41.59^{abc}**
	1.5%	49.00	39.46	38.89	36.69	36.09	**40.03^{cdef}**
Bee Wax	**5%**	49.00	38.13	37.60	35.04	34.67	**38.89^{ef}**
	10%	49.00	42.00	40.98	36.53	35.05	**40.71^{bcd}**
	15%	49.00	42.89	39.26	34.52	31.01	**39.34^{def}**
Control		49.00	44.39	39.61	32.01	27.72	**38.56^{f}**
Mean		**49.00^{a}**	**42.64^{b}**	**40.39^{c}**	**35.95^{d}**	**33.94^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 1.70 **Days (D)** = 1.20 **D x T** = 3.80					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 5: Effect of different edible coatings and storage interval on the juice per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

4.1.6 TSS (%)

Data pertaining to TSS content influenced by post-harvest application of edible coatings revealed an identical trend during the storage period (Table 6). In 2016-17, Fruits coated with CMC 2 per cent registered the maximum average TSS content (11.06%) followed by treatment of CMC 1.5 per cent (10.68%). On the other hand, the control fruits registered the lowest average TSS (10.03%). It was further observed that in CMC (2 and 1.5%) coated fruits the TSS content increased slowly and steadily up to 60 days of the storage (13.55 and 12.65 %) and thereafter followed a decline till the end of the storage i.e., 11.65 and 12.20 per cent, respectively.

The similar trends were also noticed in 2017-18. The highest average TSS content was registered in the fruits coated with CMC 2 per cent (11.06%) followed by its 1.5 per cent concentration (10.95%), whereas the control fruits recorded the lowest average TSS content (10.27%). Fruits coated with CMC 2 and 1.5 per cent shown a gradual increase in TSS content up to 60 days (13.70 and 13.00 %, respectively); thereafter followed a sharp and abrupt decline till the end of the storage (11.50 and 11.20 %, respectively). The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were further confirmed through the pooled mean analysis of both years (Table 6a and Fig 6). CMC 2 per cent proved best in terms of maintaining the highest mean TSS (11.06%) content followed by its 1.5 per cent concentration (10.81%)whereas, control fruits registered the lowest mean TSS (10.15%) content. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, a increase in TSS content; might be due to berrier properties of coating reduces the rate of respiration of fruits and simultaneously the respiration process delay the hydrolysis of starch into sugars (Biliaderis *et al* 1985 and Wills *et al* 1980). The delayed increase in TSS content in coated fruits under cold storage condition; might be attributed that coating retard ripening and senescence processes and simultaneously delayed the conversion of starch into sugars.

The results on TSS content in the present study are in agreement with the findings of Shah *et al* (2015) who observed a gradual increase in soluble solids concentration irrespective of coating treatment with CMC in Kinnow fruit. The post-harvest application of chitosan delayed an increase in TSS content; might be due to catabolic process and respiration rate in plum fruit (Kumar *et al* 2017) kiwi fruit (Kaya *et al* 2016) papaya (Ali *et al* 2011) and apricot (Ghasmnezhad *et al* 2010).

Table 6: Effect of different edible coatings and storage interval on total soluble solids per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

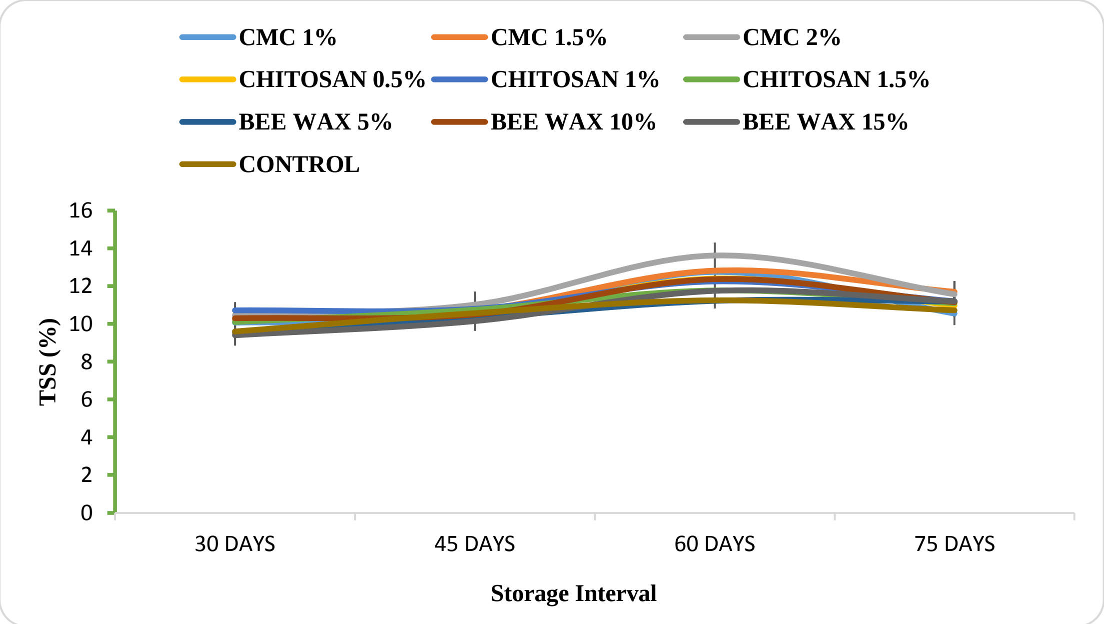
TREATMENT		Total soluble solids (%)											
		2016-17						**2017-18**					
		Storage interval (Days)						**Storage interval (Days)**					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	8.75	9.75	10.05	12.05	10.45	**10.21[cd]**	8.45	10.40	10.55	13.45	10.65	**10.70[bc]**
	1.5%	8.75	9.55	10.25	12.65	12.20	**10.68[b]**	8.45	10.90	11.20	13.00	11.20	**10.95[ab]**
	2%	8.75	10.50	10.85	13.55	11.65	**11.06[a]**	8.45	10.45	11.20	13.70	11.50	**11.06[a]**
Chitosan	**0.5%**	8.75	9.20	10.00	12.00	10.80	**10.15[cd]**	8.45	9.75	10.85	12.80	11.15	**10.60[cd]**
	1%	8.75	10.35	10.45	12.65	10.70	**10.58[b]**	8.45	11.10	11.15	11.85	11.70	**10.85[abc]**
	1.5%	8.75	9.20	10.40	11.80	11.05	**10.24[cd]**	8.45	11.00	11.10	11.75	11.15	**10.69[bc]**
Bee Wax	**5%**	8.75	9.00	10.15	11.55	10.90	**10.07[d]**	8.45	10.15	10.50	11.50	10.90	**10.30[de]**
	10%	8.75	9.90	10.25	12.30	11.05	**10.45[bc]**	8.45	10.70	10.75	12.45	11.25	**10.72[bc]**
	15%	8.75	8.90	9.60	11.75	11.55	**10.11[d]**	8.45	9.90	10.70	11.75	10.85	**10.33[de]**
Control		8.75	9.35	10.25	11.15	10.65	**10.03[d]**	8.45	9.85	10.90	11.35	10.80	**10.27[e]**
Mean		**8.75[e]**	**9.57[d]**	**10.22[c]**	**12.14[a]**	**11.10[b]**		**8.45[d]**	**10.42[c]**	**10.89[b]**	**12.36[a]**	**11.11[b]**	
LSD (P≤0.05)		**Treatment (T) =** 0.31 **Days (D) =** 0.22 **D x T =** 0.70						**Treatment (T) =** 0.32 **Days (D) =** 0.23 **D x T =** 0.71					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 6a: Effect of different edible coatings and storage interval on the total soluble solids per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Total soluble soilds (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	8.60	10.07	10.30	12.75	10.55	**10.45**^{cde}
	1.5%	8.60	10.22	10.72	12.82	11.70	**10.81**^{ab}
	2%	8.60	10.47	11.02	13.62	11.57	**11.06a**
Chitosan	**0.5%**	8.60	9.47	10.42	12.40	10.97	**10.37**^{def}
	1%	8.60	10.72	10.80	12.25	11.20	**10.71**^{bc}
	1.5%	8.60	10.10	10.75	11.77	11.10	**10.46**^{cde}
Bee Wax	**5%**	8.60	9.57	10.32	11.22	11.20	**10.18**^{f}
	10%	8.60	10.30	10.50	12.37	11.15	**10.58**^{bcd}
	15%	8.60	9.40	10.15	11.75	11.20	**10.22**^{ef}
Control		8.60	9.60	10.57	11.25	10.72	**10.15**^{f}
Mean		**8.60**^{e}	**9.99**^{d}	**10.56**^{c}	**12.22**^{a}	**11.14**^{b}	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.26 **Days (D)** = 0.18 **D x T** = 0.58					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.6: Effect of different edible coatings and storage interval on the total soluble solids (TSS) per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

4.1.7 Reducing sugars (%)

The data pertaining to effect of edible coatings on reducing sugars content revealed an increasing- decreasing trend during storage (Table 7). In 2016-17, fruits coated with CMC 2 per cent registered the maximum average reducing sugars (4.21%) followed by its 1.5 per cent concentration (3.90%). On the other hand, control fruits recorded the lowest average reducing sugar (3.36%). It was further observed that in CMC (2 and 1.5%) coated fruits the reducing sugars increased slowly and steadily up to 60 days, i.e. 4.86 and 4.68 % respectively. and thereafter followed a decline till the end of the storage i.e., 4.39 and 3.96%, respectively. The similar trend was also noticed in 2017-18. The average maximum reducing sugar (3.41%) registered by fruits coated with CMC 2 per cent followed by its 1.5 per cent concentration (3.18%). However, control fruits yet again registered the lowest mean reducing sugars (2.66%). A gradual rise in reducing sugars content was noticed in the fruits coated with CMC 2 and 1.5 per cent after 60 days of storage i.e. 5.54 and 5.43 %; respectively; thereafter followed an abrupt decline till the end of the storage i.e. 4.28 and 4.07, respectively. On the other hand control fruits recorded the lowest reducing sugars content after 60 days of storage i.e. 4.07 and 4.10 per cent in 2016-17 and 2017-18 respectively. The pooled mean analysis of both years (Table 7a and Fig 7)revealed the similar findings as fruits coated with CMC 2 per cent registered the maximum mean reducing sugars (3.81%) followed by its 1.5 per cent concentration (3.54%) on the other hand, control fruits registered the lowest reducing sugar content (3.01%). The interaction between treatments and storage interval was found to be significant. In the present study, the increase in sugars (total and reducing sugars) might be due to breakdown of starch into sugars, as on complete hydrolysis of starch no further increase in sugars occurs and subsequently a decline in these parameter is predictable as they along with other organic acids are primary substrate for respiration (Wills *et al* 1980). The delayed decrease in the sugar content in the fruits coated with different coatings attributed to the inherent property of coatings in delaying the metabolic activities of fruit during storage due to delay in ethylene production and respiration rate.

Irrespective of coating with CMC a gradual increase in sugars was observed in Kinnow fruit during storage (Shah *et al* 2015). Kumar *et al* (2017) observed that chitosan delayed the increase in sugars content in plum, kiwi fruit (Kaya *et al* 2016) apricot (Ghasmnezhad *et al* 2010) and papaya (Ali *et al* 2011).

Table 7: Effect of different edible coatings and storage interval on the reducing sugar per cent in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

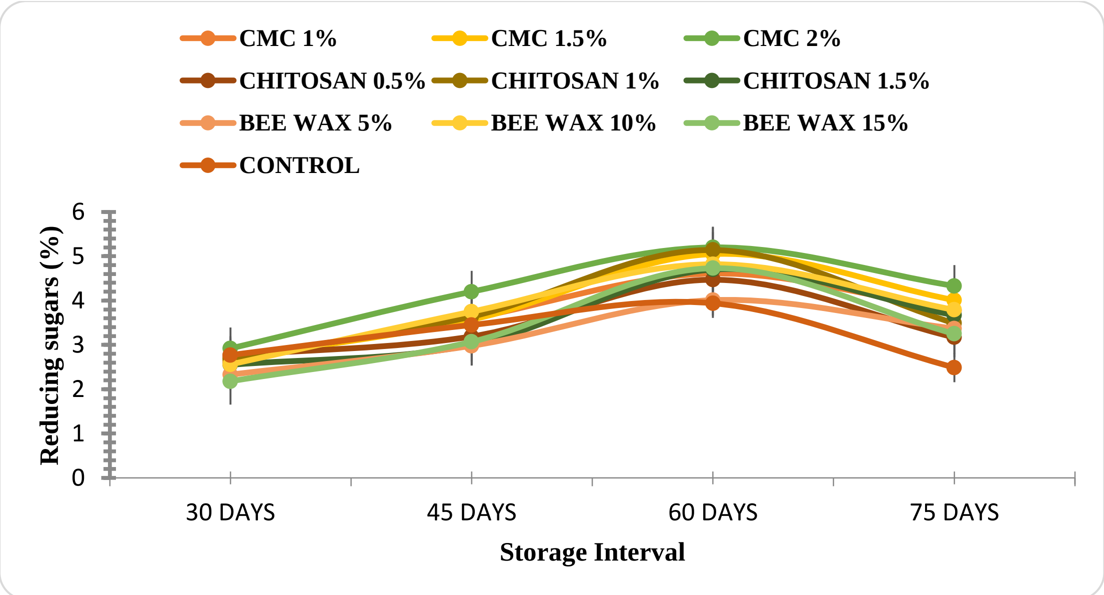
TREATMENT		Reducing sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	3.11	3.18	3.73	4.78	3.59	**3.68^{cd}**	1.67	2.07	3.47	4.44	3.95	**3.12^{b}**
	1.5%	3.11	3.36	4.41	4.68	3.96	**3.90^{b}**	1.67	2.00	2.74	5.43	4.07	**3.18^{b}**
	2%	3.11	3.92	4.79	4.86	4.39	**4.21^{a}**	1.67	1.93	3.62	5.54	4.28	**3.41^{a}**
Chitosan	**0.5%**	3.11	3.08	3.90	4.44	3.23	**3.55^{ef}**	1.67	2.45	2.48	4.52	3.11	**2.85^{d}**
	1%	3.11	2.93	4.46	4.49	3.91	**3.78^{c}**	1.67	2.45	2.81	5.80	3.08	**3.16^{b}**
	1.5%	3.11	3.14	3.78	4.20	3.70	**3.58^{de}**	1.67	1.97	2.23	5.19	3.64	**2.94^{c}**
Bee wax	**5%**	3.11	2.69	3.36	4.14	3.55	**3.37^{gh}**	1.67	1.98	2.61	3.89	3.19	**2.67^{e}**
	10%	3.11	3.40	4.22	4.43	3.69	**3.77^{c}**	1.67	1.73	3.29	5.22	3.89	**3.16^{b}**
	15%	3.11	2.64	3.86	4.82	2.95	**3.47^{fg}**	1.67	1.73	2.29	4.65	3.55	**2.78^{d}**
Control		3.11	3.26	3.78	4.07	2.59	**3.36^{h}**	1.67	2.28	2.84	4.10	2.40	**2.66^{e}**
Mean		**3.11^{d}**	**3.16^{d}**	**4.03^{b}**	**4.49^{a}**	**3.55^{c}**		**1.67^{e}**	**2.06^{d}**	**2.84^{c}**	**4.88^{a}**	**3.51^{b}**	
LSD (P≤0.05)		**Treatment (T)** = 0.11 **Days (D)** = 0.07 **D x T** = 0.24						**Treatment (T)** = **0.07** **Days (D)** = 0.05 **D x T** = 0.16					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 7a: Effect of different edible coating and storage interval on the reducing sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Reducing sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	2.39	2.62	3.60	4.61	3.77	**3.40**[bcd]
	1.5%	2.39	2.68	3.57	5.05	4.01	**3.54**[b]
	2%	2.39	2.92	4.20	5.20	4.33	**3.81**[a]
Chitosan	**0.5%**	2.39	2.76	3.19	4.47	3.17	**3.20**[def]
	1%	2.39	2.69	3.64	5.14	3.49	**3.47**[bc]
	1.5%	2.39	2.55	3.00	4.70	3.67	**3.26**[cde]
Bee Wax	**5%**	2.39	2.33	2.98	4.01	3.37	**3.02**[f]
	10%	2.39	2.56	3.75	4.82	3.79	**3.46**[bc]
	15%	2.39	2.18	3.07	4.73	3.25	**3.13**[ef]
Control		2.39	2.77	3.45	3.94	2.49	**3.01**[f]
Mean		**2.39**[d]	**2.61**[c]	**3.45**[b]	**4.67**[a]	**3.53**[b]	
LSD (P≤0.05)		**Treatment (T)** = 0.24 **Days (D)** = 0.17 **D x T** = 0.54					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.7: Effect of different edible coatings and storage interval on the reducing sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

4.1.8 Total sugar (%)

Perusal of the effect of edible coatings on storage life of Kinnow fruit revealed an identical trend for total sugars content during storage (Table 8). In 2016-17, fruits coated with CMC 2 per cent registered the maximum average total sugars content (8.61 %) followed by its 1.5 per cent concentration where it was recorded as 8.10 per cent. On the other hand, control fruits recorded the lowest average total sugar content (6.93 %). It was further observed that the total sugars content in the fruits coated with CMC 2 and 1.5 per cent increased slowly and steadily up to 60 days i.e. 9.95 and 9.64 per cent, respectively and thereafter notched up a decline till end of the storage i.e. 9.50 and 8.88 per cent, respectively. The similar trend was also noticed in 2017-18. Fruits coated with CMC 2 per cent registered the maximum mean total sugars (6.92%) followed by treatment of CMC 1.5 per cent (6.89%) whereas, control fruits yet again registered the lowest average total sugars content (5.80 %). Fruits coated with CMC 2 and 1.5 per cent registered the maximum total sugars after 60 days of storage i.e. 8.61 and 8.74 per cent, respectively which declined gradually till the end of storage i.e. 8.51 and 8.62 per cent, respectively. The interaction between treatments and storage interval was found to be significant during both seasons of investigation. The data further confirmed the findings through pooled mean analysis of both the years (Table 8a and Fig 8). CMC 2 per cent was the best in terms of registering the maximum mean total sugars (7.76%) followed by its 1.5 per cent concentration (7.50%), whereas control fruits registered the lowest average total sugars (6.51%) content. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.

4.1.9 Vitamin C (mg/100g)

The data on effect of edible coatings on ascorbic acid content of Kinnow fruit registered a linear decline in its level throughout the storage period (Table 9). The treatments showed a significant difference among themselves with regard to loss in vitamin C content. In 2016-17, fruits coated with CMC 2 per cent retained the highest average ascorbic acid (23.95 mg/100g pulp) content followed by its 1.5 per cent concentration (22.95 mg/100g pulp). The control fruits retained the lowest average ascorbic acid (19.72 mg/100g pulp) content. It was further noticed that the ascorbic acid content in fruits coated with CMC 2 and 1.5 per cent ranged from 29.71 to 13.80 and 23.82 to 15.73 mg/100g pulp, respectively from 30 days to 75 days of storage period. However, the control fruits followed a continuous decline at faster pace and thereby retained the lowest ascorbic acid content ranged from 24.00 to 8.50 mg/100g pulp from 30 days to 75 days of storage period. Similar trend was also registered in 2017-18. The fruits coated with CMC 2 and 1.5 per cent maintained the maximum mean ascorbic acid (27.84 and 26.75 mg/100 pulp), respectively.However, the control fruits yet again revealed the lowest average ascorbic acid (21.72 mg/100g pulp) content. It was further noticed that the ascorbic acid content in the fruits coated CMC 2 and 1.5 per cent ranged from 30.16 to 23.41 mg/100g pulp

Table 8: Effect of edible different coatings and storage interval on the total sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

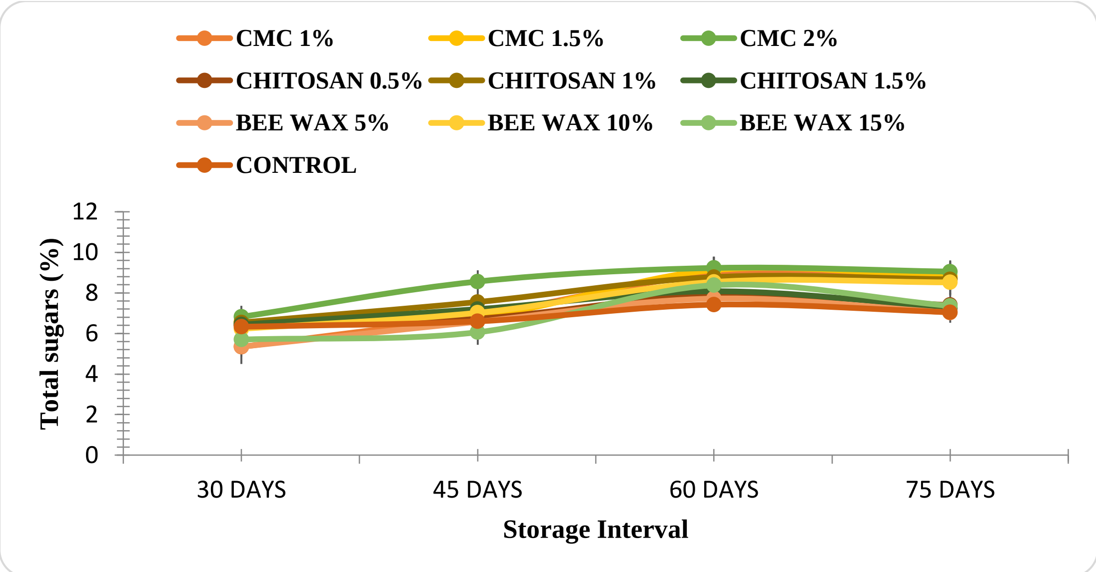
TREATMENT		Total sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	**1%**	5.65	5.98	7.97	9.89	8.12	**7.52^{cd}**	4.65	4.70	5.80	9.70	7.55	**6.48^{bc}**
	1.5%	5.65	7.75	8.57	9.64	8.88	**8.10^{b}**	4.65	5.37	7.09	8.74	8.62	**6.89^{a}**
	2%	5.65	8.67	9.29	9.95	9.50	**8.61^{a}**	4.65	4.98	7.83	8.61	8.51	**6.92^{a}**
Chitosan	**0.5%**	5.65	7.29	7.51	8.37	7.72	**7.31^{de}**	4.65	5.53	5.95	8.10	6.44	**6.13^{de}**
	1%	5.65	7.49	8.47	9.39	9.08	**8.01^{b}**	4.65	5.60	6.63	8.48	7.96^{e}	**6.66^{b}**
	1.5%	5.65	7.48	7.79	8.05	7.82	**7.36^{d}**	4.65	4.65	6.61	8.35	6.49	**6.30^{cd}**
Bee wax	**5%**	5.65	7.17	7.30	7.75	7.21	**7.02^{f}**	4.65	4.75	4.98	9.02	6.32	**5.94^{fg}**
	10%	5.65	7.06	7.09	9.65	8.63	**7.61^{c}**	4.65	5.41	6.95	8.41	7.44	**6.57^{b}**
	15%	5.65	6.66	7.14	8.40	7.74	**7.12^{ef}**	4.65	5.49	5.90	7.10	6.90	**6.01^{ef}**
Control		5.65	5.80	7.34	8.00	7.84	**6.93^{f}**	4.65	4.89	5.81	7.61	6.06	**5.80^{g}**
Mean		**5.65^{e}**	**7.13^{d}**	**7.89^{c}**	**8.90^{a}**	**8.25^{b}**		**4.65^{v}**	**5.21^{d}**	**6.35^{c}**	**8.41^{a}**	**7.23^{b}**	
LSD (P≤0.05)		**Treatment (T)** = 0.23 **Days (D)** = 0.17 **D x T** = 0.52						**Treatment (T)** = 0.19 **Days (D)** = 0.13 **D x T** = 0.42					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 8a: Effect of different edible coatings and storage intervalon the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Total sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	5.15	5.34	6.88	8.91	8.72	**7.00^{de}**
	1.5%	5.15	6.56	6.82	9.13	8.81	**7.50^{ab}**
	2%	5.15	6.82	8.56	9.23	9.05	**7.76^{a}**
Chitosan	**0.5%**	5.15	6.41	6.73	7.91	7.40	**6.72^{ef}**
	1%	5.15	6.54	7.55	8.78	8.67	**7.34^{bc}**
	1.5%	5.15	6.44	7.20	8.08	7.27	**6.83^{de}**
Bee Wax	**5%**	5.15	5.35	6.58	7.72	7.03	**6.36^{g}**
	10%	5.15	6.23	7.02	8.54	8.52	**7.09^{cd}**
	15%	5.15	5.70	6.06	8.38	7.36	**6.53^{fg}**
Control		5.15	6.33	6.60	7.42	7.05	**6.51^{fg}**
Mean		**5.15^{e}**	**6.17^{d}**	**7.10^{c}**	**8.41^{a}**	**7.99^{b}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.29 **Days (D)** = 0.20 **D x T** = 0.65					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.8: Effect of different edible coatings and storage interval on the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 9: Effect of different edible coatings and storage interval on the vitamin C content (mg/100g) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

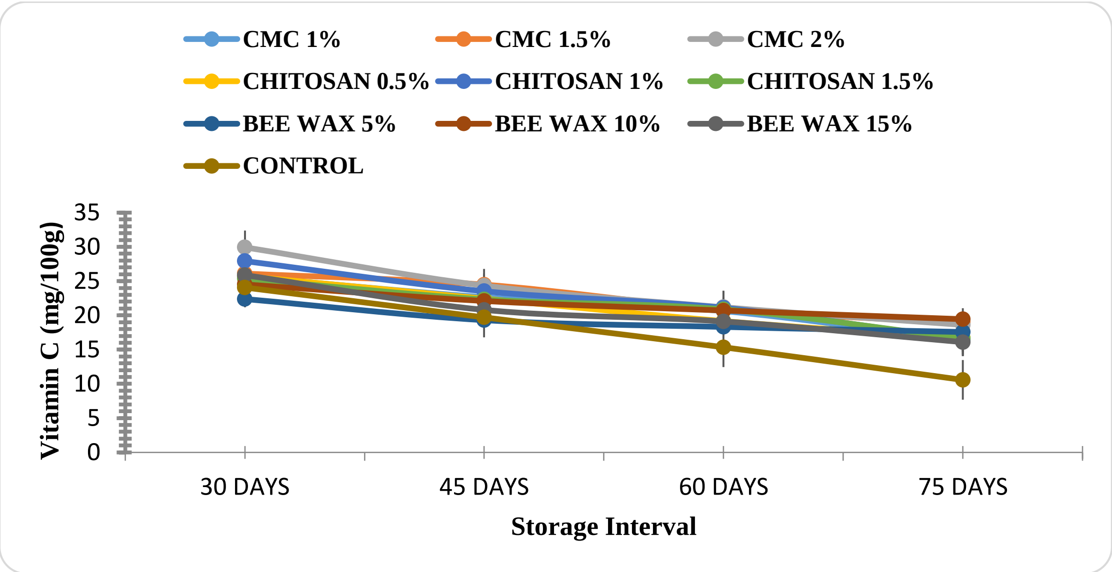
TREATMENT		Vitamin C (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	33.97	23.23	20.75	18.60	11.85	**21.68^{cd}**	33.88	27.68	24.56	22.65	20.68	**25.97^{cd}**
	1.5%	33.97	23.82	23.23	18.00	15.73	**22.95^{ab}**	33.88	28.38	25.73	23.68	22.09	**26.75^{b}**
	2%	33.97	29.71	21.62	17.66	13.80	**23.35^{a}**	33.88	30.16	27.06	24.71	23.41	**27.84^{a}**
Chitosan	**0.5%**	33.97	21.45	19.73	17.00	14.60	**21.35^{d}**	33.88	30.00	25.15	21.32	18.74	**25.82^{d}**
	1%	33.97	27.65	20.28	17.94	13.20	**22.61^{b}**	33.88	28.20	26.76	24.26	22.00	**26.58^{bc}**
	1.5%	33.97	23.00	20.75	18.45	12.56	**21.68^{cd}**	33.88	28.20	24.26	23.32	20.68	**25.96^{cd}**
Bee wax	**5%**	33.97	17.94	17.43	16.47	15.80	**20.32^{e}**	33.88	26.81	21.18	20.16	19.35	**24.28^{f}**
	10%	33.97	21.76	19.94	18.91	16.88	**22.29^{bc}**	33.88	27.26	24.26	22.52	22.00	**25.98^{cd}**
	15%	33.97	24.41	17.94	16.60	13.45	**21.27^{e}**	33.88	27.33	23.67	21.62	18.73	**25.05^{e}**
Control		33.97	24.00	18.78	13.35	8.50	**19.72^{e}**	33.88	24.12	20.63	17.33	12.64	**21.72^{f}**
Mean		**33.97^{a}**	**23.70^{b}**	**20.01^{c}**	**17.30^{d}**	**13.64^{e}**		**33.88^{a}**	**27.80^{b}**	**24.33^{c}**	**22.16^{d}**	**19.81^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.712 **Days (D)** = 0.504 **D x T** = 1.593						**Treatment (T)** = 0.722 **Days (D)** = 0.511 **D x T** = 1.615					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 9a: Effect of different edible coatings and storage interval on the vitamin C (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Vitamin C (mg/100)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	33.92	25.66	22.65	20.62	16.26	**23.83[cde]**
	1.5%	33.92	26.10	24.48	20.84	18.91	**24.85[ab]**
	2%	33.92	29.93	24.34	21.18	18.61	**25.60[a]**
Chitosan	**0.5%**	33.92	25.72	22.44	19.16	16.67	**23.58[de]**
	1%	33.92	27.92	23.52	21.10	16.49	**24.59[bc]**
	1.5%	33.92	25.34	22.33	20.88	16.62	**23.82[cde]**
Bee Wax	**5%**	33.92	22.38	19.30	18.31	17.57	**22.30[f]**
	10%	33.92	24.51	22.10	20.71	19.44	**24.14[bcd]**
	15%	33.92	25.87	20.80	19.11	16.09	**23.16[ef]**
Control		33.92	24.06	19.70	15.34	10.57	**20.72[g]**
Mean		**33.92[a]**	**25.75[b]**	**22.17[c]**	**19.73[d]**	**16.72[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.89 **Days (D)** = 0.63 **D x T** = 2.00					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.9: Effect of different edible coatings and storage interval on the vitamin C (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

and 28.38 to 22.09 mg/100g pulp, respectively from 30 days to 75 days of storage. On the other hand, control fruits revealed an abrupt decline in ascorbic acid content at faster pace and thereby ranged from 24.12 to 12.64 mg/100g pulp from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 9a and Fig 9). CMC 2 per cent was emerged as best in terms of retaining and maintaining the maximum mean ascorbic acid content (25.60 mg/100g pulp) followed by its 1.5 per cent concentration (24.85 mg/100g pulp) while, control fruits retained the lowest mean ascorbic acid (20.72 mg/100g pulp) content. The interaction between treatments and storage interval was found to be significant. In the present study decline in ascorbic acid content during storage may be due to conversion of ascorbic acid to dehydroascorbic acid by the action of ascorbic acid oxidase (Mapson 1970)

The results are in corroboration with the findings of Shah *et al* (2015) who reported that the post-harvest application of CMC coating initially enhanced the ascorbic acid content with advancement of storage. The post-harvest application of chitosan registered the maximum retention of ascorbic acid content in peach (Li and Yu 2000) plum (Kumar *et al* 2017) papaya (Ali *et al* 2011) and apricot fruit (Ghasmnezhad *et al* 2010).

4.1.10 Total Carotenoids (mg/100g)

The data pertaining to effect of edible coatings on total carotenoids content revealed an identical trend during storage (Table 10). The treatments showed a significant effect with regard to maintain the total carotenoids content during storage. In 2016-17, the average maximum total carotenoids (0.62 mg/100g) content was recorded in fruits coated with CMC 2 per cent followed by its 1.5 per cent concentration (0.55 mg/100g). The control fruits registered the lowest total carotenoids (0.47 mg %) content. It was further noticed that fruits coated with CMC 2 and 1.5 per cent registered a gradual increase in total carotenoids content after 30 days of storage i.e. 0.86 and 0.88 mg/100g, respectively; thereafter followed a continuous decline till the end of the storage i.e. 0.42 and 0.41 mg/100g pulp, respectively. On the other hand, control fruits followed an abrupt and sharp decline at faster pace in total carotenoids content ranged from 0.78 to 0.25 mg/100g pulp from 30 days to 75 days of storage period. The similar trends were also noticed in 2017-18. CMC (2 and 1.5%) were statistically at par and maintained the mean maximum carotenoids content (0.53 and 0.51 mg/100g pulp, respectively) throughout the storage period, whereas the control fruits registered the lowest average carotenoids content (0.33 mg/100g). The fruits coated with CMC 2 and 1.5 per cent showed a gradual rise in total carotenoids content after 30 days of storage i.e. 0.82 and 0.89 mg/100g pulp, respectively; thereafter followed a continuous decline till the end of the storage i.e. 0.34 and 0.33 mg/100g pulp, respectively. On the other hand, control fruits followed a decline at faster pace in total carotenoids content ranged from 0.58 to

Table 10: Effect of edible coatingand storage interval on the total carotenoids content (mg/100g) of Kinnow fruit stored at 5-7°C and 90-95% RH

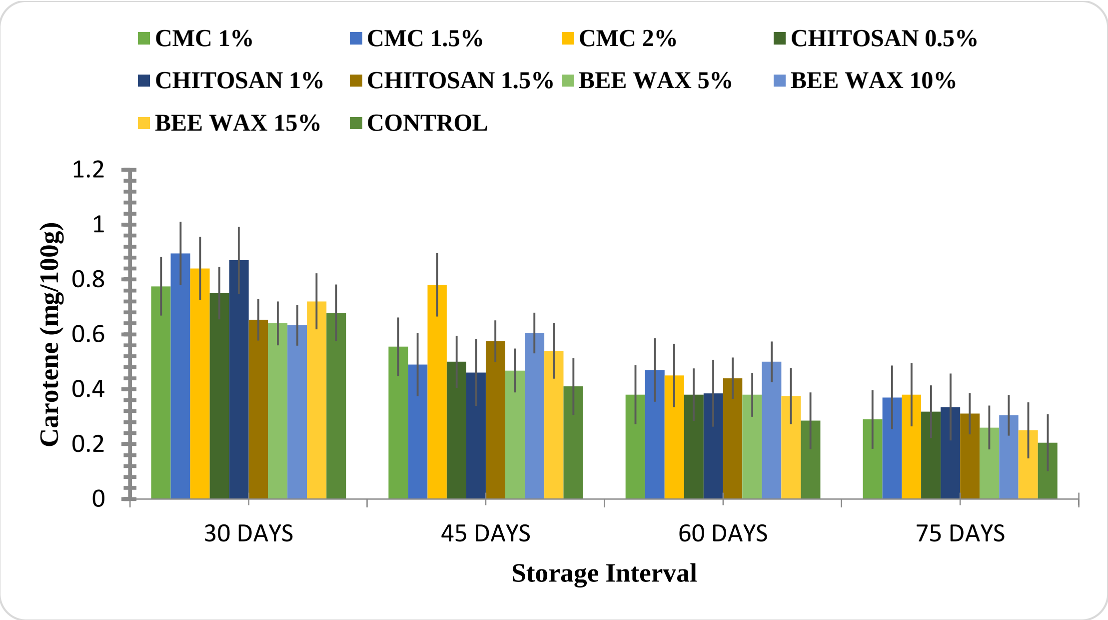
TREATMENT		Total carotenoids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.480	0.710	0.650	0.480	0.400	**0.544**^{bc}	0.370	0.840	0.460	0.280	0.180	**0.426**^{bc}
	1.5%	0.480	0.880	0.560	0.440	0.410	**0.554**^{b}	0.370	0.890	0.500	0.480	0.330	**0.514**^{a}
	2%	0.480	0.860	0.810	0.530	0.420	**0.620**^{a}	0.370	0.820	0.750	0.370	0.340	**0.530**^{a}
Chitosan	**0.5%**	0.480	0.930	0.490	0.380	0.360	**0.528**^{de}	0.370	0.570	0.510	0.380	0.276	**0.421**^{c}
	1%	0.480	0.900	0.480	0.460	0.410	**0.546**^{bc}	0.370	0.606	0.363	0.330	0.160	**0.441**^{bc}
	1.5%	0.480	0.770	0.650	0.480	0.320	**0.540**^{bcd}	0.370	0.536	0.500	0.400	0.303	**0.422**^{c}
Bee wax	**5%**	0.480	0.800	0.560	0.450	0.290	**0.516**^{e}	0.370	0.480	0.376	0.310	0.230	**0.353**^{e}
	10%	0.480	0.660	0.650	0.490	0.450	**0.546**^{bc}	0.370	0.480	0.363	0.330	0.160	**0.436**^{bc}
	15%	0.480	0.810	0.640	0.490	0.250	**0.534**^{cd}	0.370	0.630	0.440	0.260	0.250	**0.390**^{d}
Control		0.480	0.780	0.470	0.350	0.250	**0.466**^{f}	0.370	0.576	0.350	0.220	0.160	**0.335**^{f}
Mean		**0.480**^{c}	**0.810**^{a}	**0.596**^{b}	**0.455**^{d}	**0.356**^{e}		**0.370**^{c}	**0.681**^{a}	**0.481**^{b}	**0.354**^{d}	**0.249**^{e}	
LSD (P≤0.05)		**Treatment (T)** = 0.0159 **Days (D)** = 0.0112 **D x T** = 0.0356						**Treatment (T)** = 0.0160 **Days (D)** = 0.0113 **D x T** = 0.0359					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 10a: Effect of different edible coating and storage interval on the total carotenoids content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total carotenoids (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.425	0.775	0.555	0.380	0.290	**0.485^{cd}**
	1.5%	0.425	0.895	0.490	0.470	0.370	**0.530^{b}**
	2%	0.425	0.840	0.780	0.450	0.380	**0.575^{a}**
Chitosan	**0.5%**	0.425	0.750	0.500	0.380	0.318	**0.474^{cd}**
	1%	0.425	0.870	0.461	0.385	0.335	**0.495^{c}**
	1.5%	0.425	0.653	0.575	0.440	0.311	**0.481^{cd}**
Bee Wax	**5%**	0.425	0.640	0.468	0.380	0.260	**0.434^{e}**
	10%	0.425	0.633	0.605	0.500	0.305	**0.493^{c}**
	15%	0.425	0.720	0.540	0.375	0.250	**0.462^{de}**
Control		0.425	0.678	0.410	0.285	0.205	**0.400^{f}**
Mean		**0.425^{c}**	**0.745^{a}**	**0.538^{b}**	**0.404^{d}**	**0.302^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.027 **Days (D)** = 0.019 **D x T** = 0.062					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.10: Effect of different edible coatings and storage interval on the total carotenoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

0.16 mg/100g pulp from 30 days to 75 days of storage period. The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The pooled mean analysis of both the years (Table 10a and Fig 10) also confirmed the findings as fruits coated with CMC 2 per cent recorded the mean maximum carotenoids content (0.57 mg/100g pulp) followed by its 1.5 per cent concentration (0.53 mg/100g pulp). However, control fruits retained the lowest average carotenoids content (0.40 mg/100g). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the control fruits followed a continuous instability and subsequent reduction of total carotenoids because of the vulnerability to oxidation and geometric isomerization of its polyene chain during storage (Sanchez-Moreno *et al* 2003). Ethylene causes the loss of chlorophylls, produces some minor changes in carotenoids, induces carotenoid synthesis and thus has the potential to re-establish the orange colors (El-Zeftawi and Garrett 1978).

The results are in the conformity to the findings of Samra *et al* (2014) who reported that the postharvest application of CMC, chitosan and beeswax registered the maximum carotenoids in tangor fruit cv. 'Murcott' at the end of storage. Edible coatings retained the maximum carotenoids content over control fruits during storage in carambola (Gol *et al* 2015), prickly pear (Mohamed *et al* 2013), tomato (Ambarsari *et al* 2017) and carrot (Li and Barth 1998) may be due to the fact that edible coatings serve as carriers of antioxidants, texture enhancers and nutraceuticals which help in decreasing the water vapor and oxygen gas transfer, resulting in the diminished respiration rate and ethylene production (Rojas-Grau *et al* 2008).

4.1.11 Pectin (Ca pectate %)

The results pertaining to the effect of the edible coatings revealed a gradual decrease in pectin content in all the fruits during storage period irrespective of the treatment (Table 11). In 2016-17, the maximum mean pectin (0.56%) content was recorded in the fruits treated with CMC 2 per cent followed by its 1.5 per cent concentration (0.54%). However, control fruits showed the highest rate of pectin depletion and registered the lowest average pectin content (0.46%). The data further revealed that the pectin content in the fruits treated with CMC 2 and 1.5 per cent ranged from 0.76 to 0.30 and 0.72 to 0.26 per cent, respectively from 30 days to 75 days of the storage. On the other hand, control fruits registered an abrupt decline in pectin content ranged from 0.65 to 0.12 per cent from 30 days to 75 days of the storage. The similar trend was also noticed in 2017-18. Fruits coated with CMC 2 per cent werestatistically at par with CMC 1.5 per cent and retained the mean maximum pectin content (0.34 and 0.33 %, respectively). On the other hand, control fruits followed a faster decline in pectin content and thereby registered the lowest average pectin content (0.28%). The data further revealed that the pectin content in fruits coated with CMC 2 and 1.5 per cent ranged from 0.43 to 0.16 and 0.45 to 0.23 per cent, respectively from 30 days to 75 days of storage. However, control fruits

Table 11: Effect of different edible coatings and storage interval on the pectin (Ca pectate %) of Kinnow fruit stored at 5-7°C and 90-95% RH

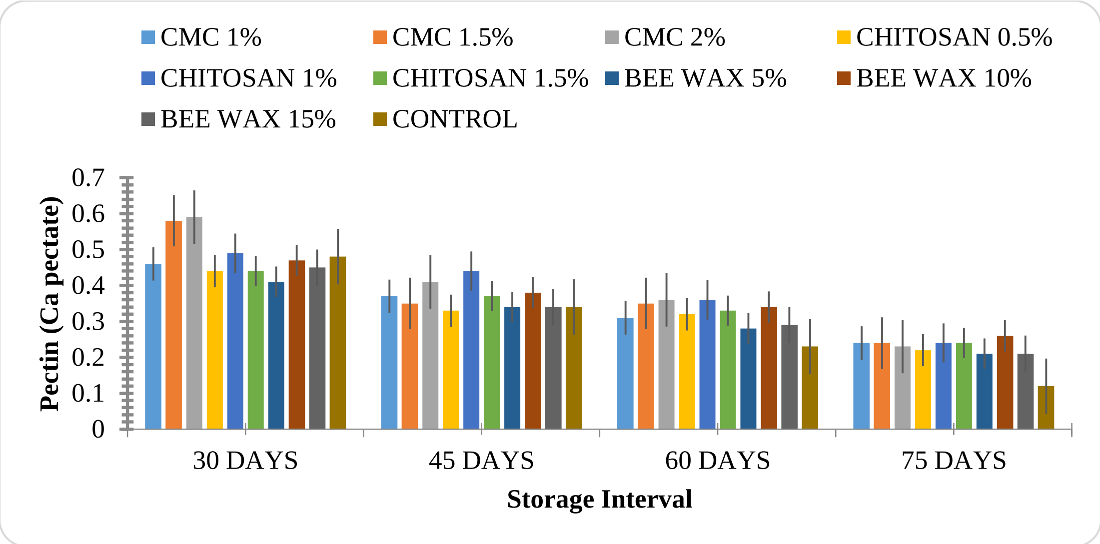
TREATMENT		Pectin (Calcium pectate %)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	**1%**	0.80	0.60	0.42	0.40	0.32	**0.51^{d}**	0.50	0.33	0.32	0.22	0.17	**0.31^{bc}**
	1.5%	0.80	0.72	0.47	0.46	0.26	**0.54^{b}**	0.50	0.45	0.24	0.24	0.23	**0.33^{a}**
	2%	0.80	0.76	0.51	0.44	0.30	**0.56^{a}**	0.50	0.43	0.31	0.29	0.16	**0.34^{a}**
Chitosan	**0.5%**	0.80	0.60	0.40	0.39	0.29	**0.50^{de}**	0.50	0.29	0.27	0.25	0.15	**0.29^{d}**
	1%	0.80	0.65	0.56	0.46	0.24	**0.54^{b}**	0.50	0.33	0.32	0.27	0.24	**0.33^{a}**
	1.5%	0.80	0.60	0.48	0.40	0.28	**0.51^{cd}**	0.50	0.29	0.27	0.27	0.19	**0.30^{c}**
Bee wax	**5%**	0.80	0.55	0.44	0.32	0.25	**0.47^{g}**	0.50	0.28	0.24	0.24	0.17	**0.28^{de}**
	10%	0.80	0.58	0.49	0.44	0.32	**0.53^{bc}**	0.50	0.37	0.26	0.25	0.20	**0.32^{b}**
	15%	0.80	0.62	0.45	0.36	0.20	**0.49^{ef}**	0.50	0.28	0.23	0.23	0.22	**0.29^{d}**
Control		0.80	0.65	0.45	0.26	0.12	**0.46^{g}**	0.50	0.32	0.23	0.21	0.13	**0.28^{e}**
Mean		**0.80^{a}**	**0.63^{b}**	**0.47^{c}**	**0.39^{d}**	**0.26^{e}**		**0.50^{a}**	**0.34^{b}**	**0.27^{c}**	**0.25^{d}**	**0.19^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.0163 **Days (D)** = 0.0115 **D x T** = 0.0365						**Treatment (T)** = 0.00097 **Days (D)** = 0.00069 **D x T** = 0.0218					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 11a: Effect of different edible coatings and storage interval on the pectin content (Ca pectate %) in Kinnow fruit stored at 5-7°C and 90-95% RH

Pectin (Ca pectate %)							
Storage interval (Days)							
TREATMENTS		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.65	0.46	0.37	0.31	0.24	**0.41^{cd}**
	1.5%	0.65	0.58	0.35	0.35	0.24	**0.44^{ab}**
	2%	0.65	0.59	0.41	0.36	0.23	**0.45^{a}**
Chitosan	**0.5%**	0.65	0.44	0.33	0.32	0.22	**0.39^{cde}**
	1%	0.65	0.49	0.44	0.36	0.24	**0.44^{ab}**
	1.5%	0.65	0.44	0.37	0.33	0.24	**0.40^{bcd}**
Bee Wax	**5%**	0.65	0.41	0.34	0.28	0.21	**0.38^{e}**
	10%	0.65	0.47	0.38	0.34	0.26	**0.42^{abc}**
	15%	0.65	0.45	0.34	0.29	0.21	**0.39^{de}**
Control		0.65	0.48	0.34	0.23	0.12	**0.37^{e}**
Mean		**0.65^{a}**	**0.48^{b}**	**0.37^{c}**	**0.32^{d}**	**0.22^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.029 **Days (D)** = 0.020 **D x T** = 0.064					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.11: Effect of different edible coatings and storage interval on the pectin content (Ca pectate %) of Kinnow fruit stored at 5-7°C and 90-95% RH

showed an abrupt and sharp decline in pectin content and ranged 0.32 to 0.12 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 11a and Fig 11). CMC 2 percent was proved best in terms of retaining and maintaining average maximum pectin (0.45%) content followed by its 1.5 per cent concentration (0.44%) on the other hand, control fruits registered the lowest pectin content (0.37%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the loss in pectin content might be due to the degree of fruit ripening affects the pectin contents, which supports the hypothesis that softening is closely related to pectin solubilisation and depolymerization (Kurz *et al* 2008 and Rosli *et al* 2004).

These results are in conformity to the findings of Samra *et al* (2014) however, who observed that tangor fruits cv. Murcott coated with CMC, chitosan and bees wax registered the lowest pectin content in contrast to control during storage; this might be due to the role of edible coatings in reducing moisture loss and respiratory activity and thus maintained the turgidity of the cells (Ribeiro *et al* 2007 and Adetunji *et al* 2012). Jongsri *et al* (2017) reported that combined application of chitosan (1%) and spermidine (0.1 ppm) registered lower soluble pectin content in mango cv. 'Nam Dok Mai' than that of control. Edible coating *viz* starch coating led to a higher content of soluble pectins in contrast to the control in radish (Schreiner *et al* (2003).

4.1.12 Total phenol (mg/100g)

The data pertaining to the effect of edible coatings on total phenolics content revealed an identical trend during storage (Table 12). All the coating treatments showed a significant effect with regard to maintain the total phenol content during storage. In the 2016-17, Fruits treated with CMC 2 per cent followed by its 1.5 per cent concentration registered the average maximum total phenol (143.26 and 131.98 mg/100g pulp) content. On the other hand, the control fruits registered the lowest average total phenol (110.31 mg/100g pulp) content. A gradual increase in total phenol content was noticed in the fruits treated with CMC 2 and 1.5 per cent after 30 days of storage i.e. 243.61 and 206.30 mg/100g, respectively; thereafter followed an abrupt decline till the end of the storage i.e. 37.39 and 71.43 mg/100g pulp, respectively. On the other hand, the control fruits followed an abrupt decline in total phenol content at faster pace with further prolongation in storage period and thereby ranged from 190.79 to 30.75 mg/100 g pulp, respectively from 30 days to 75 days of storage. Similar trend was also noticed in 2017-18. CMC 2 and 1.5 per cent were statistically at par with each other and emerged as superior in terms of retaining the highest average phenol content during storage (147.08 and 142.67 mg/100g pulp), respectively. However, the control fruits retained the lowest average total phenolics (118.57 mg/100g pulp) content. The data further revealed that fruits coated with CMC 2 and 1.5 per cent registered a gradual rise in total phenol after

Table 12: Effect of edible coatings and storage interval on the total phenol content (mg/100g) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

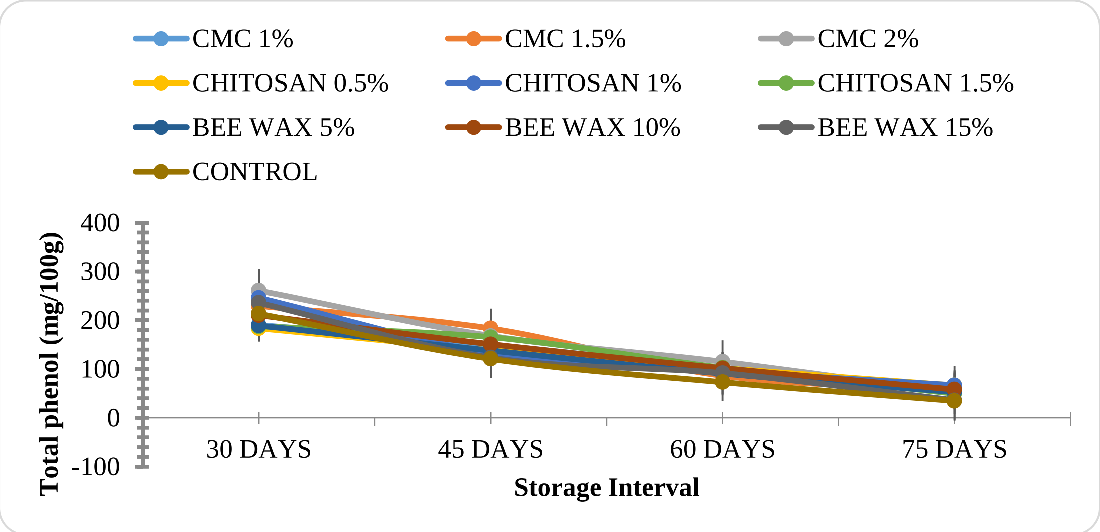
TREATMENT		Total phenols (mg/100g)											
		2016-17						**2017-18**					
		Storage interval (Days)						**Storage interval (Days)**					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	128.13	192.20	117.26	113.68	65.80	**123.41**^{c}	131.84	188.49	182.48	89.64	66.11	**131.71**^{d}
	1.5%	128.13	206.39	170.08	83.89	71.43	**131.98**^{b}	131.84	252.56	196.42	88.62	43.89	**142.67**^{ab}
	2%	128.13	243.61	167.90	139.26	37.39	**143.26**^{a}	131.84	278.13	168.16	90.79	66.50	**147.08**^{a}
Chitosan	**0.5%**	128.13	166.11	130.43	115.98	69.61	**122.05**^{c}	131.84	201.15	146.67	87.72	63.30	**126.14**^{ef}
	1%	128.13	215.73	146.16	90.54	65.00	**129.11**^{b}	131.84	276.21	119.18	102.05	68.93	**139.64**^{bc}
	1.5%	128.13	181.07	170.46	96.04	39.44	**123.03**^{c}	131.84	194.50	160.36	109.46	59.85	**131.20**^{de}
Bee wax	**5%**	128.13	184.27	108.18	98.85	59.28	**115.74**^{d}	131.84	194.25	167.90	82.86	46.44	**124.66**^{f}
	10%	128.13	206.78	117.77	93.61	70.85	**123.43**^{c}	131.84	214.07	184.27	110.10	45.28	**137.11**^{c}
	15%	128.13	218.54	127.62	100.64	31.40	**121.27**^{c}	131.84	253.07	119.44	82.75	40.90	**125.60**^{f}
Control		128.13	190.79	131.21	70.68	30.75	**110.31**^{e}	131.84	236.06	110.74	75.40	38.80	**118.57**^{g}
Mean		**128.13**^{c}	**200.55**^{a}	**138.71**^{b}	**100.32**^{d}	**54.09**^{e}		**131.84**^{c}	**228.85**^{a}	**155.56**^{b}	**91.94**^{d}	**54.00**^{e}	
LSD (P≤0.05)		**Treatment (T)** = 4.99 **Days (D)** = 3.53 **D x T** = 11.15						**Treatment (T)** = 5.09 **Days (D)** = 3.60 **D x T** = 11.38					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 12a: Effect of different edible coatings and storage interval on the total phenol content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total phenols (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	129.99	190.35	149.87	101.66	65.96	**127.56^{cde}**
	1.5%	129.99	229.48	183.25	86.25	57.66	**137.32^{b}**
	2%	129.99	260.87	168.03	115.03	51.94	**145.17^{a}**
Chitosan	**0.5%**	129.99	183.63	138.55	101.85	66.46	**124.10^{de}**
	1%	129.99	245.97	132.67	96.29	66.96	**134.38^{bc}**
	1.5%	129.99	187.79	165.41	102.75	49.65	**127.11^{cde}**
Bee Wax	**5%**	129.99	189.26	138.04	90.85	52.86	**120.20^{ef}**
	10%	129.99	210.42	151.02	101.85	58.07	**130.27^{bcd}**
	15%	129.99	235.80	123.53	91.70	36.15	**123.43^{de}**
Control		129.99	213.43	120.98	73.04	34.78	**114.44^{f}**
Mean		**129.99^{c}**	**214.70^{a}**	**147.14^{b}**	**96.13^{d}**	**54.05^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 7.65 **Days (D)** = 5.41 **D x T** = 17.12					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 12: Effect of different edible coating and storage interval on the total phenol content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

30 days of storage (278.13 and 252.56 mg/100g pulp), respectively which thereafter declined till the end of the storage i.e. 66.50 and 43.89 mg/100 g pulp, respectively. On the other hand, control fruits followed a continuous decline in total phenol at faster pace with prolongation in storage period and ranged from 236.06 to 38.80 mg/100g pulp from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant in 2016-17 and 2017-18. The pooled mean analysis of both the years (Table 12a and Fig 12) also revealed the similar findings as fruits coated with CMC 2 per cent retained the mean maximum total phenol (145.17 mg/100g pulp) followed by its 1.5 per cent concentration (137.32 mg/100g pulp), while control fruits recorded the lowest average total phenol (114.44 mg/100g pulp) content. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, coating retained the maximum total phenol content in contrast to control; might be due to coating serves as a protective barrieron the fruit surface and reduce the oxygen supply for enzymatic oxidation of phenolics compound ((Zhang and Quantick 1997).

The results are in corroboration with the findings of Dang and Wang (2017) and Gol *et al* (2013) who observed that the post-harvest application of CMC exhibited the highest level of total phenol content in strawberry fruit. Nair *et al* (2018) reported that the post-harvest application of chitosan registered the higher content of total phenol content in guava fruit. Similar results were also reported in plum (Kumar *et al* 2017); kiwi fruit (Kaya *et al* 2016); carambola (Gol *et al* 2015); blueberry (Duan *et al* 2011) and apricot fruit during storage (Ghasmnezhad *et al* 2010).

4.1.13 Pectin methylesterase (PME) activity

The results pertaining to effect of edible coatings on PME activity (micro equi. acid produced/min/g tissue) illustrated that the enzyme activity registered significant changes over the storage intervals (Table 13). In general, the maximum PME activity with respect to storage interval was recorded after 60 days of storage followed by a sudden decline at 75 days of storage. In 2016-17, The lowest averagePME activity (0.26 micro equi. acid produced/min/ml tissue) was noticed in the fruits coated with CMC 2 per cent followed by its 1.5 per cent concentration (0.27 micro equi. acid produced/min/ml tissue), respectively. On the other hand, control fruits registered the highest average PME activity (0.33 micro equi. acid produced/min/ml tissue). The data further revealed that fruits coated with CMC 2 per cent and its 1.5 per cent concentration delayed peak in PME activity after 60 days of storage i.e. 0.37 and 0.44 micro equi. acid produced/min/ml tissue, respectively. However, control fruits showed an earliest peak in PME activity after 45 days of storage i.e. 0.59 micro equi. acid produced /min/ ml tissue. Similar trend was also noticed during 2017-18. Fruits coated with CMC 2 and 1.5 per cent treatments registered the lowest average PME activity (1.58 and 1.77 micro equi. acid produced /min/ ml tissue), respectively. On the other hand, the control fruits registered the

Table 13: Effect of different edible coating and storage interval on PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

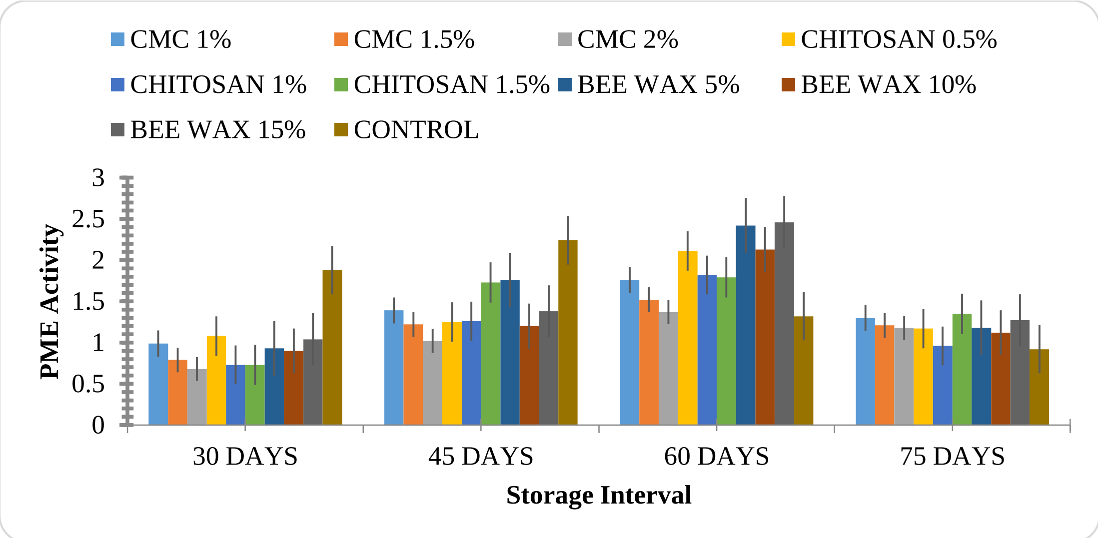
TREATMENT		PME activity (unit/ml)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.12	0.18	0.41	0.46	0.33	**0.30**^{b}	0.63	1.80	2.36	3.06	2.26	**2.02**^{e}
	1.5%	0.12	0.17	0.31	0.44	0.33	**0.27**^{de}	0.63	1.40	2.13	2.60	2.10	**1.77**^{f}
	2%	0.12	0.20	0.35	0.37	0.29	**0.26**^{e}	0.63	1.17	1.67	2.40	2.06	**1.58**^{g}
Chitosan	**0.5%**	0.12	0.22	0.34	0.50	0.35	**0.31**^{b}	0.63	1.27	2.16	3.73	2.00	**2.09**^{d}
	1%	0.12	0.23	0.39	0.44	0.22	**0.28**^{cd}	0.63	1.23	2.13	3.20	1.70	**1.78**^{f}
	1.5%	0.12	0.19	0.36	0.46	0.37	**0.30**^{b}	0.63	1.27	3.10	3.13	2.33	**2.09**^{d}
Bee wax	**5%**	0.12	0.23	0.39	0.51	0.42	**0.33**^{a}	0.63	1.63	3.13	4.33	1.93	**2.33**^{b}
	10%	0.12	0.20	0.37	0.46	0.28	**0.29**^{c}	0.63	1.60	2.03	3.80	1.96	**2.00**^{e}
	15%	0.12	0.22	0.40	0.63	0.25	**0.32**^{a}	0.63	1.86	2.03	4.30	2.30	**2.29**^{c}
Control		0.12	0.41	0.59	0.31	0.20	**0.33**^{a}	0.63	3.36	3.36	2.33	1.65	**2.37**^{a}
Mean		**0.12**^{e}	**0.22**^{d}	**0.40**^{b}	**0.45**^{a}	**0.30**^{c}		**0.63**^{e}	**1.72**^{d}	**2.66**^{b}	**3.04**^{a}	**2.03**^{c}	
LSD (**P≤0.05**)		**Treatment (T)** =0.0115 **Days (D)** =0.000810 **D x T** = 0.026						**Treatment (T)** = 0.048 **Days (D)** = 0.034 **D x T** = 0.107					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 13a: Effect of different edible coatings and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

PME activity (unit/ml)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.37	0.99	1.39	1.76	1.30	**1.16^{abc}**
	1.5%	0.37	0.79	1.22	1.52	1.21	**1.02^{bc}**
	2%	0.37	0.68	1.02	1.37	1.18	**0.92^{c}**
Chitosan	**0.5%**	0.37	1.08	1.25	2.11	1.17	**1.20^{ab}**
	1%	0.37	0.73	1.26	1.82	0.96	**1.03^{bc}**
	1.5%	0.37	0.73	1.73	1.79	1.35	**1.20^{ab}**
Bee Wax	**5%**	0.37	0.93	1.76	2.42	1.18	**1.33^{a}**
	10%	0.37	0.90	1.20	2.13	1.12	**1.14^{abc}**
	15%	0.37	1.04	1.38	2.46	1.27	**1.31^{a}**
Control		0.37	1.88	2.24	1.32	0.92	**1.35^{a}**
Mean		0.37	**0.97^{d}**	**1.44^{b}**	**1.87^{a}**	**1.17^{c}**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 0.25 **Days (D)** = 0.18 **D x T** = 0.56					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 13: Effect of different edible coatings and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

highest average PME activity (2.37 micro equi. acid produced /min/ ml tissue). A delayed peak in PME activity was noticed in the fruits coated with CMC 2 and its 1.5 per centconcentration after 60 days of storage i.e. 2.40 and 2.60 micro equi. acid produced /min/ ml tissue), respectively while, control fruits recorded an earliest peak in PME activity after 45 days of storage i.e 3.36 micro equi. acid produced/min/ml tissue. The interaction between treatments and storage interval was found to be significant during both years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 13a and Fig 13). CMC 2 per cent registered the lowest average PME activity (0.92 micro equi. acid produced /min/ ml tissue) followed by its 1.5 per cent concentration (1.02 micro equi. acid produced /min/ ml tissue) whereas, control fruits registered the highest average PME activity (1.35 micro equi. acid produced /min/ ml tissue). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present investigation, the coated Kinnow fruits delayed a peak in PME activity as pectins are the main constituents of the middle lamella and primary cell wall of the fruit, and are hydrolyzed by PME to generate demethylated pectins that can be more easily hydrolyzed by PG and thus causing the depolymerization of pectins in coated fruit contributed to the enhanced retention of brittleness and firmness during storage (Zhou *et al* 2011).

The results are in corroboration with the findings of Gol *et al* (2013) who reported that combined application of HPMC (1%) + chitosan (%) restricted the PME activity in strawberry fruit during cold storage. Likewise, Gol *et al* (2015) studied the effect of chitosan, gum arabic and alginate coatings on quality and shelf-life of carambola fruit and found that coating with chitosan exhibited the lowest PME activity in contrast to control. Kumar *et al* (2017) who observed that the coating with chitosan resulted linear activity of PME in contrast to control in the plum fruit during the storage.. Inhibition of carbon dioxide production in chitosan-coated fruits due to suppressed respiration rate during storage can be one of the factors for reduced PME activity in coated plum fruits (Liu *et al* 2014).

4.1.14 Cellulase activity

The data pertaining to the effect of edible coating on cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$) illustrated that the enzyme activity registered a significant change with an adavncement in storage period (Table 14). In general, the maximum cellulase activity was registered after 60 days of storage followed by a sudden decline after 75 days of storage. In 2016-17, the lowest average cellulase activity (1.75 mg glucose per min^{-1} mg $protein^{-1}$) was noticed in the fruits coated with CMC 2 per cent followed by CMC 1.5 per cent concentration (1.85 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, the control fruits registered the maximum cellulase activity (2.92 mg glucose per min^{-1} mg $protein^{-1}$). The data further revealed that fruits coated with CMC 2 per cent and 1.5 per cent concentration showed a delayed peak in cellulase activity after 60 days of storage i.e. 3.59 and 3.57 mg glucose per min^{-1} mg $protein^{-1}$,

Table 14: Effect of different edible coatings and storage interval on the cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$) of Kinnow fruit stored at 5-7°C and 90-95% RH

TREATMENT		Cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.85	1.94	2.49	4.67	1.31	**2.20^{d}**	1.68	1.76	1.95	9.18	2.28	**3.37^{e}**
	1.5%	0.85	1.56	2.39	3.57	0.87	**1.85^{f}**	1.68	1.82	3.33	3.58	0.86	**2.29^{g}**
	2%	0.85	1.66	2.25	3.59	0.38	**1.75^{g}**	1.68	2.25	2.30	3.87	1.27	**2.19^{h}**
Chitosan	**0.5%**	0.85	2.62	3.80	3.86	0.94	**2.41^{c}**	1.68	3.83	3.91	8.64	0.93	**3.80^{c}**
	1%	0.85	1.61	1.97	4.21	0.90	**1.91^{e}**	1.68	2.46	4.06	5.68	1.39	**3.05^{f}**
	1.5%	0.85	1.66	1.82	6.28	0.43	**2.21^{d}**	1.68	2.87	4.70	6.59	1.48	**3.47^{d}**
Bee wax	**5%**	0.85	2.04	4.10	6.29	1.29	**2.91^{a}**	1.68	4.54	5.08	10.34	4.26	**5.18^{a}**
	10%	0.85	1.94	2.72	2.49	1.25	**2.18^{d}**	1.68	2.87	4.62	6.16	0.72	**3.09^{f}**
	15%	0.85	2.19	2.72	5.87	2.11	**2.75^{b}**	1.68	2.95	8.22	10.32	1.60	**4.95^{b}**
Control		0.85	2.75	5.78	4.83	0.28	**2.92^{a}**	1.68	6.08	13.49	4.24	0.53	**5.20^{a}**
Mean		**0.85^{e}**	**1.97^{c}**	**3.01^{b}**	**4.73^{a}**	**0.98^{d}**		**1.68^{d}**	**3.05^{c}**	**5.17^{b}**	**6.86^{a}**	**1.53^{e}**	
LSD ($P\leq0.05$)		**Treatment (T) =** 0.058 **Days (D) =** 0.041 **D x T** = 0.13						**Treatment (T)** = 0.084 **Days (D)** = 0.059 **D x T** = 0.19					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

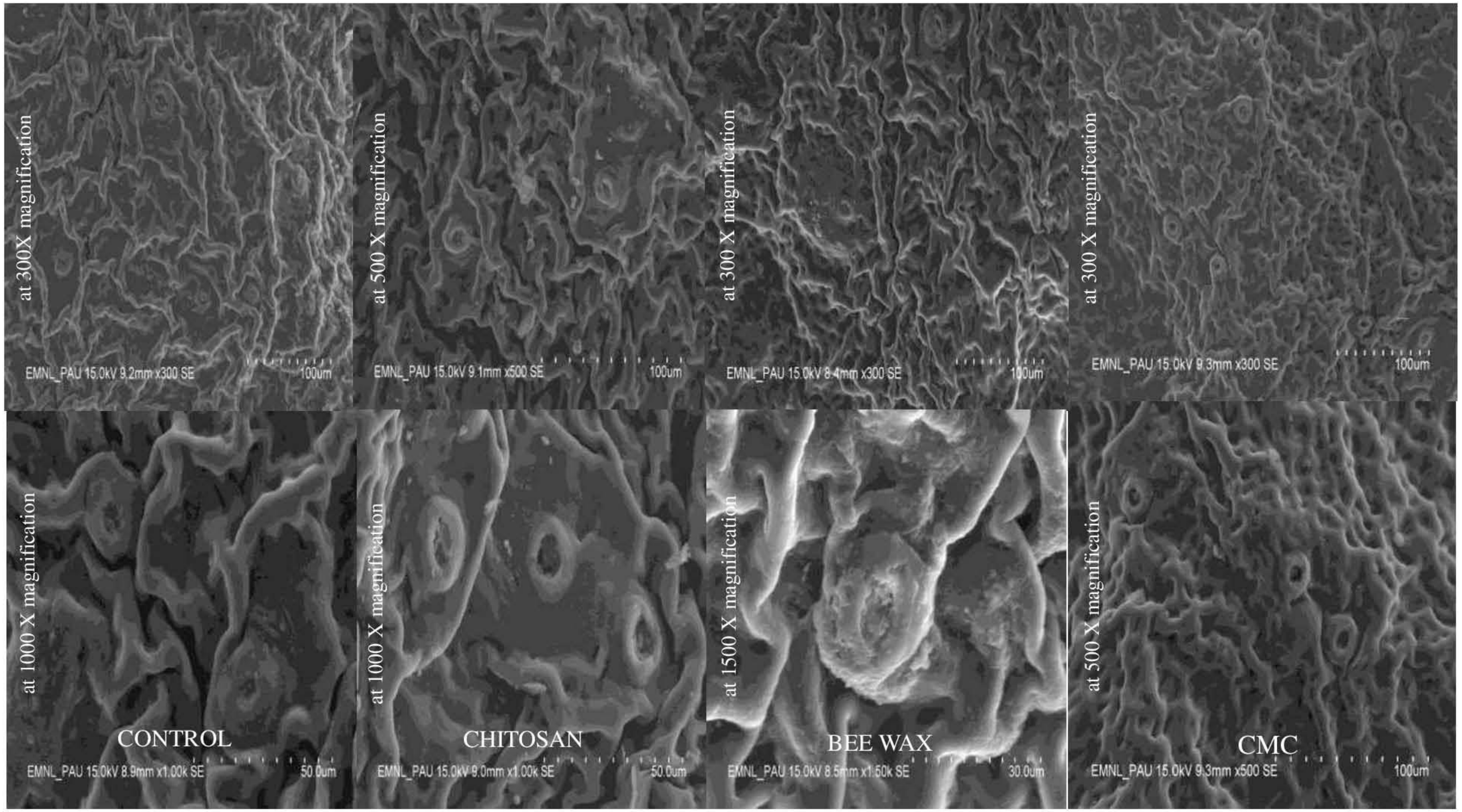


Fig. 1. Scanning electron microscope (SEM) micrographs at two different magnifications of Kinnow fruit surface, showing an un-waxed fruit surface as a control, fruit coated with chitosan (1%), bees wax (10%) and CMC (2%) after 30 days of storage

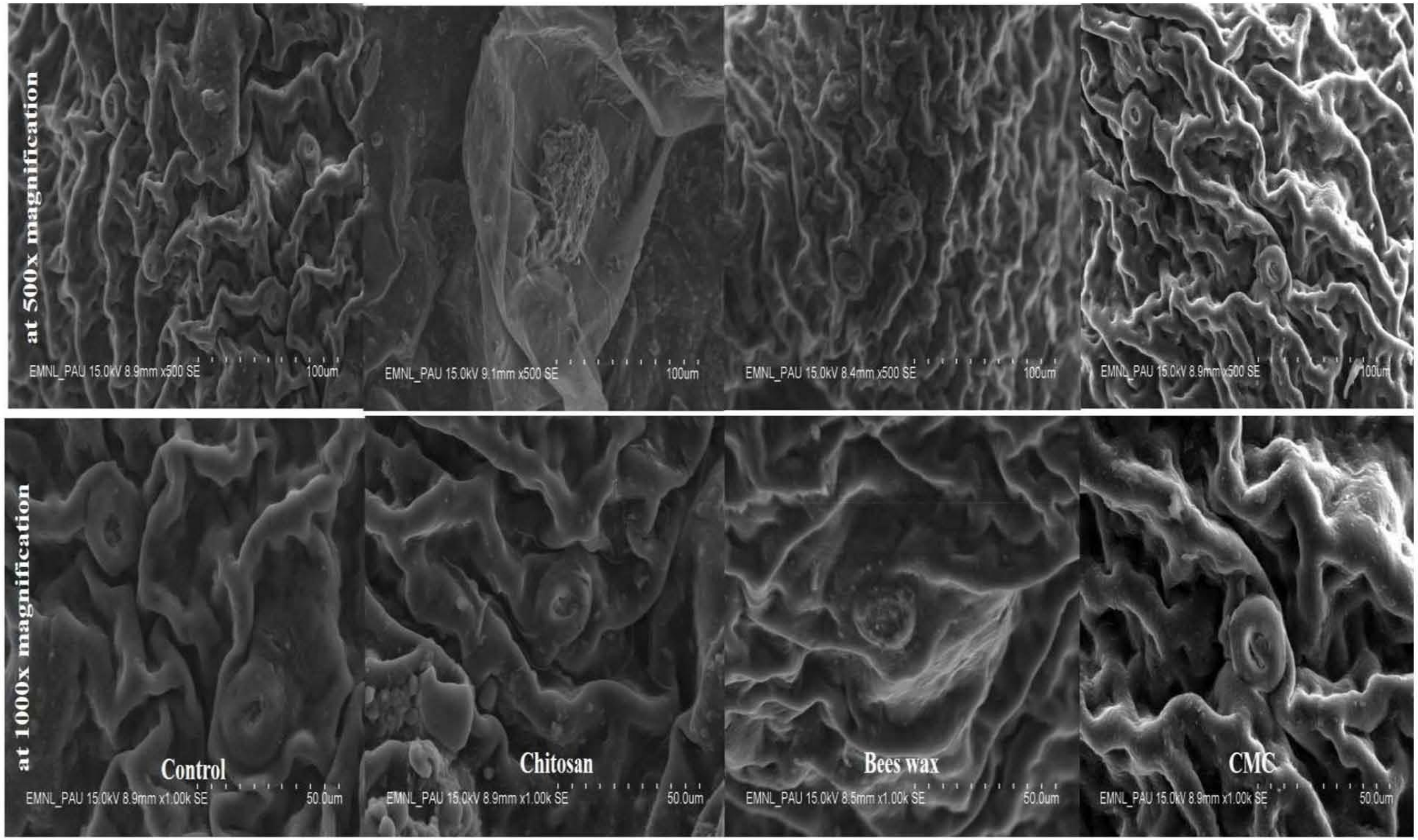


Fig. 2 Scanning electron microscope (SEM) micrographs at two different magnifications of Kinnow fruit surface, showing an un-waxed fruit surface as a control, fruit coated with chitosan (1%), bees wax (10%) and CMC (2%) after 45 days of storage

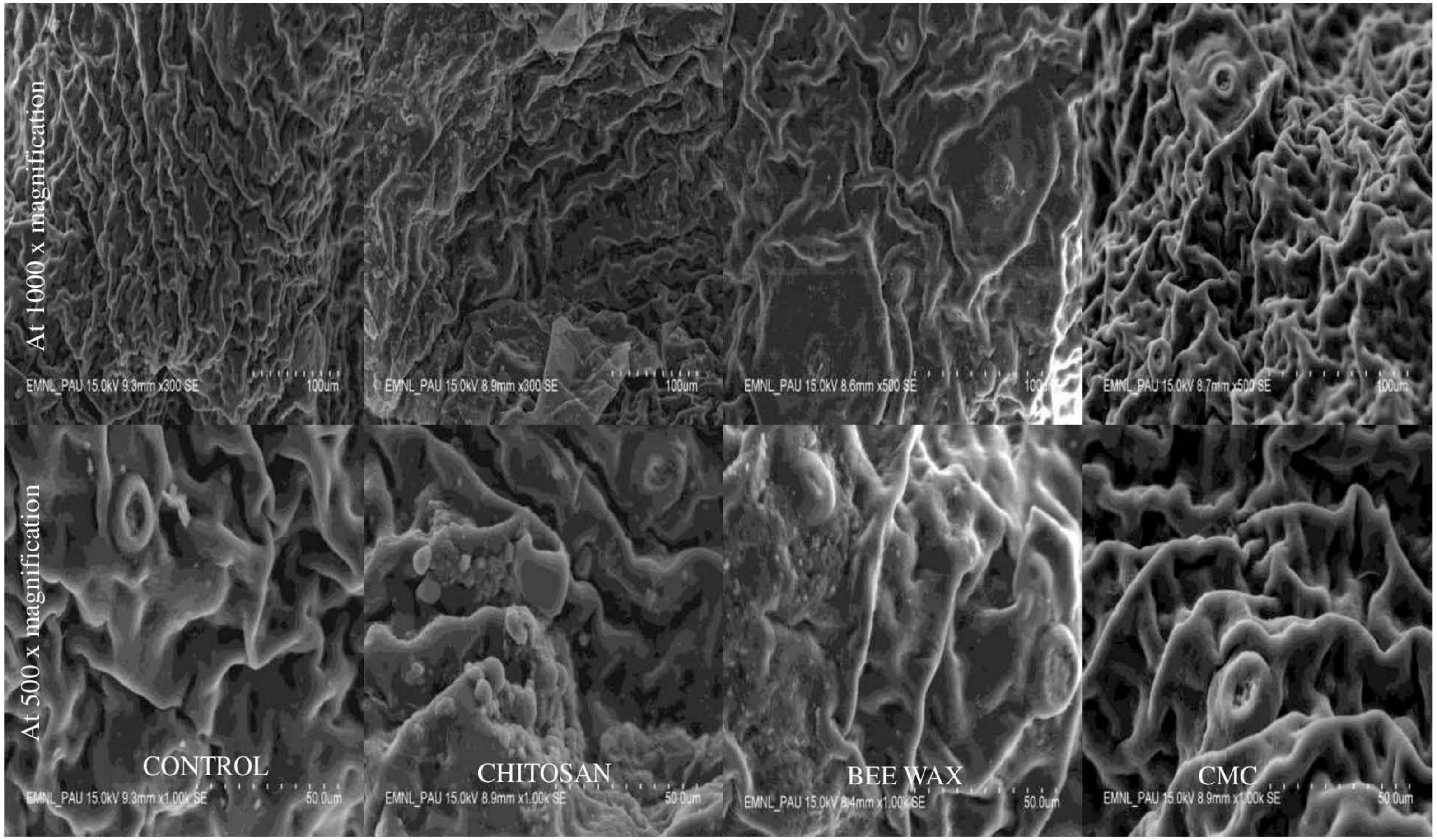


Fig. 3 Scanning electron microscope (SEM) micrographs at two different magnifications of Kinnow fruit surface, showing an un-waxed fruit surface as a control, fruit coated with chitosan (1%), bees wax (10%) and CMC (2%) after 60 days of storage

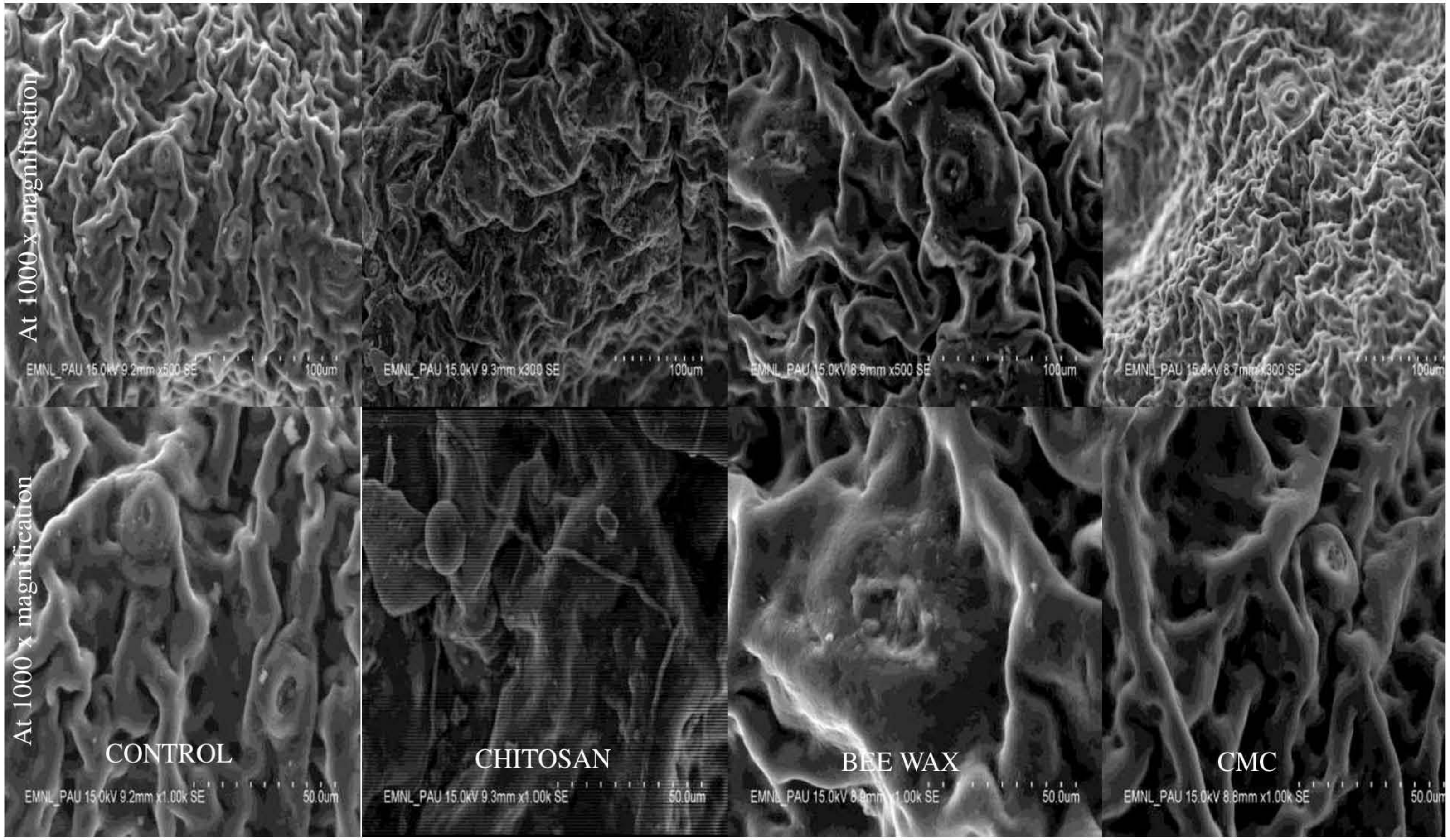


Fig. 4 Scanning electron microscope (SEM) micrographs at two different magnifications of Kinnow fruit surface, showing an un-waxed fruit surface as a control, fruit coated with chitosan (1%), bees wax (10%) and CMC (2%) after 75 days of storage

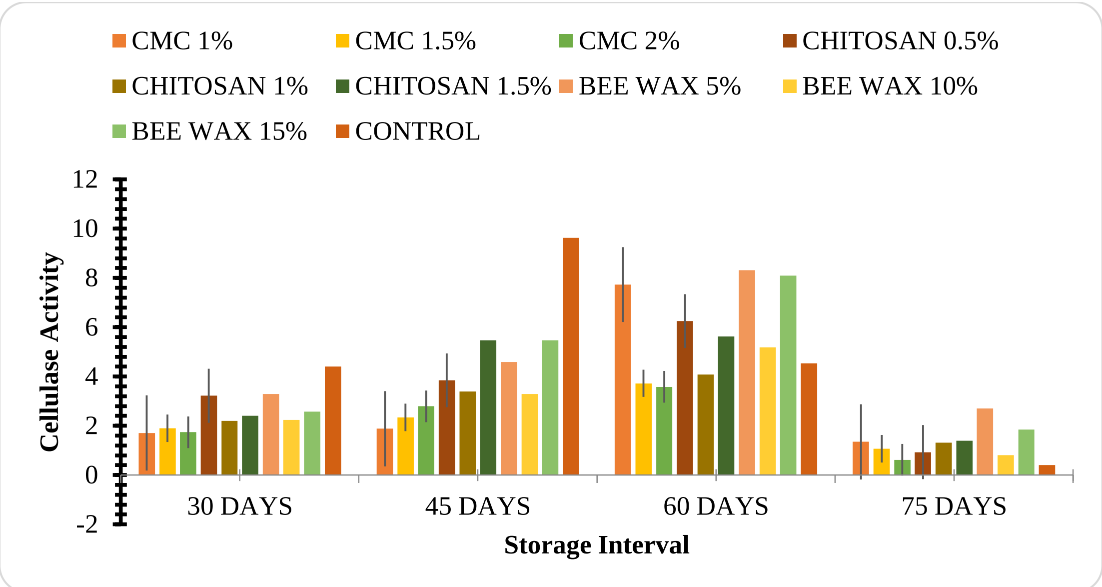
PIC : KINNOW FRUITS COATED WITH CMC— 2%

PIC: KINNOW FRUITS (CONTROL)

Table 14a: Effect of different edible coatings and storage interval on the cellulase activity (mg glucose per min^{-1} mg protein^{-1}) in Kinnow fruit stored at 5-7°C and 90-95% RH

Cellulase activity (mg glucose per min^{-1} mg protein^{-1})							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	1.26	1.71	1.88	7.73	1.35	**2.79^{d}**
	1.5%	1.26	1.90	2.34	3.72	1.07	**2.06^{g}**
	2%	1.26	1.74	2.79	3.58	0.62	**2.00^{g}**
Chitosan	**0.5%**	1.26	3.22	3.85	6.25	0.93	**3.11^{c}**
	1%	1.26	2.20	3.39	4.08	1.32	**2.45^{f}**
	1.5%	1.26	2.41	5.47	5.63	1.39	**2.86^{d}**
Bee Wax	**5%**	1.26	3.29	4.59	8.31	2.71	**4.03^{a}**
	10%	1.26	2.24	3.29	5.18	0.81	**2.56^{e}**
	15%	1.26	2.57	5.47	8.09	1.85	**3.85^{b}**
Control		1.26	4.41	9.63	4.53	0.40	**4.05^{a}**
Mean		**1.26^{d}**	**2.57^{c}**	**4.08^{b}**	**5.71^{a}**	**1.25^{d}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.07 **Days (D)** = 0.049 **D x T** = 0.16					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 14: Effect of different edible coatings and storage interval on the cellulase activity (mg glucose per min^{-1} mg protein^{-1}) in Kinnow fruit stored at 5-7°C and 90-95% RH

respectively. However, an earliest peak in cellulase activity was noticed in the control fruits after 45 days of storage i.e. 5.78 mg glucose per min^{-1} mg $protein^{-1}$. The similar trend was also noticed in 2017-18. Fruits coated with CMC 2 and CMC 1.5 per cent concentration registered the lowest cellulase activity (2.19 and 2.29 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, control fruits registered the maximum cellulase activity i.e. 5.20 mg glucose per min^{-1} $mgprotein^{-1}$. A delayed peak in cellulase activity was noticed in the fruits treated with CMC 2 and CMC 1.5 per cent after 60 days of storage i.e. 3.87 and 3.58 mg glucose per min^{-1} mg $protein^{-1}$, respectively. However, the control fruits registered an earliest peak in cellulase activity after 45 days of storage i.e. 13.49 mg glucose per min^{-1} mg $protein^{-1}$. The interaction between treatments and storage interval was found to be significant during 2016-17 and 2017-18. The findings were further confirmed through pooled mean analysis of both the years (Table 14a and Fig 14) as fruits coated with CMC 2 per cent registered the lowest average cellulase activity (2.00 mg glucose per min^{-1} mg $protein^{-1}$) followed by CMC 1.5 per cent where it was recorded as 2.06 mg glucose per min^{-1} mg $protein^{-1}$. However, control fruits registered the maximum cellulase activity (4.05 mg glucose per min^{-1} mg $protein^{-1}$). The interaction between treatments and storage interval was found to be significant during both the seasons of investigation.

Fruit softening is associated with cell wall disassembly (Seymour and Gross 1996) and modifications to the pectin fraction are some of the most apparent changes that take place in the cell wall during ripening (Marin-Rodriguez *et al* 2002). The general observation is that softening is accompanied by solubilization of pectin, involving the action of enzymes pectinesterase (PE), polygalacturonase (PG) and pectate lyases (PL) (White 2002).

These results are in corroboration with the findings of Gol *et al* (2013) who demonstrated the effect of CMC, HPMC and chitosan and found that combined application of HPMC + chitosan and CMC + chitosan registered the lowest cellulase activity in contrast to control in strawberry fruit after 12 days of storage. Edible coatings registered inhibition in cellulase activity in pear (Zhou *et al* 2011) and strawberry (Wang and Gao 2013). Chitosan has the ability to inactivate or inhibit activity of several enzymes which cause deterioration of fruit and vegetables (Bhaskar-Reddy *et al* 2000).

4.2 Effect of different anti-senescence compounds on physical, biochemical and enzymatic parameters

4.2.1 Physiological loss in weight (%)

The data pertaining to effect of anti-senescence compounds on physiological loss in weight (PLW) in Kinnow fruit revealed a declining trend with prolongation in storage period (Table 15). In the season of 2016-17, it was noticed that the lowest average PLW (4.02 %) was recorded in the fruits treated with MeJA 1mM followed by 1-MCP 1500 ppb (4.31%), whereas, control fruits registered the highest average PLW (10.32%). The PLW in the fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) ranged from 2.23 to 8.13 and 2.37 to 8.91 per cent,

Table 15: Effect of different anti-senescence compounds and storage interval on physiological loss in weight per centage of Kinnow fruit stored at 5-7°C and 90-95% RH

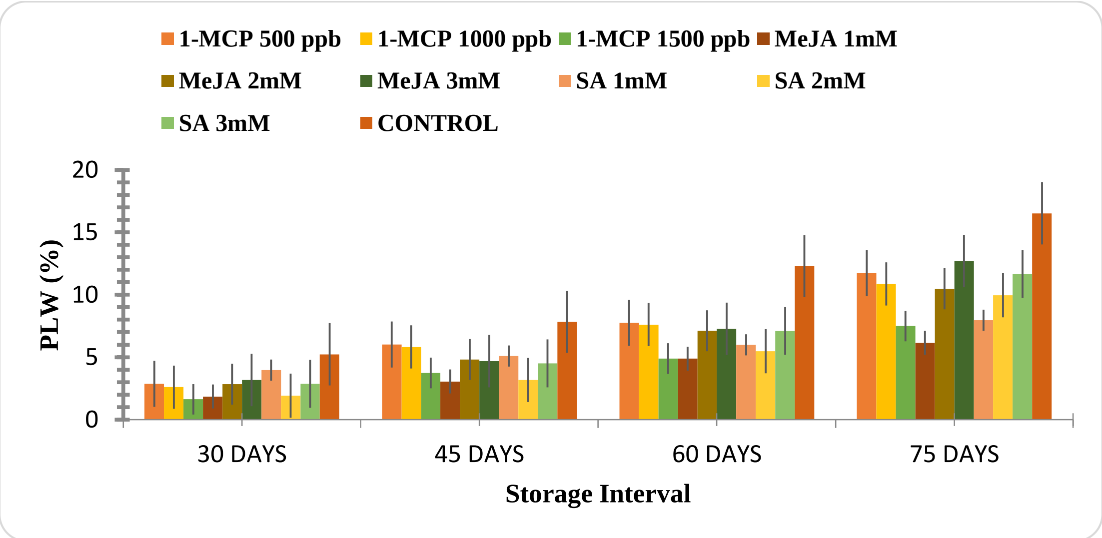
TREATMENT		Physiological loss in weight (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.00	3.00	7.80	9.80	15.00	**7.12[b]**	0.00	2.73	4.22	5.71	8.44	**4.22[b]**
	1000 ppb	0.00	3.40	7.35	9.80	14.50	**7.01[bc]**	0.00	1.81	4.30	5.43	7.24	**3.76[d]**
	1500 ppb	0.00	2.37	4.55	5.74	8.91	**4.31[f]**	0.00	0.90	2.93	4.05	6.08	**2.79[g]**
Methyl Jasmonates	**1 mM**	0.00	2.23	3.65	6.09	8.13	**4.02[f]**	0.00	1.47	2.45	3.68	4.17	**2.35[h]**
	2 mM	0.00	3.97	6.69	9.62	13.17	**6.69[b]**	0.00	1.71	2.93	4.63	7.80	**3.41[e]**
	3 mM	0.00	3.35	5.45	8.80	17.81	**7.08[b]**	0.00	2.99	3.91	5.75	7.59	**4.05[c]**
Salicylic acid	**1mM**	0.00	6.00	7.03	7.66	8.69	**5.88[d]**	0.00	1.92	3.13	4.33	7.21	**3.32[e]**
	2mM	0.00	2.40	3.71	6.12	13.12	**5.07[e]**	0.00	1.45	2.66	4.84	6.78	**3.15[f]**
	3mM	0.00	3.16	5.48	9.28	15.61	**6.71[b]**	0.00	2.58	3.52	4.93	7.71	**3.75[d]**
Control		0.00	6.40	9.22	15.44	20.55	**10.32[a]**	0.00	4.06	6.44	9.15	12.49	**6.43[a]**
Mean		**0.00[e]**	**3.63[d]**	**6.09[c]**	**8.83[b]**	**13.55[a]**		**0.00[e]**	**2.16[d]**	**3.65[c]**	**5.25[b]**	**7.55[a]**	
LSD (P≤0.05)		**Treatment (T) =** 0.37 **Days (D) =** 0.26 **D x T =** 0.83						**Treatment (T) =** 0.15 **Days (D) =** 0.10 **D x T =** 0.33					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 15a: Effect of different anti-senescence compounds and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Physiological loss in weight (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.00	2.86	6.01	7.75	11.72	**5.67[b]**
	1000 ppb	0.00	2.60	5.82	7.61	10.87	**5.38[c]**
	1500 ppb	0.00	1.63	3.74	4.89	7.49	**3.55[g]**
Methyl Jasmonates	**1mM**	0.00	1.85	3.05	4.88	6.15	**3.19[h]**
	2mM	0.00	2.84	4.81	7.12	10.48	**5.05[d]**
	3mM	0.00	3.17	4.68	7.27	12.70	**5.56[b]**
Salicylic acid	**1mM**	0.00	3.96	5.08	5.99	7.95	**4.60[e]**
	2mM	0.00	1.92	3.18	5.48	9.95	**4.11[f]**
	3mM	0.00	2.87	4.50	7.10	11.66	**5.23[c]**
Control		0.00	5.23	7.83	12.29	16.52	**8.37[a]**
Mean		**0.00[e]**	**2.89[d]**	**4.87[c]**	**7.04[b]**	**10.55[a]**	
LSD (P≤0.05)		**Treatment (T)** = 0.17 **Days (D)** = 0.12 **D x T** = 0.38					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 15: Effect of different anti-senescence compounds and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

respectively from 30 days to 75 days of storage. On the other hand, the control fruits followed an abrupt continuous rise in PLW and ranged from 6.40 to 20.55 per cent from 30 days to 75days of storage. Similar trends were noticed during 2017-18. Fruits treated with MeJA1mM registered the lowest average PLW (2.35%) followed by 1-MCP 1500 ppb (2.79%). However, the control fruits recorded the maximum mean PLW (6.43%). The data further revealed that the PLW in the fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) ranged from 1.47 to 4.17 and 0.90 to 6.08 per cent, respectively from 30 to 75 days of the storage. On the other hand, control fruits registered a concomitant increase in PLW at faster pace with prolongation in storage period; thereby ranged from 4.06 to 12.49 per cent, respectively from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were further confirmed through pooled mean analysis of both the years (Table 15a and Fig 15). MeJA 1mM proved best in terms of reducing loss in physiological weight (3.19%) followed by 1-MCP 1500 ppb (3.55%) while, the maximum PLW (8.37%) was recorded in control fruits. The interaction between treatments and storage interval was found to be significant. In the present investigation, fruits treated with different anti-senescence compounds exhibited the lowest PLW; might be due to anti-senescent action maintenance cellular integrity, decreased respiration rates and thereby weight loss by stomata closing (Manthe *et al* 1992; Zheng and Zhang 2004).

The postharvest application of MeJA registered the minimum PLW in apricot (Ezzat *et al* 2017) and mango cv. Kent (Gonzalez-Aguilar *et al* (2000). Tavallali and Moghadam (2011) observed that 1-MCP treatment reduced the rate of dehydration and registered minimum PLW in Kinnow during storage. Similar results were also reported in plum (Manganaris *et al* 2008) and medlar fruit (Selcuk and Erkan 2015) during cold storage. Davarynejad *et al* (2015) found that plum fruits cv. ‘Santa Rosa’ subjected to combination of SA and putrescine resulted minimum PLW in contrast to control during storage.

4.2.2 Spoilage (%)

The data pertaining to the effect of anti-senescence compounds on the spoilage revealed a significant decrease in the average cumulative spoilage per cent as compared to control (Table 16). In 2016-17, the fruits treated with MeJA 1mM and 1-MCP 1500 ppb registered the lowest spoilage (1.67%) which was followed by the fruits treated with salicylic acid 2mM where the mean spoilage of fruits recorded as 3.33 per cent. Fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) showed a comparative delay in spoilage (8.33%) upto 75 days of the storage period. However, Interestingly, fruits treated with 1-MCP 500 ppb inititated an earlier spoilage thereby registered the mean maximum spoilage of 14.98 per cent even higher than those of control fruits. The spoilage in 1-MCP 500 ppb treated fruits ranged from 8.33 to 41.66 per cent from 45 days to 75 days of the storage period.Similar trend was

Table 16: Effect of different anti-senescence compounds and storage interval on spoilage per centage in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

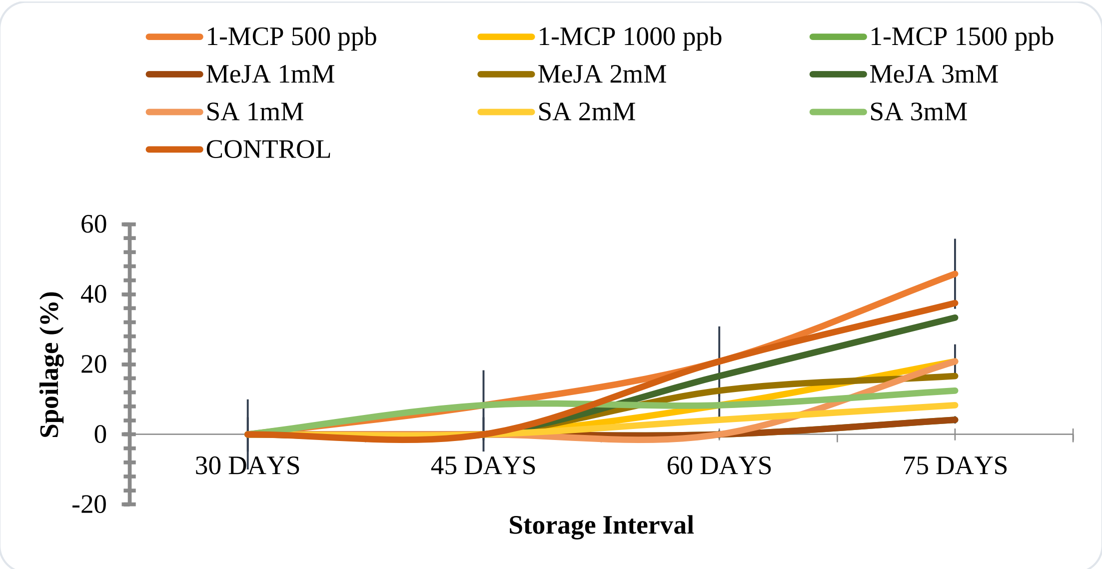
TREATMENT		Spoilage (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	0.00	0.00	8.33	25.00	41.66	**14.98^{a}**	0.00	0.00	8.33	16.66	50.00	**15.00^{a}**
	1000 ppb	0.00	0.00	0.00	8.33	25.00	**6.66^{d}**	0.00	0.00	0.00	8.33	16.66	**5.00^{d}**
	1500 ppb	0.00	0.00	0.00	0.00	8.33	**1.67^{g}**	0.00	0.00	0.00	0.00	0.00	**0.00^{g}**
Methyl Jasmonates	1 mM	0.00	0.00	0.00	0.00	8.33	**1.67^{g}**	0.00	0.00	0.00	0.00	0.00	**0.00^{g}**
	2 mM	0.00	0.00	0.00	16.66	16.66	**6.66^{d}**	0.00	0.00	0.00	8.33	16.66	**4.99^{d}**
	3 mM	0.00	0.00	0.00	16.66	41.66	**11.66^{c}**	0.00	0.00	0.00	16.66	25.00	**8.33^{c}**
Salicylic acid	1mM	0.00	0.00	0.00	0.00	25	**5.00^{e}**	0.00	0.00	0.00	0.00	16.66	**3.33^{e}**
	2mM	0.00	0.00	0.00	8.33	8.33	**3.33^{f}**	0.00	0.00	0.00	0.00	8.33	**1.67^{f}**
	3mM	0.00	0.00	8.33	8.33	16.66	**6.66^{d}**	0.00	0.00	8.33	8.33	8.33	**5.00^{d}**
Control		0.00	0.00	0.00	25.00	41.66	**13.33^{b}**	0.00	0.00	0.00	16.66	33.33	**10.00^{b}**
Mean		**0.00^{d}**	**0.00^{d}**	**1.67^{c}**	**10.83^{b}**	**23.33^{a}**		**0.00^{d}**	**0.00^{d}**	**1.67^{c}**	**7.50^{b}**	**17.50^{a}**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 0.55 **Days (D) =** 0.39 **D x T =** 1.24						**Treatment (T) =** 0.36 **Days (D) =** 0.25 **D x T =** 0.80					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15fruits/replication)

Table 16a: Effect of different anti-senescence compounds and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Spoilage (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.00	0.00	8.33	20.83	45.83	**15.00[a]**
	1000 ppb	0.00	0.00	0.00	8.33	20.83	**5.83[d]**
	1500 ppb	0.00	0.00	0.00	0.00	4.16	**0.83[g]**
Methyl Jasmonates	**1mM**	0.00	0.00	0.00	0.00	4.16	**0.83[g]**
	2mM	0.00	0.00	0.00	12.49	16.66	**5.83[d]**
	3mM	0.00	0.00	0.00	16.66	33.33	**10.00[c]**
Salicylic acid	**1mM**	0.00	0.00	0.00	0.00	20.83	**4.17[e]**
	2mM	0.00	0.00	0.00	4.16	8.33	**2.50[f]**
	3mM	0.00	0.00	8.33	8.33	12.49	**5.83[d]**
Control		0.00	0.00	0.00	20.83	37.49	**11.66[b]**
Mean		**0.00[d]**	**0.00[d]**	**1.67[c]**	**9.16[b]**	**20.41[a]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.33 **Days (D)** = 0.23 **D x T** = 0.74					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 16: Effect of different anti-senescence compounds and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

also noticed in 2017-18, however, no spoilage was recorded in the fruits treated MeJA (1mM) and 1-MCP (1500 ppb), respectively. On the other hand, the 1-MCP 500 ppb treated fruits recorded the maximum spoilage (15.00%). The spoilage in 1-MCP 500 ppb treated fruits ranged from 8.33 to 50.00 per cent from 45 days to 75 days of the storage period. The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 16a and Fig 16). MeJA 1mM and 1-MCP 1500 ppb were the most effective in terms of delaying the spoilage where it was recorded only 0.83 per cent. On the other hand, fruits treated with 1-MCP 500 ppb registered the maximum mean spoilage of 15.00 per cent. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) delayed the spoilage as MeJA induces the expression of pathogenesis-related genes and increases the activity of defense-related enzymes in horticultural crops; thus delayed the incidence of fruit decay (Yao and Tian 2005).

The results in the present investigations are in agreement with the findings of Geransayeh *et al* 2015) who reported that the postharvest application of MeJA delayed the fruit spoilage in strawberry. Similar studies were reported by in loquat (Cao *et al* 2008) and mango cv. Kent (Gonzalez-Aguilar *et al* 2000). The post-harvest application with 1-MCP treatments registered minimum chilling injury and fruit decay in Kinnow (Tavallali and Moghadam 2015) Kiwi fruit cv. ‘Hayward’ (Park *et al* 2015) and pear (Gamrasni *et al* 2010). Khademi and Ersadi (2013) observed that fruits of peach subjected to SA registered minimum decay percentage as compared to control after 42 days of storage.

4.2.3 Organoleptic sensory attributes (Hedonic scale 1-9)

The data on sensory quality of Kinnow fruits influenced by different anti-senescence compounds revealed an identical trends during storage (Table 17). In 2016-17, the maximum mean sensory score (7.65) was shown by MeJA 1mM followed by the fruits treated with 1-MCP 1500 ppb (7.19) treated fruits. However, the control fruits registered the lowest average palatability rating (6.15). The data further revealed that fruits treated with MeJA (1mM) and 1-MCP 1500 registered a gradual rise in palatability rating after 30 days of the storage i.e. 8.05 and 8.08, respectively; thereafter followed a continuous decline till the end of the of storage i.e. 7.42 and 6.45, respectively. On the other hand control fruits followed a sharp and abrupt decline in sensory score at faster pace and reached to its minimum level at the end of the storage i.e. 5.40. Similar trend was also noticed during 2017-18. The fruits treated with MeJA 1mM were superior with respect to retaining the maximum mean palatability rating (8.38) followed by the fruits treated with 1-MCP 1500 ppb (8.30), whereas control fruits registered the lowest average palatability rating (7.15). It was further noticed that MeJA (1mM) and 1-MCP (1500 ppb) registered a gradual rise in palatability rating after 30 days of storage i.e. 8.93 and 8.70,

Table 17: Effect of anti-senescence compounds and storage interval on organoleptic sensory attributes in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

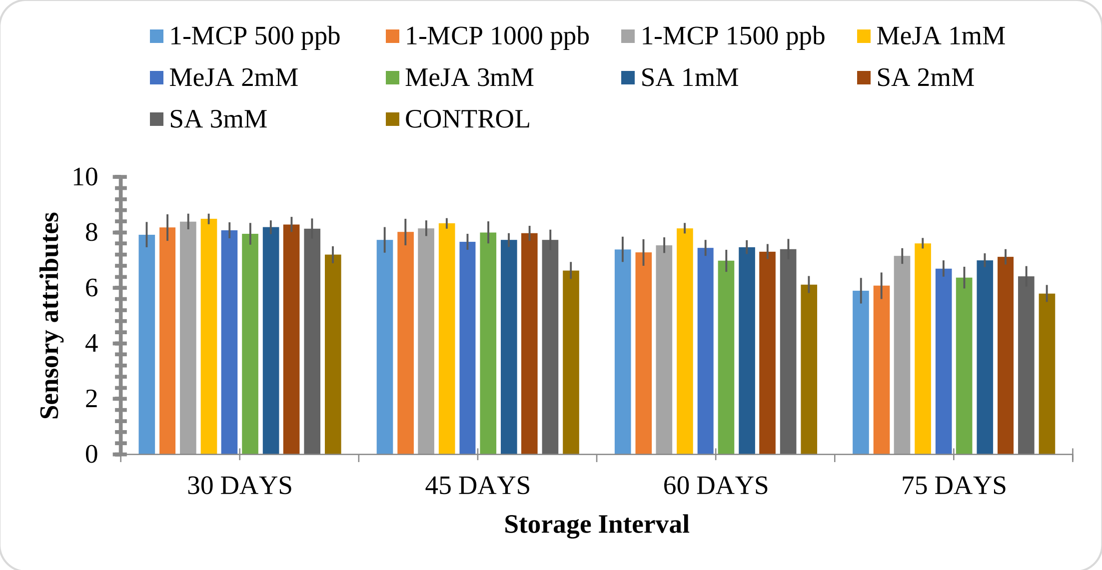
TREATMENT		Organoleptic sensory attributes (Hedonic scale 1-9)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	7.00	7.25	7.21	6.78	5.50	**6.75^f**	8.00	8.60	8.25	8.00	6.30	**7.83^d**
	1000 ppb	7.00	7.66	7.50	6.90	5.37	**6.89^{ef}**	8.00	8.70	8.55	7.67	6.80	**7.94^{cd}**
	1500 ppb	7.00	8.08	7.72	6.71	6.45	**7.19^b**	8.00	8.70	8.58	8.38	7.86	**8.30^{ab}**
Methyl Jasmonates	**1 mM**	7.00	8.05	8.00	7.80	7.42	**7.65^a**	8.00	8.93	8.67	8.50	7.80	**8.38^a**
	2 mM	7.00	7.66	7.33	6.88	5.90	**6.95^{cde}**	8.00	8.50	8.00	8.00	7.50	**8.00^{cd}**
	3 mM	7.00	7.50	7.35	6.16	5.95	**6.79^{ef}**	8.00	8.40	8.66	7.80	6.80	**7.93^{cd}**
Salicylic acid	**1mM**	7.00	7.69	7.14	7.05	6.40	**7.05^{bcd}**	8.00	8.70	8.33	7.90	7.60	**8.11^{bc}**
	2mM	7.00	7.75	7.45	6.70	6.50	**7.08^{bc}**	8.00	8.83	8.50	7.93	7.75	**8.20^{abc}**
	3mM	7.00	7.54	7.11	6.80	6.05	**6.90^{def}**	8.00	8.75	8.35	8.00	6.80	**7.98^{cd}**
Control		7.00	6.50	6.09	5.75	5.40	**6.15^g**	8.00	7.90	7.17	6.50	6.20	**7.15^e**
Mean		**7.00^c**	**7.57^a**	**7.29^b**	**6.75^d**	**6.09^e**		**8.00^c**	**8.60^a**	**8.31^b**	**7.87^c**	**7.14^d**	
LSD (P≤0.05)		**Treatment (T) =** 0.16 **Days (D) =** 0.12 **D x T =** 0.37						**Treatment (T) =** 0.27 **Days (D) =** 0.19 **D x T =** 0.61					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 17a: Effect of different anti-senescence compounds and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

Organoleptic sensory attributes (Hedonic scale 1-9)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	7.50	7.92	7.73	7.39	5.90	**7.29[f]**
	1000 ppb	7.50	8.18	8.02	7.28	6.08	**7.41[ef]**
	1500 ppb	7.50	8.39	8.15	7.54	7.15	**7.75[b]**
Methyl Jasmonates	**1mM**	7.50	8.49	8.33	8.15	7.61	**8.02[a]**
	2mM	7.50	8.08	7.66	7.44	6.70	**7.48[de]**
	3mM	7.50	7.95	8.00	6.98	6.37	**7.36[ef]**
Salicylic acid	**1mM**	7.50	8.19	7.73	7.47	7.00	**7.58[cd]**
	2mM	7.50	8.29	7.97	7.31	7.12	**7.64[bc]**
	3mM	7.50	8.14	7.73	7.40	6.42	**7.44[e]**
Control		7.50	7.20	6.63	6.12	5.80	**6.65[g]**
Mean		**7.50[c]**	**8.08[a]**	**7.80[b]**	**7.31[d]**	**6.62[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.13 **Days (D)** = 0.095 **D x T** = 0.30					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 17: Effect of different anti-senescence compounds and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

respectively, thereafter followed a continuous decline till the end of the storage i.e 7.80 and 7.86, respectively. On the other hand, control fruits followed an abrupt decline in palatability rating and reached to its minimum level (6.20) at the end of the storage.

The interaction between treatment and storage interval was found to be significant during both the season of investigation. The pooled mean analysis of both the years (Table 17a and Fig 17) further confirmed the findings as MeJA 1mM was the best in terms of maintaining maximum mean sensory score of 8.02 followed by 7.75 in the fruits treated with 1-MCP 1500 ppb while, control fruits registered the lowest mean score for palatability rating (6.65). The interaction between treatments and storage interval was found to be significant. In the present study, the loss in overall acceptability scores of control fruit during storage might be due to degradation of different parameters *viz* colour, aroma, taste and texture due to browning, moisture losses, and breakdown of sugars, acids and volatile compounds whereas, MeJA reduced pectin-methyl-esterase (PME) activity to decrease de-esterifi cation of pectin and hence maintained fruit texture (Meng *et al* 2009).

These results are in corroboration with findings of Ezzat *et al* (2017) who reported that apricot fruits subjected to MeJA and SA registered the maximum score for sensory attributes over control after 21 days of storage. Gamrasni *et al* (2010) observed that 1-MCP registered the maximum score for sensory attributes in pear fruit in contrast to control after two weeks of storage.

4.2.4 Firmness (Kg Force)

The data on firmness influenced by different anti-senescence compounds revealed a declining trend during storage (Table 18). In 2016-17, the fruits treated with MeJA 1mM registered the average maximum firmness (5.01 kg f) followed by those treated with 1-MCP 1500 ppb (4.96 kg f) whereas, the control fruits registered the lowest average firmness (4.07 kgf). The firmness in the fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) ranged from 5.00 to 4.49 and 5.30 to 3.95 kg force, respectively from 30 days to 75 days of storage period. On the other hand control fruits continued to shrivel at faster pace and thereby registered a sharp decline in firmness ranged from 4.40 to 2.80 kg force from 30 days to 75 days of storage. Similar results were also obtained during 2017-18. However, MeJA 1mM was treatment was statistically superior with fruit firmness of 5.22 kg f to all other treatments except that of fruits treated with 1-MCP 1500 ppb and salicylic acid 2mM and 1mM where the fruit firmness was recorded as 5.20, 5.16 and 5.12, respectively. The control fruits recorded the lowest average firmness (4.36 kg f). The data further revealed that the firmness in the fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) ranged from 6.18 to 3.60 and 5.94 to 4.12 kg force, respectively from 30 days to 75 days of storage period. On the other hand, control fruits registered an abrupt decline in firmness ranged from 4.69 to 3.23 kg force from 30 days to 75 days of storage. The interaction between treatment and storage interval

Table 18: Effect of different anti-senescence compounds and storage interval on the firmness (Kg force) of Kinnow fruit stored at 5-7^{o}C and 90-95% RH

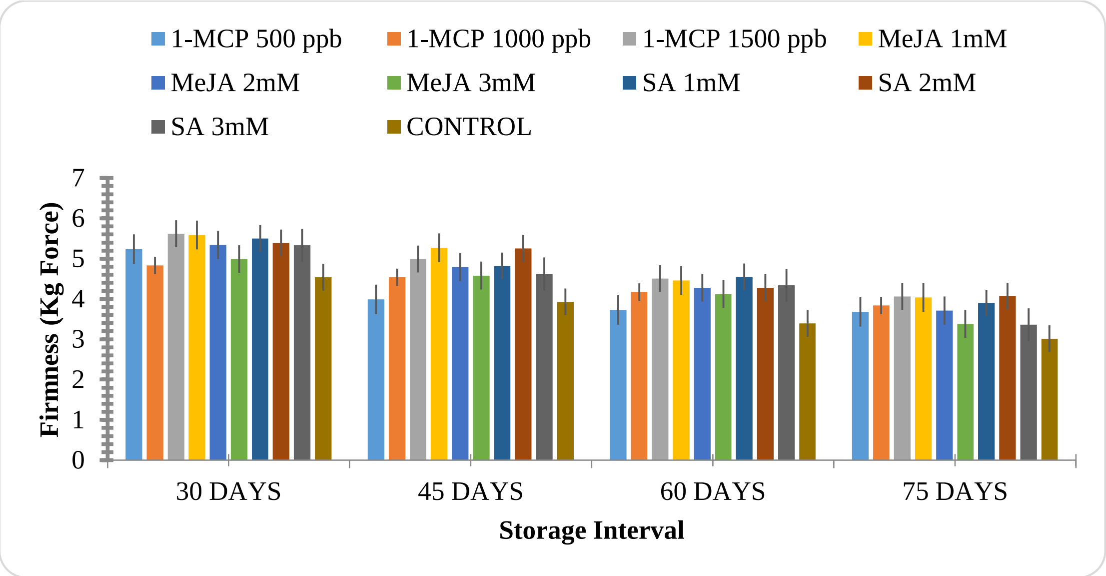
TREATMENT		Firmness (Kg Force)											
		2016-17						2017-18					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	6.13	4.56	3.90	3.50	3.45	**4.31^{f}**	6.25	5.40	4.73	4.44	3.32	**4.82^{e}**
	1000 ppb	6.13	4.72	4.16	4.10	3.62	**4.55^{de}**	6.25	4.95	4.93	4.25	4.06	**4.89^{d}**
	1500 ppb	6.13	5.30	4.77	4.64	3.95	**4.96^{ab}**	6.25	5.94	4.80	4.45	4.12	**5.20^{a}**
Methyl Jasmonates	1 mM	6.13	5.00	4.88	4.53	4.49	**5.01^{a}**	6.25	6.18	5.66	4.40	3.60	**5.22^{a}**
	2 mM	6.13	4.72	4.66	4.27	3.72	**4.70^{c}**	6.25	5.96	4.93	4.30	3.70	**5.03^{bc}**
	3 mM	6.13	4.58	4.43	3.81	3.44	**4.48^{e}**	6.25	5.92	4.08	3.97	3.91	**4.83^{d}**
Salicylic acid	1mM	6.13	5.07	4.85	4.66	3.68	**4.88^{b}**	6.25	5.48	5.37	4.24	4.30	**5.12^{ab}**
	2mM	6.13	5.30	5.13	4.32	3.85	**4.95^{ab}**	6.25	5.94	5.22	4.39	4.18	**5.16^{a}**
	3mM	6.13	4.53	4.36	4.12	3.89	**4.61^{d}**	6.25	6.14	4.88	4.56	2.84	**4.93^{cd}**
Control		6.13	4.40	3.70	3.30	2.80	**4.07^{g}**	6.25	4.69	4.17	3.48	3.23	**4.36^{f}**
Mean		**6.13^{a}**	**4.82^{b}**	**4.48^{c}**	**4.12^{d}**	**3.69^{e}**		**6.25^{a}**	**5.68^{b}**	**4.88^{c}**	**4.25^{d}**	**3.73^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.09 **Days (D)** = 0.06 **D x T** = 0.20						**Treatment (T)** = 0.11 **Days (D)** = 0.08 **D x T** = 0.26					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 18a: Effect of different anti-senescence compounds and storage interval on the firmness (kg f) per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Firmness (Kg Force)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	6.19	5.24	3.99	3.73	3.68	**4.57[f]**
	1000 ppb	6.19	4.83	4.54	4.17	3.84	**4.72[de]**
	1500 ppb	6.19	5.62	4.99	4.51	4.06	**5.08[ab]**
Methyl Jasmonates	**1mM**	6.19	5.59	5.27	4.46	4.04	**5.11[a]**
	2mM	6.19	5.34	4.79	4.28	3.71	**4.86[c]**
	3mM	6.19	4.99	4.58	4.12	3.38	**4.65[ef]**
Salicylic acid	**1mM**	6.19	5.50	4.82	4.55	3.90	**4.99[b]**
	2mM	6.19	5.39	5.25	4.28	4.07	**5.04[ab]**
	3mM	6.19	5.33	4.62	4.34	3.36	**4.77[cd]**
Control		6.19	4.54	3.93	3.39	3.01	**4.21[g]**
Mean		**6.19[a]**	**5.24[b]**	**4.68[c]**	**4.19[d]**	**3.71[e]**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 0.095 **Days (D)** = 0.067 **D x T** = 0.21					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 18: Effect of anti-senescence compound and storage interval on the firmness (kg f) per cent of Kinnow fruit stored at 5-7°C and 90-95% RH

was found to be significant during 2016-17 and 2017-18. The findings were further confirmed through the pooled mean analysis of both the years (Table 18a and Fig 18). MeJA 1mM was the most effective in retaining and maintain the mean maximum firmness (5.11 kg f) followed by 1-MCP 1500 ppb (5.08 kg f). However, control fruits recorded the lowest average firmness (4.21 kg f). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, fruits treated with MeJA (1mM) and 1-MCP (1500 ppb) registered the highest fruit firmness; this might be due to their anti-senescent action inhibited cell wall and membrane degrading enzymes such as polygalacturonase, lipoxygenase, cellulase and pectin methyl esterase, leading to decreased fruit softening rate (Asghari and Aghdam 2010).

These results are in conformity to the findings of Ezzat *et al* (2017) who observed that apricot fruits subjected to MeJA maintained higher fruit firmness than that of control after 21 days of storage. Zapata *et al* (2014) who, however, examined the effect of pre-harvest application of methyl jasmonates (MeJA) on plum cultivars and found that fruits subjected to MeJA maintained the higher firmness in contrast to control after 9 days of storage. The post-harvest application of 1-MCP maintained higher firmness in Kinnow (Tavallali and Moghadam 2015); kiwi fruit (Park *et al* 2015 and Cantin *et al* 2011); pear (Calvo and Sozzi 2009); plum (Manganaris *et al* 2008) and Mangosteen (Piriyavinit *et al* 2011).

4.2.5 Juice (%)

The data on juice content influenced by different anti-senescence compounds in general, followed a declining trend commensurate with advancement in storage period (Table 19). In the first year of investigation, MeJA 1mM retained the maximum mean juice content (38.02%) followed by 1-MCP 1500 ppb (37.89%) and salicylic acid 2mM (37.63%) whereas, the control fruits maintained the lowest average juice content of 34.38 per cent. Fruits treated with MeJA 1mM and 1-MCP 1500 ppb registered a gradual decline in juice content ranged from 38.76 to 30.17 and 44.15 to 29.90 per cent, respectively from 30 days to 75 days of the storage. However, the control fruits followed a decline at faster pace and retained the lowest juice volume ranged from 41.81 to 20.80 per cent from 30 days to 75 days of storage. Similar results were also obtained in the year of 2017-18. The fruits treated with MeJA 1mM emerged as superior with respect to retaining and maintaining the maximum mean juice content (46.03%) followed by 1-MCP 1500 ppb (45.35%). On the other hand, control fruits retained the lowest juice content (41.14%). The data further revealed that juice content in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb ranged from 47.12 to 41.94 and 46.45 to 41.10 per cent, respectively from 30 days to 75 days of storage whereas, the control fruits revealed a sharp and abrupt decline ranged from 46.98 to 28.65 per cent from 30 days 75 days of storage. The interaction between treatments and the storage interval was found to be significant during both the seasons of investigation. The pooled mean analysis of both the years (Table 19a and Fig 19)

Table 19: Effect of different anti-senescence compounds and storage interval on juice per centage of Kinnow fruit stored at 5-7°C and 90-95% RH

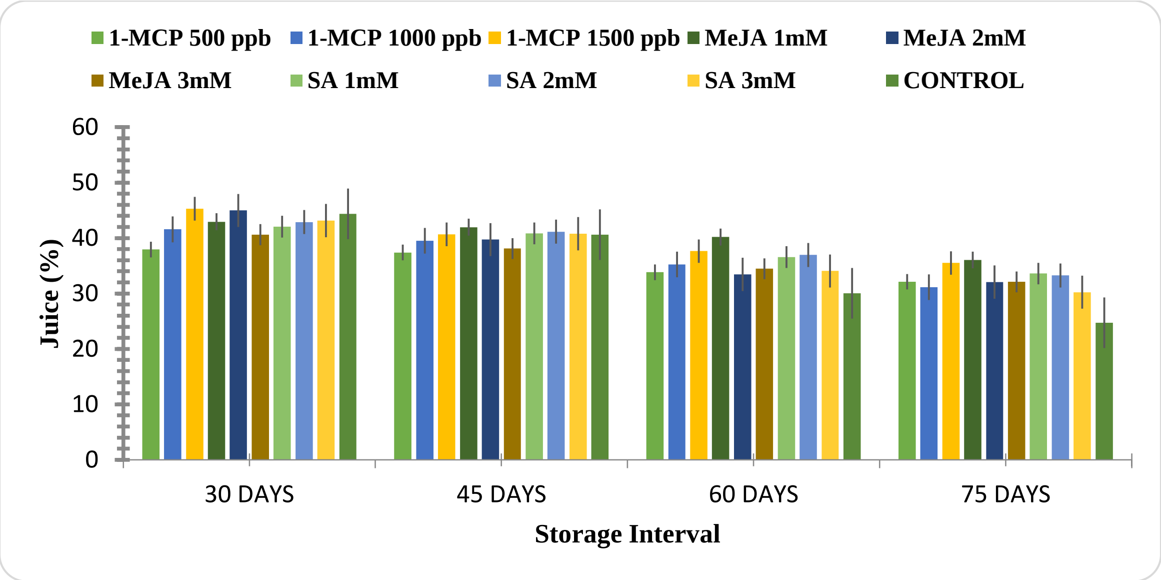
TREATMENT		Juice (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	48.50	34.37	34.24	27.88	27.11	**34.42^{ef}**	49.50	41.51	40.54	39.78	37.14	**41.69^{cd}**
	1000 ppb	48.50	36.08	35.96	31.20	26.00	**35.55^{cde}**	49.50	47.06	43.05	39.33	36.29	**43.04^{b}**
	1500 ppb	48.50	44.15	35.63	31.29	29.90	**37.89^{a}**	49.50	46.45	45.70	43.99	41.10	**45.35^{a}**
Methyl Jasmonates	**1 mM**	48.50	38.76	37.00	35.67	30.17	**38.02^{a}**	49.50	47.12	46.93	44.69	41.94	**46.03^{a}**
	2 mM	48.50	43.24	38.92	27.09	24.35	**36.42^{bc}**	49.50	46.74	40.54	39.82	39.77	**43.27^{bc}**
	3 mM	48.50	35.84	35.31	29.25	24.54	**34.69^{def}**	49.50	45.39	40.91	39.69	39.67	**43.03^{b}**
Salicylic acid	**1mM**	48.50	39.84	38.63	31.36	27.43	**37.15^{ab}**	49.50	44.28	43.04	41.80	39.77	**43.67^{b}**
	2mM	48.50	41.01	39.85	32.55	26.22	**37.63^{a}**	49.50	44.78	42.46	41.35	40.30	**43.68^{b}**
	3mM	48.50	42.10	37.73	26.20	24.53	**35.81^{cd}**	49.50	44.21	43.84	41.94	35.92	**43.08^{b}**
Control		48.50	41.81	35.55	25.22	20.80	**34.38^{f}**	49.50	46.98	45.67	34.88	28.65	**41.14^{c}**
Mean		**48.50^{a}**	**39.72^{b}**	**36.88^{c}**	**29.77^{d}**	**26.10^{e}**		**49.50^{a}**	**45.45^{b}**	**43.27^{c}**	**40.72^{d}**	**38.05^{e}**	
LSD ($P\leq0.05$)		**Treatment (T) =** 1.14 **Days (D) =** 0.81 **D x T =** 2.55						**Treatment (T) =** 1.23 **Days (D) =** 0.87 **D x T =** 2.76					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 19a: Effect of different anti-senescence compounds and storage interval on the juice per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Juice (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	49.00	37.94	37.39	33.83	32.12	**38.06^{ef}**
	1000 ppb	49.00	41.57	39.50	35.26	31.14	**39.30^{cd}**
	1500 ppb	49.00	45.30	40.66	37.64	35.50	**41.62^{a}**
Methyl Jasmonates	**1mM**	49.00	42.94	41.96	40.18	36.05	**42.03^{a}**
	2mM	49.00	44.99	39.73	33.45	32.06	**39.85^{bc}**
	3mM	49.00	40.61	38.11	34.47	32.10	**38.86^{de}**
Salicylic acid	**1mM**	49.00	42.06	40.83	36.58	33.60	**40.41^{b}**
	2mM	49.00	42.89	41.15	36.95	33.26	**40.65^{b}**
	3mM	49.00	43.15	40.78	34.07	30.22	**39.45^{cd}**
Control		49.00	44.39	40.61	30.05	24.72	**37.76^{f}**
Mean		**49.00^{a}**	**42.59^{b}**	**40.07^{c}**	**35.25^{d}**	**32.08^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.85 **Days (D)** = 0.60 **D x T** = 1.90					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 19: Effect of different anti-senescence compounds and storage interval on the juice per centage of Kinnow fruit stored at 5-7°C and 90-95% RH

also confirmed the findings as MeJA 1mM was the best in terms of retaining the maximum juice (42.03%) content followed by 1-MCP 1500 ppb (41.62%). On the other hand, control fruits retained the lowest average juice content of 37.76 per cent only. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, control fruits registered the maximum loss in juice content; might be due to dry atmosphere around the fruits leading to faster respiration and transpiration causing drying of the juicy vesicles.

The results are in line with findings of Juan *et al* (2009) who reported that hot air treatments delayed the decrease of extractable juice content in loquat (*Eriobotrya japonica* Lindl.cv. Jiefangzhong) after stored at 4°C. Fruits of peach (cv. Flordasun) were subjected to hot water treatment registered an increase in juice yield with prolongation in storage (Bakshi *et al* 2009).

4.2.6 TSS (%)

The data pertaining to the effect of anti-senescence compounds on total soluble solids revealed an identical trends during the storage period (Table 20). In 2016-17, fruits treated with MeJA 1mM registered the maximum average TSS content of 11.00 per cent followed by 1-MCP 1500 ppb where it was recorded as 10.72 per cent. However, the control fruits recorded the lowest average TSS of 10.07 per cent. The data further revealed that the fruits treated with MeJA 1mM and 1-MCP 1500 ppb revealed an increase in TSS slowly and steadily up to 60 days of the storage which was recorded as 12.65 and 12.55 per cent, respectively and thereafter followed a decline till the end of the storage i.e. 12.15 and 11.60 per cent, respectively. The similar trends were noticed in 2017-18. However, MeJA 1mM was statistically superior in terms of showing highest TSS content (10.97%) followed by 1-MCP 1500 ppb (10.72%), which was at par with MeJA 1mM and 1-MCP 1500 ppb registered a gradual increase in TSS up to 60 days of the storage where it was registered as 12.25 and 11.90, respectively, thereafter followed a sharp decline in TSS content till the end of the storage (11.75 and 11.55%, respectively).The interaction between treatments and storage interval was found to be significant during both the years of investigation 2016-17 and 2017-18, respectively. The findings were also confirmed through the pooled mean analysis of both the years (Table 20a and Fig 20). MeJA 1mM was the best in registering the maximum TSS (10.98%) content followed by 1-MCP 1500 ppb (10.72%). However, control fruits recorded the lowest average TSS (10.17%) content. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the increasing- decreasing trend in TSS content during storage might be due to hydrolysis of starch into sugars. On the completion of starch hydrolysis, no further increase occurred and subsequently the TSS content declined as the sugars act as substrate during respiration (Wills *et al* 1980).

Table 20: Effect of different anti-senescence compounds and storage interval on the total soluble solids per cent in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

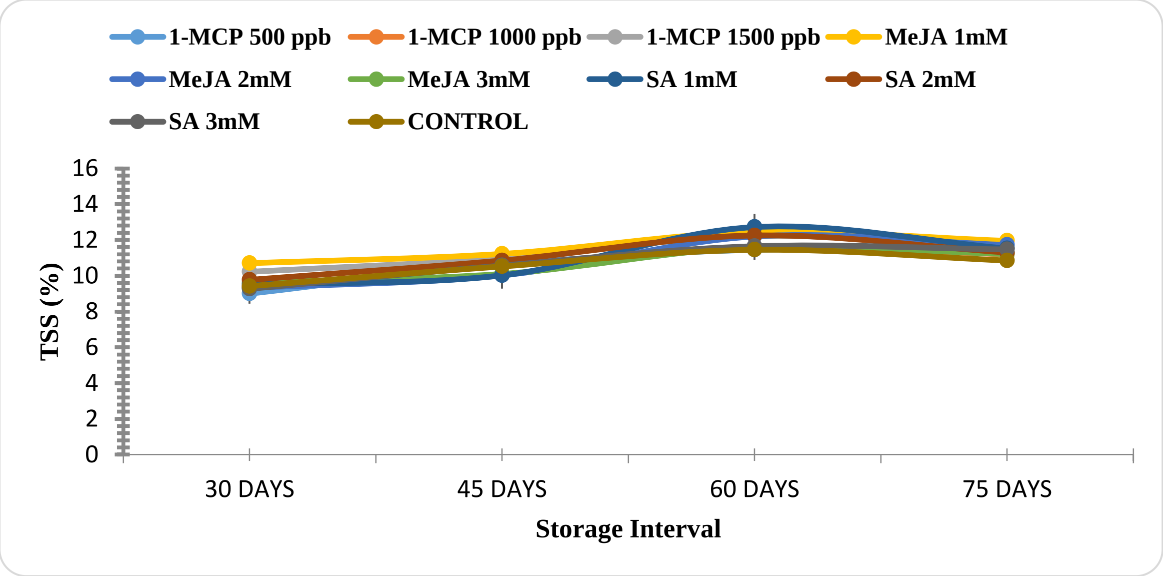
TREATMENT		Total soluble solids (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	8.75	9.00	10.25	11.65	10.85	**10.10^{de}**	8.45	9.00	11.00	11.75	11.25	**10.29^{cd}**
	1000 ppb	8.75	9.25	10.55	11.25	10.85	**10.13^{de}**	8.45	9.50	10.60	12.00	11.55	**10.42^{bcde}**
	1500 ppb	8.75	9.85	10.85	12.55	11.60	**10.72^{b}**	8.45	10.60	11.10	11.90	11.55	**10.72^{ab}**
Methyl Jasmonates	**1 mM**	8.75	10.25	11.20	12.65	12.15	**11.00^{a}**	8.45	11.15	11.25	12.25	11.75	**10.97^{a}**
	2 mM	8.75	8.95	9.85	12.40	11.65	**10.32^{cde}**	8.45	9.70	10.20	12.00	11.80	**10.43^{bcd}**
	3 mM	8.75	9.45	10.20	11.35	10.85	**10.12^{de}**	8.45	9.80	10.00	11.85	11.60	**10.34^{cd}**
Salicylic acid	**1mM**	8.75	9.15	9.75	13.15	11.05	**10.37^{cd}**	8.45	9.86	10.30	12.30	12.00	**10.58^{bc}**
	2mM	8.75	9.05	10.55	12.65	11.25	**10.45^{bc}**	8.45	10.50	11.15	11.85	11.35	**10.66^{b}**
	3mM	8.75	9.60	10.40	11.25	11.00	**10.20^{cde}**	8.45	8.95	10.75	12.05	11.95	**10.43^{bcd}**
Control		8.75	9.00	10.15	11.55	10.90	**10.07^{e}**	8.45	9.85	10.90	11.35	10.80	**10.27^{d}**
Mean		**8.75^{e}**	**9.35^{d}**	**10.37^{c}**	**12.04^{a}**	**11.21^{b}**		**8.45^{e}**	**9.89^{d}**	**10.72^{c}**	**11.93^{a}**	**11.56^{b}**	
LSD (P≤0.05)		**Treatment (T) =** 0.28 **Days (D) =** 0.20 **D x T =** 0.62						**Treatment (T) =** 0.30 **Days (D) =** 0.21 **D x T =** 0.67					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 20a: Effect of different anti-senescence compounds and storage interval on the total soluble solids per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Total soluble solids (%)							
Storage interval (Days)							
TREATMENTS		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	8.60	9.00	10.62	11.45	11.30	**10.19[ef]**
	1000 ppb	8.60	9.37	10.57	11.62	11.20	**10.27[ef]**
	1500 ppb	8.60	10.22	10.97	12.22	11.57	**10.72[b]**
Methyl Jasmonates	**1mM**	8.60	10.70	11.22	12.45	11.95	**10.98[a]**
	2mM	8.60	9.32	10.02	12.20	11.72	**10.37[cde]**
	3mM	8.60	9.62	10.10	11.60	11.22	**10.23[ef]**
Salicylic acid	**1mM**	8.60	9.50	10.02	12.72	11.52	**10.48[cd]**
	2mM	8.60	9.77	10.85	12.25	11.30	**10.55[bc]**
	3mM	8.60	9.27	10.57	11.65	11.47	**10.31[def]**
Control		8.60	9.42	10.52	11.45	10.85	**10.17[f]**
Mean		**8.60[e]**	**9.62[d]**	**10.55[c]**	**11.96[a]**	**11.41[b]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.19 **Days (D)** = 0.13 **D x T** = 0.42					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 20: Effect of different anti-senescence compounds and storage interval on the total soluble solids per cent of Kinnow fruit stored at 5-7°C and 90-95% RH

4.2.7 Reducing sugars (%)

These results are in conformity to the findings of Gonzalez-Aguilar *et al* (2000) who registered the maximum sugar content in mango cv. 'Kent' subjected to MeJA as compared to control during storage. Fruits of pear cv. 'Bartlett' treated with 1-MCP registered the higher soluble sugar content as compared to control at the end of the storage (Calvo and Sozzi 2009). Similar results were also reported in apple (Lu *et al* 2013) kiwi fruit (Park *et al* 2015) and plum (Zapata *et al* 2014).

The data pertaining to the effect of anti-senescence compounds on reducing sugars content of Kinnow fruits revealed an increasing-decreasing trends during storage (Table 21). In 2016-17, the average maximum reducing sugars (4.06%) content was registered in the fruits treated with MeJA 1mM followed by fruits treated with 1-MCP 1500 ppb and salicylic acid 2mM where it was recorded as 3.78 and 3.77 per cent, respectively. On the other hand, the control fruits registered the lowest (3.38%) average reducing sugars content.It was noticed that, fruits treated with MeJA 1mM and 1-MCP 1500 ppb revealed a gradual increase in reducing sugars content till 60 days of the storage i.e. 4.85 and 4.73 per cent, respectively; thereafter followed a decline till the end of the storage i.e. 4.51 and 3.82, respectively. Similar trends were also noticed in the year of 2017-18. Fruits treated with MeJA 1mM registered the maximum reducing sugars of 3.28 per cent followed by the fruits treated with 1-MCP 1500 ppb and salicylic acid 2mM where it was recorded as 3.22 and 3.20 per cent, respectively. On the other hand, control fruits recorded the lowest reducing sugars of 2.66 per cent. The data further revealed that fruits treated with MeJA 1mM and 1-MCP 1500 ppb showed a gradual increase in reducing sugars content till 60 days of the storage i.e. 5.74 and 4.73 per cent respectively; thereafter followed a continuous decline till the end of the storage i.e. 3.94 and 4.13 per cent, respectively. The interaction between treatments and storage interval was found to be significant in 2016-17 and 2017-18. The pooled mean analysis of both the years (Table 21a and Fig 21) further confirmed the findings as fruits treated with MeJA 1mM registered the maximum reducing sugars of 3.68 per cent followed by the fruits treated with 1-MCP 1500 ppb and salicylic acid 2mM where it was recorded as 3.50 and 3.48 per cent, respectively. On the other hand control fruits recorded the lowest reducing sugars of 3.02 per cent. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.

4.2.8 Total sugars (%)

Perusal of the effect of anti-senescence compounds on total sugars content of Kinnow fruit revealed an identical trend during storage (Table 22). In 2016-17, fruits treated with MeJA 1mM registered the average maximum total sugars (7.87%) content followed by 1-MCP 1500 ppb (7.74%). On the other hand, the control fruits recorded the lowest average total sugars (7.02) content. The data further revealed that the fruits treated with MeJA 1mM and 1-MCP 1500 ppb revealed a gradual increase in total sugars up to 60 days of the storage

Table 21: Effect of different edible coatings and storage interval on reducing sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

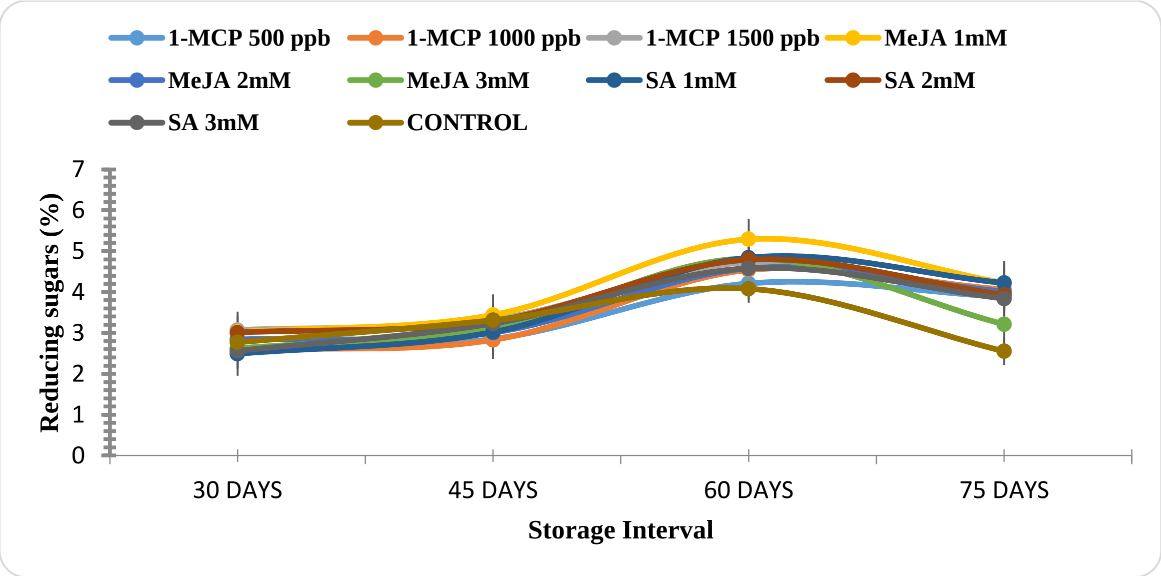
TREATMENT		Reducing sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	3.11	3.17	3.26	3.95	3.66	**3.43gh**	1.67	2.01	2.44	4.48	4.10	**2.94f**
	1000 ppb	3.11	3.20	3.39	4.22	3.74	**3.53ef**	1.67	1.99	2.28	4.87	4.39	**3.04de**
	1500 ppb	3.11	3.54	3.68	4.73	3.82	**3.78b**	1.67	2.60	2.98	4.73	4.13	**3.22ab**
Methyl Jasmonates	1 mM	3.11	3.65	4.20	4.85	4.51	**4.06a**	1.67	2.40	2.69	5.74	3.94	**3.28a**
	2 mM	3.11	3.28	3.60	4.24	3.90	**3.62cd**	1.67	2.41	2.42	4.93	4.13	**3.11cd**
	3 mM	3.11	3.38	3.51	4.12	3.22	**3.47fg**	1.67	1.86	2.75	5.52	3.20	**2.99ef**
Salicylic Acid	1 mM	3.11	3.27	3.38	4.37	4.18	**3.66c**	1.67	1.71	2.67	5.31	4.26	**3.12c**
	2 mM	3.11	3.66	3.67	4.61	3.79	**3.77b**	1.67	2.37	2.91	4.98	4.08	**3.20b**
	3 mM	3.11	3.33	4.07	4.17	3.24	**3.58de**	1.67	1.79	2.40	5.00	4.45	**3.06cde**
Control		**3.11**	3.26	3.78	4.07	2.70	**3.38h**	1.67	2.28	2.84	4.10	2.40	**2.66g**
Mean		**3.11d**	**3.37c**	**3.65b**	**4.33a**	**3.67b**		**1.67e**	**2.14d**	**2.64c**	**4.97a**	**3.91b**	
LSD (P≤0.05)		**Treatment (T) =** 0.075 **Days (D) =** 0.05 **D x T =** 0.17						**Treatment (T) =** 0.078 **Days (D) =** 0.05 **D x T =** 0.17					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (when n =15 fruits/replication)

Table 21a: Effect of different anti-senescence compounds and storage interval on the reducing sugars per cent of Kinnow fruit stored at 5-7°C and 90-95% RH

Reducing sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	2.39	2.59	2.85	4.21	3.88	**3.18^{f}**
	1000 ppb	2.39	2.59	2.83	4.54	4.06	**3.29^{de}**
	1500 ppb	2.39	3.07	3.33	4.73	3.97	**3.50^{b}**
Methyl Jasmonates	**1mM**	2.39	3.02	3.44	5.29	4.22	**3.68^{a}**
	2mM	2.39	2.84	3.01	4.58	4.01	**3.37^{c}**
	3mM	2.39	2.62	3.13	4.82	3.21	**3.23^{ef}**
Salicylic acid	**1mM**	2.39	2.49	3.02	4.84	4.22	**3.39^{c}**
	2mM	2.39	3.01	3.29	4.79	3.93	**3.48^{b}**
	3mM	2.39	2.56	3.23	4.58	3.84	**3.32^{cd}**
Control		2.39	2.77	3.31	4.08	2.55	**3.02^{g}**
Mean		**2.39^{d}**	**2.76^{cd}**	**3.15^{c}**	**4.65^{a}**	**3.79^{b}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.075 **Days (D)** = 0.053 **D x T** = 0.168					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 21: Effect of different anti-senescence compounds and storage interval on the reducing sugars per cent of Kinnow fruit stored at 5-7°C and 90-95% RH

Table 22: Effect of different anti-senescence compounds and storage interval on total sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

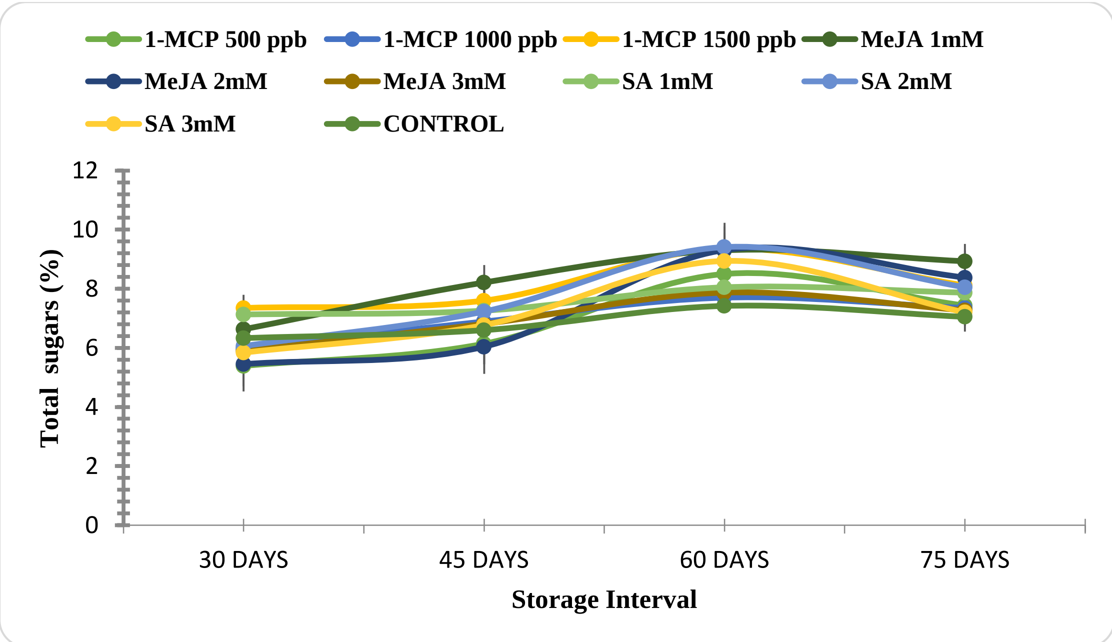
TREATMENT		Total sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	5.65	6.00	6.95	8.60	7.96	**7.03^{d}**	4.65	4.78	5.34	8.41	6.90	**6.02^{d}**
	1000 ppb	5.65	6.30	7.20	8.45	7.90	**7.10^{d}**	4.65	5.67	6.58	6.96	6.80	**6.13^{d}**
	1500 ppb	5.65	7.58	7.79	9.85	7.85	**7.74^{a}**	4.65	7.12	7.42	8.86	8.38	**7.28^{a}**
Methyl Jasmonates	1 mM	5.65	6.78	7.86	9.87	9.20	**7.87^{a}**	4.65	6.49	8.57	8.74	8.66	**7.42^{a}**
	2 mM	5.65	5.95	6.95	9.10	8.14	**7.16^{cd}**	4.65	4.96	5.13	9.52	8.62	**6.57^{c}**
	3 mM	5.65	6.64	7.38	8.10	7.75	**7.10^{d}**	4.65	5.17	6.24	7.64	6.80	**6.10^{d}**
Salicylic acid	1mM	5.65	6.99	7.14	8.52	8.36	**7.33^{bc}**	4.65	7.28	7.38	7.59	7.39	**6.86^{b}**
	2mM	5.65	6.67	7.35	9.95	7.68	**7.46^{b}**	4.65	5.46	7.11	8.88	8.43	**6.90^{b}**
	3mM	5.65	5.92	7.05	9.29	7.80	**7.14^{cd}**	4.65	5.77	6.49	8.60	6.61	**6.42^{c}**
Control		5.65	7.17	7.30	7.75	7.21	**7.02^{d}**	4.65	5.49	5.90	7.10	6.90	**6.00^{d}**
Mean		**5.65^{e}**	**6.60^{d}**	**7.30^{c}**	**8.95^{a}**	**7.98^{b}**		**4.65^{e}**	**5.82^{d}**	**6.62^{c}**	**8.23^{a}**	**7.55^{b}**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 0.19 **Days (D) =** 0.14 **D x T =** 0.43						**Treatment (T) =** 0.17 **Days (D) =** 0.12 **D x T =** 0.38					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 22a: Effect of different anti-senescence compounds and storage interval on the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Total sugars (%)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	5.15	5.39	6.14	8.50	7.43	**6.52^{d}**
	1000 ppb	5.15	5.98	6.89	7.70	7.35	**6.61^{d}**
	1500 ppb	5.15	7.35	7.60	9.35	8.11	**7.51^{a}**
Methyl Jasmonates	**1mM**	5.15	6.63	8.21	9.30	8.93	**7.65^{a}**
	2mM	5.15	5.45	6.04	9.31	8.38	**6.87^{c}**
	3mM	5.15	5.90	6.81	7.87	7.27	**6.60^{d}**
Salicylic acid	**1mM**	5.15	7.13	7.26	8.05	7.87	**7.09^{b}**
	2mM	5.15	6.06	7.23	9.41	8.05	**7.18^{b}**
	3mM	5.15	5.84	6.77	8.94	7.20	**6.78^{c}**
Control		5.15	6.33	6.60	7.42	7.05	**6.51^{d}**
Mean		**5.15^{e}**	**6.21^{d}**	**6.96^{c}**	**8.59^{a}**	**7.77^{b}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.13 **Days (D)** = 0.095 **D x T** = 0.30					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 22: Effect of different anti-senescence compounds and storage interval on the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

with 9.87 and 9.85 per cent total sugars content, respectively; thereafter followed a decline till the end of the storage with 9.20 and 7.85 per cent total sugars content respectively. Similar trends were also noticed in the year of 2017-18. The maximum average total sugars was registered in the fruits treated with MeJA 1mM (7.42%) followed by 1-MCP 1500 ppb (7.28%) However, the control fruits recorded the lowest total sugars content of 6 per cent. A gradual increase in the total sugars was noticed in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb up to 60 days of the storage interval with 8.74 and 8.86 per cent total sugars content respectively; thereafter followed a decline till the end of the storage with 8.66 and 8.38 per cent total sugars content respectively. The interaction between treatments and storage interval found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 22a and Fig 22). MeJA 1mM was the best in retaining maximum total sugars (7.65%) followed by 1-MCP 1500 ppb (7.51%), whereas control fruits recorded the lowest average total sugars of 6.51 per cent. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the increase in sugars (total and reducing sugars) might be due to breakdown of starch into sugars, as on complete hydrolysis of starch no further increase in sugars occur and subsequently a decline in these parameter is predictable as they along with other organic acids are primary substrate for respiration (Wills *et al* 1980).

These results are in agreement with the findings of Gonzalez-Aguilar *et al* (2000) who registered the maximum sugar content in mango fruit cv. 'Kent' subjected to MeJA as compared to control during storage. 1-MCP treatment did not influence the sugar concentration in kiwi (Park *et al* 2015) and medlar fruit (Selcuk and Erkan 2015). Amanullah *et al* (2017) who demonstrated the effect of SA on shelf-life and quality of guava fruits and found that fruits treated with SA registered maximum total sugar in contrast to control after 10 days of storage.

4.2.9 Vitamin C (mg/100g)

The data on the effect of anti-senescence compounds on vitamin C content of Kinnow fruit registered a linear decline in its level throughout the storage period (Table 23). The treatments showed a significant difference among themselves with regard to loss in vitamin C content. In 2016-17, The average maximum ascorbic acid content of 22.67 mg/100g pulp was retained and maintained in fruits treated with MeJA 1mM, which was followed by the ascorbic acid content of 21.97 mg/100g pulp in the fruits treated with 1-MCP 1500 ppb. However, control fruit retained the lowest average ascorbic acid (19.72 mg/100g pulp) content during storage. It was further noticed that ascorbic acid content in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb ranged from 29.15 to 13.80 and 27.79 to 11.80 mg/100g pulp, respectively from 30 days to 75 days of storage period. On the other hand, the

Table 23: Effect of anti-senescence compounds and storage interval on vitamin C content (mg/100g) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

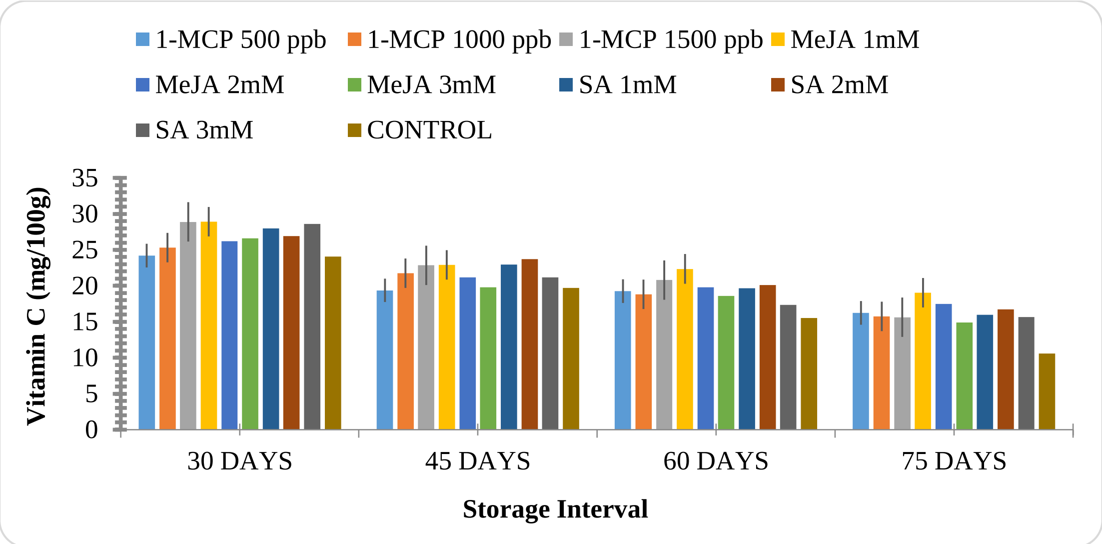
TREATMENT		Vitamin C (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	**500 ppb**	33.97	23.38	17.43	17.35	12.25	**20.88^{c}**	33.88	25.00	21.32	21.18	20.23	**24.32^{e}**
	1000 ppb	33.97	24.91	19.73	15.10	12.94	**21.33^{bc}**	33.88	25.73	23.82	22.51	18.53	**24.89^{de}**
	1500 ppb	33.97	27.79	18.49	17.79	11.80	**21.97^{b}**	33.88	30.00	27.21	23.82	19.44	**26.87^{b}**
Methyl Jasmonates	**1mM**	33.97	29.15	18.49	17.94	13.80	**22.67^{a}**	33.88	28.68	27.35	26.76	24.26	**28.19^{a}**
	2mM	33.97	24.85	18.06	17.35	14.10	**21.67^{b}**	33.88	27.56	24.26	22.28	20.88	**25.77^{c}**
	3mM	33.97	26.18	16.79	16.47	11.12	**20.90^{c}**	33.88	27.06	22.79	20.71	18.68	**24.62^{de}**
Salicylic acid	**1mM**	33.97	26.18	17.94	17.21	13.30	**21.72^{b}**	33.88	29.82	28.00	22.16	18.66	**26.50^{b}**
	2mM	33.97	23.23	22.73	17.43	12.12	**21.90^{b}**	33.88	30.59	24.71	22.80	21.32	**26.66^{b}**
	3mM	33.97	29.59	18.06	13.03	12.65	**21.46^{bc}**	33.88	27.65	24.26	21.69	18.64	**25.22^{cd}**
Control		33.97	24.00	18.78	13.35	8.50	**19.72^{d}**	33.88	24.12	20.63	17.73	12.64	**21.80^{f}**
Mean		**33.97^{a}**	**25.93^{b}**	**18.65^{c}**	**16.30^{d}**	**12.26^{e}**		**33.88^{a}**	**27.62^{b}**	**24.44^{c}**	**22.16^{d}**	**19.33^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 0.69 **Days (D) =** 0.49 **D x T =** 1.55						**Treatment (T) =** 0.72 **Days (D) =** 0.51 **D x T =** 1.61					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 23a: Effect of different anti-senescence compounds and storage interval on the vitamin C (mg/100g) content in Kinnow fruit stored at 5-7°C and 90-95% RH

Vitamin C (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	33.92	24.19	19.37	19.26	16.24	**22.60[g]**
	1000 ppb	33.92	25.32	21.77	18.80	15.73	**23.11[ef]**
	1500 ppb	33.92	28.89	22.85	20.80	15.62	**24.42[b]**
Methyl Jasmonates	**1mM**	33.92	28.91	22.92	22.35	19.03	**25.43[a]**
	2mM	33.92	26.20	21.16	19.81	17.49	**23.72[cd]**
	3mM	33.92	26.62	19.79	18.59	14.90	**22.76[fg]**
Salicylic acid	**1mM**	33.92	28.00	22.97	19.68	15.98	**24.11[bc]**
	2mM	33.92	26.91	23.72	20.11	16.72	**24.28[b]**
	3mM	33.92	28.62	21.16	17.36	15.64	**23.34[de]**
Control		33.92	24.06	19.70	15.54	10.57	**20.76[h]**
Mean		**33.92[a]**	**26.77[b]**	**21.54[c]**	**19.23[d]**	**15.79[e]**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 0.48 **Days (D)** = 0.34 **D x T** = 1.07					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.23: Effect of different anti-senescence compounds and storage interval on the vitamin C (mg/100g) content of Kinnow fruit stored at 5-7°C and 90-95% RH

control fruits followed a continuous decline at faster pace and thereby retained the lowest ascorbic acid content ranged from 24.00 to 8.50 mg/100g pulp from 30 days to 75 days of storage period. The similar trends were also noticed in the year of 2017-18. Fruits treated with MeJA 1mM were superior with respect to retaining and maintaining the maximum ascorbic acid content (28.19 mg/100g) followed by fruits treated with 1-MCP 1500 ppb (26.87 mg/100g pulp). However, the control fruits maintained the lowest average ascorbic acid content (21.80 mg/100g pulp). The data further revealed that the ascorbic acid content in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb ranged from 28.68 to 24.26 and 30.00 to 19.44 mg/100g pulp, respectively from 30 days to 75 days of storage. On the other hand, the control fruits continued to decline in ascorbic acid content at faster pace and thereby ranged 24.12 to 12.64 mg/100 g pulp from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The pooled mean analysis of both the years (Table 23a and Fig 23) also confirmed the findings as fruits treated with MeJA 1mM retained the mean maximum ascorbic acid (25.43mg/100g pulp) followed by 1-MCP 1500 ppb (24.42 mg/100g pulp). However, control fruits recorded the lowest average ascorbic acid content (20.76 mg/100g pulp). The interaction between treatments and storage interval was found to be significant. In the present study control fruits revealed the maximum loss in ascorbic acid content during storage may be due to conversion of ascorbic acid to dehydroascorbic acid by the action of ascorbic acid oxidase (Mapson 1970).

These results are in conformity with the findings of Geransayeh *et al* (2015) who observed that fruits of strawberry subjected to MeJA maintained the higher ascorbic acid content than those of untreated after 12 days of storage. Fruits of Kinnow subjected to 1-MCP maintained the higher ascorbic acid content as compared to control during storage. The similar results were also reported in medlar (Selcuk and Erkan 2015) and Chinese chive (Wu *et al* (2009). Amanullah *et al* (2017) reported that postharvest application of SA registered the higher ascorbic acid content in guava in contrast to control after 10 days of storage. Similar results were also reported in plum cv. 'Santa Rosa' (Davarynejad *et al* 2015).

4.2.10 Total Carotenoids (mg/100g)

The data on total carotenoids influenced by different anti-senescence compounds revealed an identical trends during storage (Table 24). The treatments showed a significant effect with regard to maintain the carotene content during storage. In 2016-17, the average maximum carotene (0.66 mg/100g pulp) content was recorded in the fruits treated with MeJA 1mM followed by 1-MCP 1500 ppb (0.55 mg/100g pulp). However, the control fruits recorded the lowest average carotene (0.45 mg/100g pulp) content. A gradual increase in total catotenoids was registered in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb after 30 days of the storage which was recorded as 0.94 and 0.63 mg/100g pulp respectively;

Table 24: Effect of different anti-senescence compounds and storage interval on total carotenoids (mg/100g) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

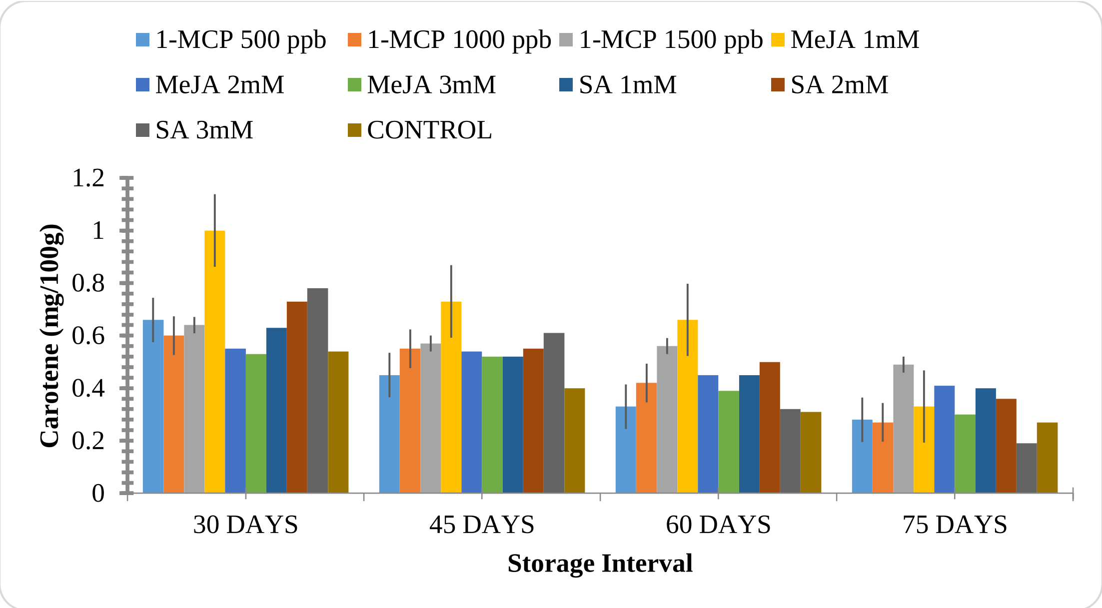
TREATMENT		Total carotenoids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.48	0.78	0.47	0.35	0.25	**0.47^f**	0.37	0.54	0.44	0.32	0.31	**0.39^f**
	1000 ppb	0.48	0.65	0.56	0.52	0.34	**0.51^e**	0.37	0.56	0.55	0.32	0.20	**0.40^f**
	1500 ppb	0.48	0.63	0.59	0.57	0.48	**0.55^b**	0.37	0.66	0.55	0.55	0.50	**0.52^b**
Methyl Jasmonates	**1 mM**	0.48	0.94	0.82	0.71	0.37	**0.66^a**	0.37	1.06	0.64	0.61	0.30	**0.59^a**
	2 mM	0.48	0.60	0.60	0.51	0.45	**0.53^{cd}**	0.37	0.50	0.48	0.40	0.37	**0.42^e**
	3 mM	0.48	0.58	0.61	0.40	0.30	**0.47^f**	0.37	0.48	0.44	0.39	0.30	**0.40^f**
Salicylic acid	**1mM**	0.48	0.70	0.54	0.51	0.43	**0.54^{cd}**	0.37	0.57	0.50	0.40	0.37	**0.44^d**
	2mM	0.48	0.70	0.58	0.55	0.39	**0.55^{bc}**	0.37	0.77	0.53	0.45	0.34	**0.49^c**
	3mM	0.48	0.79	0.71	0.40	0.21	**0.52^{de}**	0.37	0.77	0.51	0.24	0.18	**0.41^{ef}**
Control		0.48	0.50	0.46	0.41	0.38	**0.45^g**	0.37	0.58	0.35	0.22	0.16	**0.34^g**
Mean		**0.48^d**	**0.67^a**	**0.59^b**	**0.49^c**	**0.36^e**		**0.37^d**	**0.65^a**	**0.50^b**	**0.39^c**	**0.30^e**	
LSD (P≤0.05)		**Treatment (T)** = 0.0133 **Days (D)** = 0.00094 **D x T** = 0.0298						**Treatment (T)** = 0.0120 **Days (D)** = 0.000085 **D x T** = 0.027					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 24a: Effect of different anti-senescence compounds and storage interval on the total carotenoids (mg/100g pulp) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

		Total carotenoids (mg/100g)					
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.42	0.66	0.45	0.33	0.28	**0.43^{g}**
	1000 ppb	0.42	0.60	0.55	0.42	0.27	**0.45^{f}**
	1500 ppb	0.42	0.64	0.57	0.56	0.49	**0.54^{b}**
Methyl Jasmonates	**1mM**	0.42	1.00	0.73	0.66	0.33	**0.63^{a}**
	2mM	0.42	0.55	0.54	0.45	0.41	**0.47^{e}**
	3mM	0.42	0.53	0.52	0.39	0.30	**0.43^{g}**
Salicylic acid	**1mM**	0.42	0.63	0.52	0.45	0.40	**0.49^{d}**
	2mM	0.42	0.73	0.55	0.50	0.36	**0.51^{c}**
	3mM	0.42	0.78	0.61	0.32	0.19	**0.46^{e}**
Control		0.42	0.54	0.40	0.31	0.27	**0.39^{h}**
Mean		**0.42^{d}**	**0.67^{a}**	**0.54^{b}**	**0.44^{c}**	**0.33^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.010 **Days (D)** = 0.00077 **D x T** = 0.024					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 24: Effect of different anti-senescence compounds and storage interval on the total carotenoids (mg/100g pulp) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

was found to be significant during 2016-17 and 2017-18. The findings were further confirmed thereafter followed a continuous decline till the end of the storage (0.37 and 0.48 mg/100g pulp, respectively). On the other hand, control fruits followed an abrupt and sharp decline at faster pace in carotene content ranged from 0.50 to 0.38 mg/100g pulp from 30 days to 75 days of storage period. The similar trends were noticed in 2017-18. The average maximum carotene (0.59 mg/100g pulp) content was recorded in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb (0.52 mg/100g pulp) whereas, the control fruits registered the lowest average carotene (0.34 mg/100g pulp) content. The data further revealed a gradual increase in carotene content in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb after 30 days of the storage which was recorded as 1.06 and 0.99 mg per cent, respectively; thereafter followed a continuous decline till the end of the storage i.e. 0.30 and 0.50 mg per cent, respectively. On the other hand, control fruits followed an abrupt decline with an advancement in storage period and thereby ranged from 0.58 to 0.16 mg per cent from 30 days to 75 days, respectively. The interaction between treatments and storage interval was found to be significant during both the years i.e. 2016-17 and 2017-18. The findings were further confirmed through the pooled mean analysis of both the years (Table 24a and Fig 24). MeJA 1mM was the best in retaining and maintaining the maximum carotene (0.63 mg/100g pulp) content followed by 1-MCP 1500 ppb (0.54 mg/100g pulp). On the other hand, control fruits recorded the lowest average carotene (0.39 mg/100g pulp) content. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the control fruits followed a continuous instability and subsequent reduction of carotenoids is because of their vulnerability to oxidation and geometric isomerization of its polyene chain during storage (Sanchez-Moreno *et al* 2003). Ethylene causes the loss of chlorophylls, produces some minor changes in carotenoids, induces carotenoid synthesis and thus has the potential to re-establish the orange colors (El-Zeftawi and Garrett 1978).

The present results are in conformity with the findings of Boonyaritthongchai *et al* (2017) reported that fruits of mango cv. Nom Dok Mai subjected to MeJA retained the maximum carotene content than that of control fruits after 15 days of storage. Similar findings were also noticed in lettuce (Kim *et al* 2006). Sun *et al* (2012) reported that the post harvest application of 1-MCP maintained the higher content of total catotenoids in Chinese Kale during storage. Similar findings were also reported in broccoli (Fernandez-Leon *et al* 2013). Pre-harvest application of SA maintained the highest carotene content in the navel orange cv. ‘Cara Cara’ after 105 days of storage (Huang *et al* 2008).

4.2.11 Pectin (Ca pectate %)

The data pertaining to the effect of anti-senescence compounds revealed a gradual decrease in pectin content in Kinnow fruit irrespective of the treatment during storage (Table 25). In 2016-17, the maximum pectin (0.56%) was recorded in the fruits treated with MeJA 1mM (0.56 mg %) followed by 1-MCP 1500 ppb where it was recorded as 0.55 per cent. On the other hand, the control fruits registered the lowest pectin content of 0.46 per cent. The data further revealed that the pectin content in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb ranged from 0.68 to 0.28 and 0.77 to 0.15 per cent, respectively from 30 days to 75 days of storage, while the control fruits followed a continuous depletion in pectin content at faster pace ranged from 0.65 to 0.12 per cent from 30 days to 75 days of storage. The similar trends were noticed in 2017-18. Fruits treated with MeJA 1mM were superior with respect to retaining and maintaining the higher pectin (0.38%) content followed by 1-MCP 1500 ppb where it was recorded as 0.37 per cent. On the other hand, the control fruits registered the lowest pectin content (0.27%). The data further revealed that the pectin content in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb ranged from 0.41 to 0.26 and 0.44 to 0.26 per cent, respectively from 30 days to 75 days of storage period. However, control fruits followed a sharp and abrupt decline in pectin content with an advancement in storage period ranged 0.32 to 0.13 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant in 2016-17 and 2017-18. The pooled mean analysis of both years (Table 25a and Fig 25) further confirmed the findings as fruits treated with MeJA 1mM retained and maintained the maximum pectin content of 0.47 per cent followed by fruits treated with 1-MCP 1500 ppb and salicylic acid 2mM where it was recorded as 0.46 per cent whereas, as fruits which were kept under control treatment retained the lowest average pectin content of 0.36 per cent. The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the loss in pectin content might be due to the degree of fruit ripening which affects the pectin contents, which supports the hypothesis that softening is closely related to pectin solubilisation and depolymerization (Kurz *et al* 2008 and Rosli *et al* 2004).

These results are in corroboration with the findings of (Geransayeh *et al* 2015) who reported that fruits of strawberry subjected to MeJA registered the higher calcium pectate content than that of control fruits after 12 days of storage.

Table 25: Effect of different anti-senescence compounds and storage interval on pectin content (Ca pectate %) in Kinnow fruit stored at 5-7°C and 90-95% RH

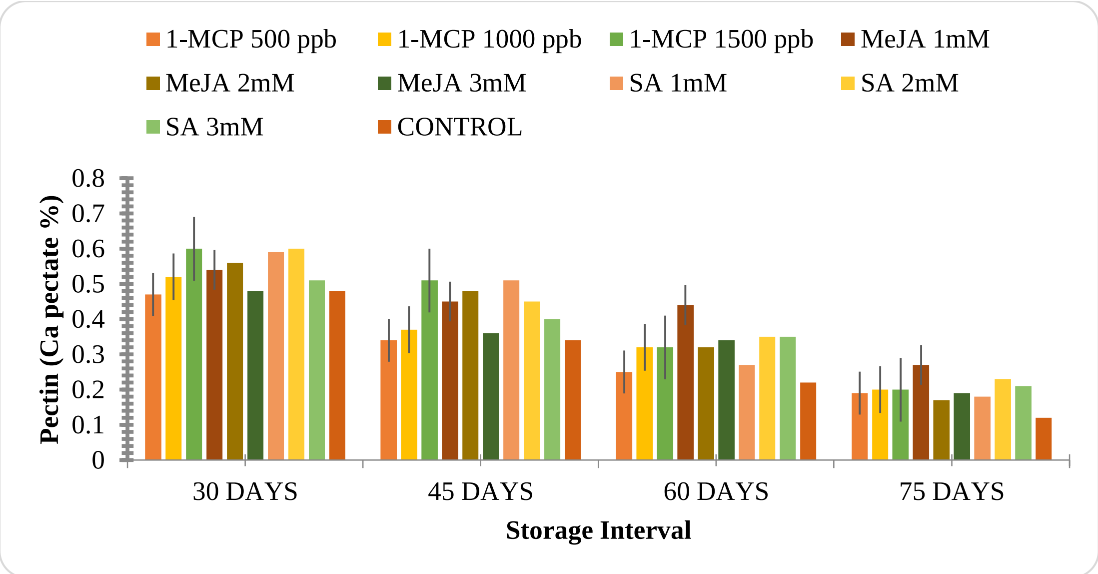
TREATMENT		Pectin (Ca pectate %)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	0.800	0.660	0.430	0.290	0.210	**0.48[f]**	0.500	0.286	0.246	0.220	0.173	**0.28[h]**
	1000 ppb	0.800	0.650	0.490	0.410	0.200	**0.51[e]**	0.500	0.340	0.250	0.236	0.224	**0.32[g]**
	1500 ppb	0.800	0.770	0.620	0.390	0.150	**0.55[ab]**	0.500	0.440	0.400	0.260	0.260	**0.37[b]**
Methyl Jasmonates	1 mM	0.800	0.680	0.520	0.500	0.280	**0.56[a]**	0.500	0.410	0.376	0.376	0.260	**0.38[a]**
	2 mM	0.800	0.700	0.540	0.430	0.190	**0.53[cd]**	0.500	0.426	0.416	0.220	0.146	**0.34[e]**
	3 mM	0.800	0.630	0.480	0.440	0.160	**0.50[e]**	0.500	0.390	0.260	0.236	0.200	**0.31[g]**
Salicylic acid	1mM	0.800	0.740	0.580	0.440	0.210	**0.54[bc]**	0.500	0.483	0.440	0.210	0.136	**0.35[d]**
	2mM	0.800	0.710	0.580	0.340	0.220	**0.54[bc]**	0.500	0.466	0.320	0.260	0.260	**0.36[c]**
	3mM	0.800	0.670	0.510	0.410	0.220	**0.52[d]**	0.500	0.350	0.300	0.286	0.206	**0.33[f]**
Control		0.800	0.650	0.450	0.260	0.120	**0.46[g]**	0.500	0.320	0.230	0.190	0.130	**0.27[i]**
Mean		**0.80[a]**	**0.69[b]**	**0.51[c]**	**0.40[d]**	**0.20[e]**		**0.50[a]**	**0.39[b]**	**0.32[c]**	**0.25[d]**	**0.20[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.0106 **Days (D)** = 0.00075 **D x T** = 0.0238						**Treatment (T)** = 0.00072 **Days (D)** = 0.000514 **D x T** = 0.0163					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 25a: Effect of different anti-senescence compounds and storage interval on the pectin (Ca pectate %) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

Pectin (Ca pectate %)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.65	0.47	0.34	0.25	0.19	**0.38^f**
	1000 ppb	0.65	0.52	0.37	0.32	0.20	**0.41^e**
	1500 ppb	0.65	0.60	0.51	0.32	0.20	**0.46^b**
Methyl Jasmonates	**1mM**	0.65	0.54	0.45	0.44	0.27	**0.47^a**
	2mM	0.65	0.56	0.48	0.32	0.17	**0.43^c**
	3mM	0.65	0.48	0.36	0.34	0.19	**0.41^e**
Salicylic acid	**1mM**	0.65	0.59	0.51	0.27	0.18	**0.44^c**
	2mM	0.65	0.60	0.45	0.35	0.23	**0.46^b**
	3mM	0.65	0.51	0.40	0.35	0.21	**0.42^d**
Control		0.65	0.48	0.34	0.22	0.12	**0.36^g**
Mean		**0.65^a**	**0.54^b**	**0.42^c**	**0.32^d**	**0.20^e**	
LSD ($P\leq0.05$)		**Treatment (T)** = 0.00096 **Days (D)** = 0.00068 **D x T** = 0.022					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 25: Effect of anti-senescence compound and storage interval on the pectin (Ca pectate %) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

4.2.12 Total phenol (mg/100g)

The data pertaining on the effect of anti-senescence compounds on total phenol revealed an identical trend during storage (Table 26). The treatments showed a significant effect with regard to maintain the total phenol content during storage. In the 2016-17, The average maximum total phenols was registered in the fruits treated with MeJA 1mM (137.30 mg/100g pulp) followed by fruits treated with 1-MCP 1500 ppb, salicylic acid 2mM and 1mM, where it was recorded as 136.40, 136.26 and 132.80 mg/100g pulp) and were at par with each other. However, the control fruits registered the lowest total phenol (110.31 mg/100g pulp) content. A gradual increase in total phenols was noticed in the fruits treated with MeJA 1mM and 1-MCP 1500 ppb after 30 days of the storage i.e. 198.39 and 224.61 mg/100g pulp, respectively; thereafter followed a continuous decline till the end of the storage i.e. 67.54 and 51.76 mg/100g pulp, respectively On the other hand, the control fruits followed an abrupt decline with an advancement in storage in total phenol content at faster pace thereby ranged from 190.79 to 28.48 mg/100 g pulp from 30 days to 75 days of storage. The similar trends were also noticed during 2017-18. Fruits treated with MeJA 1mM revealed the mean maximum total phenols (128.57 mg/100g) followed by fruits treated with salicylic acid 2mM, where it was recorded as 127.06 and 126.29 mg/100g pulp and found statistically at par with each other, whereas control fruits registered the lowest average total phenol (87.24 mg/100g pulp) content. The data further revealed that fruits treated with MeJA 1mM and 1-MCP 1500 ppb registered a gradual rise in total phenol content after 30 days of the storage which was recorded as 196.81 and 220.33 mg/100g pulp, respectively; thereafter followed a decline till the end of the storage i.e. 68.54 and 50.26 mg/100g pulp, respectively. On the other hand, the control fruits followed a sharp and abrupt decline in total phenol with an advancement in storage period and thereby ranged from 160.06 to 23.00 mg/100g pulp from 30 days to 75 days of the storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 26a and Fig 26). MeJA 1mM was the superior in terms of retaining and maintaining the maximum total phenolContent (132.94 mg/100g pulp) followed by fruits treated with 1-MCP 1500 ppb and salicylic acid 2mM (131.73 and 131.27 mg/100g pulp). On the other hand, control fruits recorded the lowest content of total phenol (98.78 mg/100g pulp). The interaction between treatments and storage interval was found to be significant. In the present study MeJA (1mM) and 1-MCP 1500 ppb registered the highest content of total phenol. However, the precise mechanism by which anti-senescence compounds increases the phenolics compounds is not yet elucidated. One explanation could be attributed to the role of anti-senescence compounds as a signal molecule inducing the biosynthesis of defence compounds, such as phenolics. In

Table 26: Effect of different anti-senescence compounds and storage interval on total phenol (mg/100g pulp) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

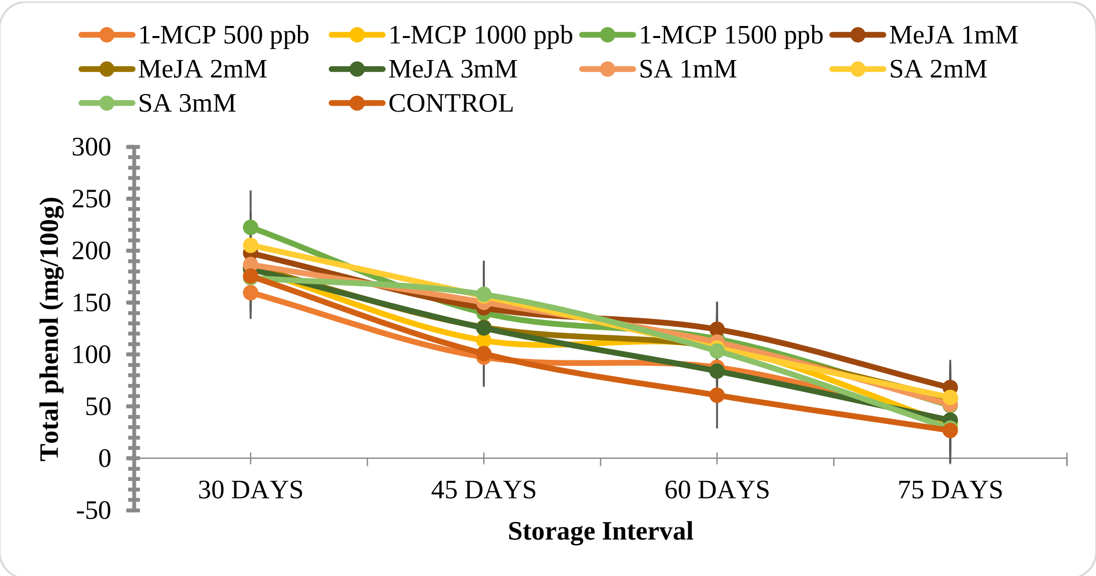
TREATMENTS		Total phenols (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	128.13	192.45	114.34	101.28	34.38	**114.12^{e}**	131.84	126.73	80.70	73.92	37.60	**90.16^{e}**
	1000 ppb	128.13	218.67	132.48	131.20	32.19	**128.53^{cd}**	131.84	147.57	94.63	84.27	33.38	**98.34^{d}**
	1500 ppb	128.13	224.61	158.82	118.67	51.76	**136.40^{ab}**	131.84	220.33	121.48	111.39	50.26	**127.06^{a}**
Methyl Jasmonates	**1 mM**	128.13	198.39	156.52	135.93	67.54	**137.30^{a}**	131.84	196.81	133.12	112.53	68.54	**128.57^{a}**
	2 mM	128.13	192.55	156.52	131.20	50.74	**131.83^{c}**	131.84	176.34	96.04	83.89	64.96	**110.61^{c}**
	3 mM	128.13	183.63	175.06	98.64	42.60	**125.61^{d}**	131.84	180.95	75.96	69.44	30.69	**97.77^{d}**
Salicylic acid	**1mM**	128.13	207.29	159.08	115.47	54.01	**132.80^{bc}**	131.84	165.73	141.56	108.19	49.74	**119.41^{b}**
	2mM	128.13	209.33	163.94	112.92	66.96	**136.26^{ab}**	131.84	201.15	148.59	99.36	50.51	**126.29^{a}**
	3mM	128.13	193.22	179.41	118.16	30.75	**129.48^{cd}**	131.84	154.60	136.32	88.75	26.98	**107.70^{c}**
Control		128.13	190.79	131.21	70.68	28.48	**110.31^{e}**	131.84	160.06	70.40	50.90	23.00	**87.24^{e}**
Mean		**128.13^{c}**	**201.09^{a}**	**152.74^{b}**	**113.41^{d}**	**45.94^{e}**		**131.84^{b}**	**173.03^{a}**	**109.88^{c}**	**88.26^{d}**	**43.57^{e}**	
LSD (P≤0.05)		**Treatment (T) =** 4.29 **Days (D) =** 3.03 **D x T =** 9.59						**Treatment (T) =** 3.69 **Days (D)** = 2.61 **D x T =** 8.25					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 26a: Effect of different anti-senescence compounds and storage interval on the total phenol (mg/100g pulp) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total phenols (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	129.98	159.59	97.52	87.60	35.99	**102.14[f]**
	1000 ppb	129.98	183.12	113.55	107.73	32.78	**113.44[e]**
	1500 ppb	129.98	222.47	140.15	115.03	51.01	**131.73[a]**
Methyl Jasmonates	**1mM**	129.98	197.60	144.82	124.23	68.04	**132.94[a]**
	2mM	129.98	184.44	126.28	107.54	57.85	**121.22[c]**
	3mM	129.98	182.29	125.51	84.04	36.64	**111.69[e]**
Salicylic acid	**1mM**	129.98	186.51	150.32	111.83	51.87	**126.10[b]**
	2mM	129.98	205.24	156.26	106.14	58.73	**131.27[a]**
	3mM	129.98	173.91	157.86	103.45	28.86	**118.82[d]**
Control		129.98	175.42	100.80	60.79	26.87	**98.78[g]**
Mean		**129.98[b]**	**187.06[a]**	**131.31[b]**	**100.84[c]**	**44.87[d]**	
LSD (P≤0.05)		**Treatment (T)** =2.29 **Days (D)** = 1.62 **D x T** = 5.12					

Mean values with same alphabets are statistically similar at $p \le 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 26: Effect of different anti-senescence compounds and storage interval on the total phenol (mg/100g pulp) in Kinnow fruit stored at 5-7°C and 90-95% RH

addition, it has been shown that SA stimulates phenylalanine ammonia lyase (PAL) activity (Yao and Tian 2005), which could be responsible for de novo synthesis of phenolic compounds.

The results are in agreement with the findings of Zapata *et al* (2014) who, however, reported that fruits of plum subjected to pre-harvest application of MeJA registered higher content of total phenols. Tavallali and Moghadam (2015) observed that Kinnow fruits subjected to 1-MCP registered the higher content of total phenol than that of control. The similar results were also obtained in apple (Gago *et al* 2015); pear (Arias *et al* 2009) and plum (Singh and Singh 2012). Amanullah *et al* (2017) evaluated the postharvest effect of SA on storage life and quality of guava and found that fruits subjected to SA registered the maximum total phenol content. Similar studies were also noticed in peach (Khademi and Ersadi 2013) and plum cv. 'Santa Rosa' (Davarynejad *et al* 2015).

4.2.13 Pectin methylesterase (PME) activity

The results pertaining to effect of anti-senescence compounds on PME activity (micro equi. acid produced/min/ml tissue) illustrated that the enzyme activity registered significant changes over the storage interval (Table 27). In general, irrespective of the treatment (except MeJA 1mM, 1-MCP 1500 ppb and SA 2mM) the maximum PME activity with respect to storage interval was recorded after 45 days of the storage; thereafter followed a sudden decline till the end of the storage. In 2016-17, the average minimum PME activity (0.26 micro equi. acid produced/min/ml/tissue) was noticed in the fruits treated with MeJA 1mM followed by 1-MCP 1500 ppb (0.27 micro equi. acid produced/min/ml/tissue). However, control fruits registered the average maximum PME activity (0.45 micro equi. acid produced/min/ml/tissue). The data further revealed that fruits treated with MeJA 1mM delayed peak in PME activity till 60 days of the storage i.e. 0.52 micro equi. acid produced/min/ml/tissue followed by 1-MCP 1500 and SA 2mM (0.38 and 0.57 micro equi. acid produced/min/ml/tissue, respectively). On the other hand, the control fruits registered an earliest peak in PME activity after 45 days of the storage i.e. 0.86 micro equi. acid produced/min/ml/tissue. The similar results were also obtained in the 2017-18. Fruits treated with MeJA 1mM registered the lowest PME activity (1.42 micro equi. acid produced/min/ml/tissue) followed by 1-MCP 1500 ppb (1.58 micro equi. acid produced/min/ml/tissue). However, the control fruits registered the average maximum PME activity (2.37 micro equi. acid produced/min/ml/tissue). It was noticed that the fruits treated with MeJA 1mM delayed peak in PME activity till 60 days of the storage period i.e. 2.63 micro equi. acid produced/min/ml/tissue followed by 1-MCP 1500 ppb and SA 2mM (2.03 and 3.26 micro equi. acid produced/min/ml/tissue, respectively). On the other hand, the control fruits registered an earliest peak in PME activity after 45 days of the storage i.e. 3.90 micro equi. acid produced/min/ml/tissue. The interaction between treatments and storage interval was found to be significant during the year of 2016-17 and 2017-18, respectively. The findings were also visualized through pooled mean analysis (Table 27a and Fig 27) as fruits treated with MeJA

Table 27: Effect of different anti-senescence compounds and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

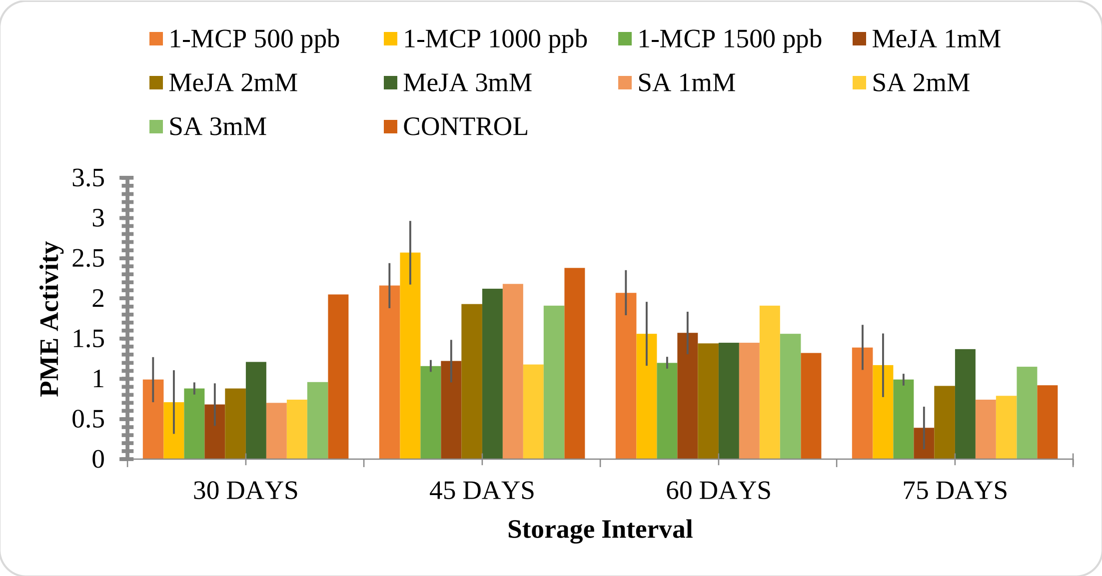
TREATMENT		PME activity (unit/ml)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.12	0.28	0.73	0.71	0.38	**0.44[a]**	0.63	1.70	3.60	3.43	2.40	**2.35[a]**
	1000 ppb	0.12	0.35	0.71	0.40	0.39	**0.39[c]**	0.63	1.07	4.43	2.73	1.96	**2.16[bc]**
	1500 ppb	0.12	0.23	0.33	0.38	0.28	**0.27[h]**	0.63	1.53	2.00	2.03	1.70	**1.58[f]**
Methyl Jasmonates	**1 mM**	0.12	0.23	0.28	0.52	0.21	**0.26[h]**	0.63	1.13	2.16	2.63	0.57	**1.42[g]**
	2 mM	0.12	0.23	0.74	0.48	0.26	**0.37[d]**	0.63	1.53	3.13	2.40	1.57	**1.85[d]**
	3 mM	0.12	0.30	0.61	0.57	0.45	**0.41[b]**	0.63	2.13	3.63	2.33	2.30	**2.20[b]**
Salicylic acid	**1mM**	0.12	0.24	0.64	0.45	0.28	**0.35[f]**	0.63	1.17	3.73	2.46	1.20	**1.84[d]**
	2mM	0.12	0.21	0.40	0.57	0.21	**0.30[g]**	0.63	1.27	1.96	3.26	1.37	**1.70[e]**
	3mM	0.12	0.16	0.47	0.47	0.28	**0.38[d]**	0.63	1.76	3.36	2.66	2.03	**2.09[c]**
Control		0.12	0.74	0.86	0.31	0.20	**0.45[a]**	0.63	3.36	3.90	2.33	1.65	**2.37[a]**
Mean		**0.12[e]**	**0.30[d]**	**0.58[b]**	**0.49[a]**	**0.29[c]**		**0.63[e]**	**1.66[d]**	**3.19[b]**	**2.63[a]**	**1.67[c]**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 0.00096 **Days (D) =** 0.00068 **D x T =** 0.021						**Treatment (T) =** 0.061 **Days (D) =** 0.043 **D x T =** 0.14					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 27a: Effect of different anti-senescence compounds and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

PME activity (unit/ml)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.37	0.99	2.16	2.07	1.39	**1.40[a]**
	1000 ppb	0.37	0.71	2.57	1.56	1.17	**1.28[b]**
	1500 ppb	0.37	0.88	1.16	1.20	0.99	**0.92[ab]**
Methyl Jasmonates	**1mM**	0.37	0.68	1.22	1.57	0.39	**0.85[g]**
	2mM	0.37	0.88	1.93	1.44	0.91	**1.11[d]**
	3mM	0.37	1.21	2.12	1.45	1.37	**1.31[b]**
Salicylic acid	**1mM**	0.37	0.70	2.18	1.45	0.74	**1.09[d]**
	2mM	0.37	0.74	1.18	1.91	0.79	**1.00[e]**
	3mM	0.37	0.96	1.91	1.56	1.15	**0.92[f]**
Control		0.37	2.05	2.38	1.32	0.92	**1.41[a]**
Mean		**0.37[d]**	**0.98[c]**	**1.88[a]**	**1.56[b]**	**0.98[c]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.029 **Days (D)** = 0.020 **D x T** = 0.065					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 27: Effect of different anti-senescence compounds and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

1mM registered the lowest PME activity (0.85 micro equi. acid produced/min/ml/tissue) followed by 1-MCP 1500 ppb (0.92 micro equi. acid produced/min/ml/tissue). However, control fruits registered the maximum PME activity (1.41micro equi. acid produced/min/ml/tissue). The interaction between treatments and storage interval was found to be significant. In the present study, MeJA (1mM) and 1-MCP 1500 ppb) revealed the lowest PME activity; might be due anti-senescent action of MeJA maintains cellular membrane integrity which reduces the de-estarification of pectins hence maintains the fruit texture (Meng *et al* 2009).

The results are in corroboration with the findings of Venkatachalam and Meenune (2015) who reported that longkong fruits subjected to MeJA registered the lowest PME activity during storage. Similar findings were reported in peach fruit (Meng *et al* 2009). Zhu *et al* (2015) and Lohani *et al* (2004) reported that fruits of banana subjected to 1-MCP treatment registered low activity of PME with an advancement in storage period. Similar findings were also reported in avocado (Jeong *et al* 2002). The fruits of 'plum' subjected to SA treatment registered the lower PME activity in contrast to control fruits after 40 days of storage (Majeed and Jawandha 2016).

4.2.14 Cellulase activity

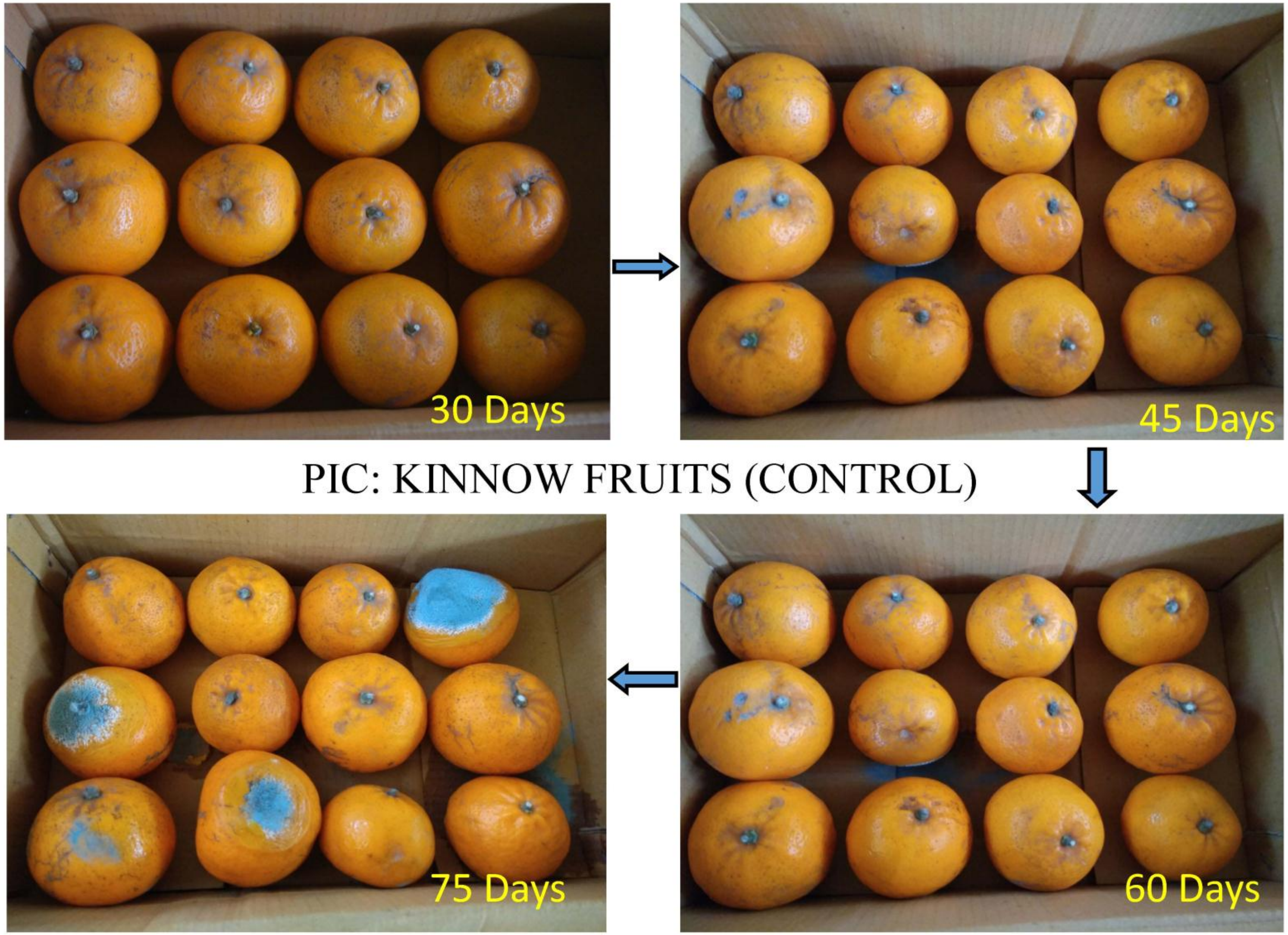
The data on cellulase activity influenced by different anti-senescence compounds revealed an identical trend during storage (Table 28). In general, Irrespective of the treatments (except MeJA 1mM, 1-MCP 1500 ppb and SA 2mM), the maximum cellulase activity with respect to storage interval was recorded after 45 days of the storage; thereafter followed a sudden decline till the end of the storage. In 2016-17, the average lowest cellulase activity (1.74 mg glucose per min^{-1} mg $protein^{-1}$) was recorded in the fruits treated with MeJA 1mM followed by 1-MCP 1500 ppb (1.89 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, the control fruits showed the mean maximum cellulase activity (3.49 mg glucose per min^{-1} mg $protein^{-1}$). The data further revealed that the fruits treated with MeJA 1mM delayed the peak in cellulase activity till 60 days of the storage i.e. 3.59 mg glucose per min^{-1} mg $protein^{-1}$ followed by 1-MCP 1500 ppb and SA 2mM (3.94 and 3.33 mg glucose per min^{-1} mg $protein^{-1}$, respectively). On the other hand, control fruits registered an earliest peak in cellulase activity after 30 days of the storage where it was 8.54 mg glucose per min^{-1} mg $protein^{-1}$. The similar trends were noticed in the year of 2017-18. Fruits treated with MeJA 1mM revealed the lowest average cellulase activity (2.37 mg glucose per min^{-1} mg $protein^{-1}$) followed by fruits 1-MCP 1500 ppb and salicylic acid 2mM where it was recorded as 3.06 and 3.33 mg glucose per min^{-1} mg $protein^{-1}$. However, the control fruits recorded the maximum cellulase activity (5.68 mg glucose per min^{-1} mg $protein^{-1}$. The fruits treated with MeJA 1mM delayed the peak in cellulase activity till 60 days of the storage i.e. 4.62 mg glucose per min^{-1} mg $protein^{-1}$

Table 28: Effect of different anti-senescence compounds and storage interval on cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

TREATMENT		Cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.84	2.77	5.19	4.13	2.90	**3.17^{b}**	1.68	4.99	7.73	7.27	3.99	**5.13^{b}**
	1000 ppb	0.84	2.33	7.44	2.86	0.72	**2.84^{d}**	1.68	4.10	5.85	5.15	3.78	**4.11^{d}**
	1500 ppb	0.84	2.03	2.27	3.94	0.38	**1.89^{g}**	1.68	2.70	4.81	4.86	1.24	**3.06^{g}**
Methyl Jasmonates	**1 mM**	0.84	1.66	2.25	3.59	0.38	**1.74^{h}**	1.68	2.25	2.58	4.62	0.72	**2.37^{h}**
	2 mM	0.84	2.21	5.00	2.63	0.29	**2.19^{f}**	1.68	4.29	9.00	3.46	0.53	**3.79^{e}**
	3 mM	0.84	1.34	7.11	3.61	2.24	**3.03^{c}**	1.68	3.38	8.94	6.85	3.00	**4.77^{c}**
Salicylic acid	**1mM**	0.84	2.40	5.31	1.84	0.31	**2.14^{f}**	1.68	3.90	9.62	1.33	0.58	**3.42^{f}**
	2mM	0.84	1.70	1.96	3.33	1.74	**1.91^{g}**	1.68	2.62	4.03	7.16	1.16	**3.33^{f}**
	3mM	0.84	2.15	5.49	2.61	1.21	**2.46^{e}**	1.68	4.65	7.36	5.60	1.16	**4.09^{d}**
Control		0.84	8.54	4.76	3.08	0.21	**3.49^{a}**	1.68	10.91	8.56	6.89	0.34	**5.68^{a}**
Mean		**0.84^{e}**	**2.71^{c}**	**4.68^{a}**	**3.16^{b}**	**1.04^{d}**		**1.68^{e}**	**4.38^{c}**	**6.85^{a}**	**5.32^{b}**	**1.65^{d}**	
LSD (P≤0.05)		**Treatment (T) =** 0.061 **Days (D) =** 0.043 **D x T =** 0.14						**Treatment (T) =** 0.12 **Days (D) =** 0.08 **D x T =** 0.27					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

PIC : KINNOW FRUITS TREATED WITH MeJA

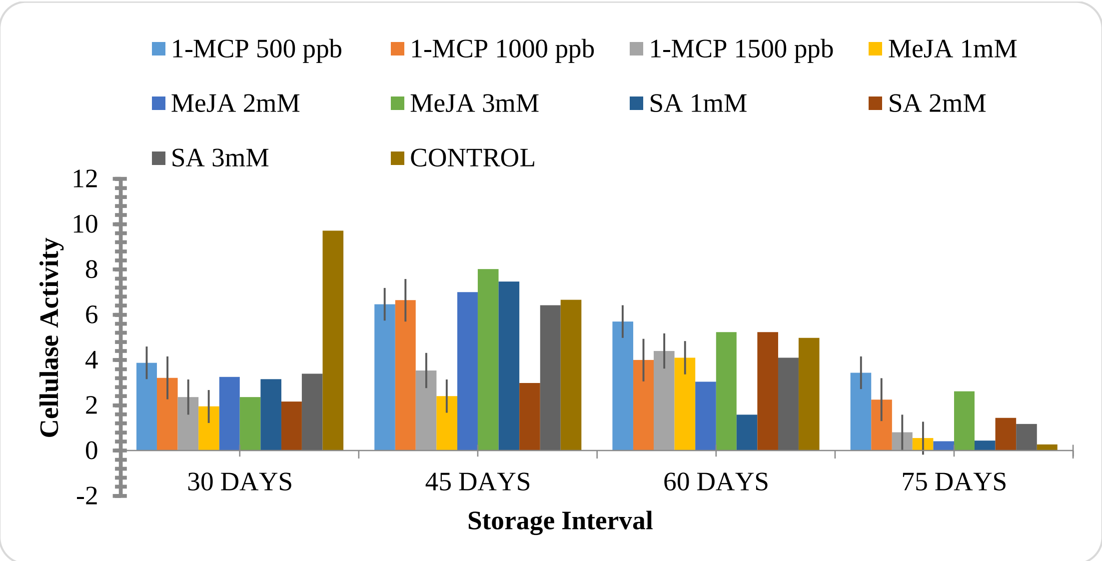


PIC: KINNOW FRUITS (CONTROL)

Table 28a: Effect of different anti-senescence compounds and storage interval on the cellulase activity (mg glucose per min^{-1} mg protein^{-1}) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

Cellulase activity (mg glucose per min^{-1} mg protein^{-1})							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	1.26	3.88	6.46	5.70	3.44	**4.15^{b}**
	1000 ppb	1.26	3.21	6.64	4.00	2.25	**3.47^{d}**
	1500 ppb	1.26	2.36	3.54	4.40	0.81	**2.47^{i}**
Methyl Jasmonates	**1mM**	1.26	1.95	2.41	4.10	0.55	**2.06^{j}**
	2mM	1.26	3.25	7.00	3.04	0.41	**2.99^{f}**
	3mM	1.26	2.36	8.02	5.23	2.62	**3.90^{c}**
Salicylic acid	**1mM**	1.26	3.15	7.46	1.58	0.44	**2.78^{g}**
	2mM	1.26	2.16	2.99	5.24	1.45	**2.62^{h}**
	3mM	1.26	3.40	6.42	4.10	1.18	**3.27^{e}**
Control		1.26	9.72	6.66	4.98	0.27	**4.58^{a}**
Mean		**1.26^{e}**	**3.54^{c}**	**5.76^{a}**	**4.24^{b}**	**1.34^{d}**	
LSD (**P≤0.05**)		**Treatment (T)** = 0.092 **Days (D)** = 0.065 **D x T** = 0.21					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 28: Effect of different anti-senescence compounds and storage interval on the cellulase activity (mg glucose per min^{-1} mg protein^{-1}) of Kinnow fruit stored at 5-7^{o}C and 90-95% RH

followed by fruits treated with 1-MCP 1500 ppb and SA 2mM (4.86 and 7.16 mg glucose per min-1 mg protein-1). On the other hand the control fruits showed an earliest peak in cellulase activity after 30 days of the storage where it was recorded as 8.56 mg glucose per min^{-1} mg $protein^{-1}$. The interaction between treatments and storage interval was found to be significant. The findings were further confirmed through the pooled mean analysis of both the years (Table 28a and Fig 28). MeJA 1mM proved best in terms of showing lowest cellulase activity (2.06 mg glucose per min^{-1} mg $protein^{-1}$) followed by 1-MCP 1500 ppb (2.47 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, control fruits registered the maximum cellulase activity (4.58 mg glucose per min^{-1} mg $protein^{-1}$). The interaction between treatments and storage interval was found to be significant. Fruit softening is associated with cell wall disassembly (Seymour and Gross 1996) and modifications to the pectin fraction are some of the most apparent changes that take place in the cell wall during ripening (Marin-Rodriguez *et al* 2002). The general observation is that softening is accompanied by solubilization of pectin, involving the action of enzymes pectinesterase (PE), polygalacturonase (PG) and pectate lyases (PL) (White 2002).

The results are in conformity with findings of Zhu *et al* (2015) and Lohani *et al* (2004) who reported that 1-MCP treated banana fruits followed slow but steady increase in cellulase activity in contrast to control fruits which registered a sudden increase initially; thereafter a sharp decline in cellulase activity during storage. The similar findings were also reported in avocado fruit (Jeong *et al* 2002).

4.3 Effect of different packaging materials on physical, biochemical and enzymatic parameters of Kinnow fruit

4.3.1 Physiological loss in weight (%)

The data pertaining to the effect of various packaging materials on physiological loss in weight of Kinnow fruit revealed a declining trend during storage (Table 29). In 2016-17 fruits wrapped in perforated PP 100 gauge film registered the lowest average PLW (0.50%) followed by perforated LDPE 100 gauge where it was recorded as 0.63 per cent whereas, control fruits recorded the maximum PLW (6.93%). It was noticed that fruits wrapped in perforated PP 100 and perforated LDPE 100 gauge films registered the PLW ranged from 0.32 to 1.07 and 0.34 to 1.40 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed an abrupt and sharp decline in PLW with an advancement in storage period thereby ranged from 4.66 to 12.84 per cent from 30 days to 75 days of storage. Similar trend was also noticed during 2017-18. The lowest PLW (0.44%) was recorded in the fruits wrapped in perforated PP 100 gauge followed by perforated LDPE 100 gauge (0.56%), whereas control fruits registered the maximum PLW (6.43%). The data further revealed that the PLW in the fruits wrapped in perforated PP 100 and perforated

Table 29: Effect of different packaging materials and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

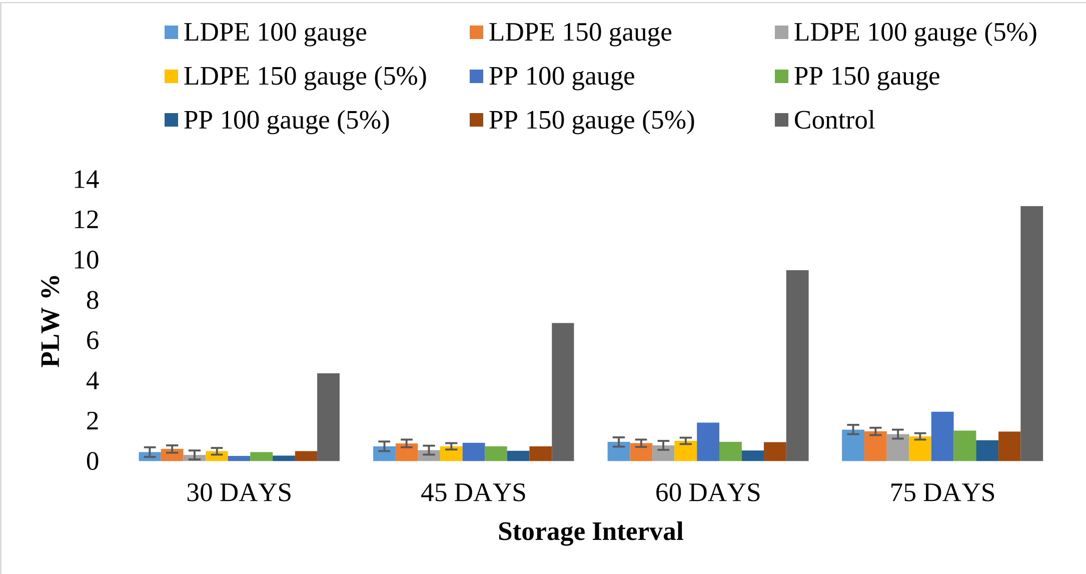
TREATMENT		Physiological loss in weight (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	0.00	0.58	0.86	0.96	1.49	**0.78[c]**	0.00	0.32	0.63	0.95	1.65	**0.71[cd]**
	150 gauge	0.00	0.64	0.92	0.94	1.55	**0.81[c]**	0.00	0.57	0.85	0.85	1.42	**0.74[c]**
LDPE (5%Perforated)	**100 gauge**	0.00	0.34	0.59	0.81	1.40	**0.63[d]**	0.00	0.26	0.51	0.77	1.28	**0.56[e]**
	150 gauge	0.00	0.51	0.76	1.06	1.29	**0.72[c]**	0.00	0.47	0.70	0.94	1.17	**0.65[d]**
PP	**100 gauge**	0.00	0.28	0.94	2.08	2.49	**1.16[b]**	0.00	0.22	0.88	1.75	2.41	**1.05[b]**
	150 gauge	0.00	0.38	0.69	1.06	1.71	**0.77[c]**	0.00	0.53	0.80	0.85	1.34	**0.70[cd]**
PP (5% Perforated)	**100 gauge**	0.00	0.32	0.54	0.58	1.07	**0.50[e]**	0.00	0.25	0.49	0.49	0.99	**0.44[f]**
	150 gauge	0.00	0.51	0.78	0.98	1.51	**0.76[c]**	0.00	0.47	0.70	0.90	1.41	**0.69[cd]**
Control		0.00	4.66	7.29	9.84	12.84	**6.93[a]**	0.00	4.06	6.44	9.15	12.49	**6.43[a]**
Mean		**0.00[e]**	**0.91[d]**	**1.48[c]**	**2.03[b]**	**2.81[a]**		**0.00[e]**	**0.79[d]**	**1.33[c]**	**1.85[b]**	**2.68[a]**	
LSD **(P≤0.05)**		**Treatment (T)** = 0.089 **Days (D)** = 0.067 **D x T** = 0.20						**Treatment (T)** = 0.070 **Days (D)** = 0.052 **D x T** = 0.16					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 29a: Effect of different packaging materials and storage intervals on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Physiological loss in weight (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	0.00	0.45	0.74	0.95	1.57	**0.74[cd]**
	150 gauge	0.00	0.60	0.88	0.89	1.48	**0.77[c]**
LDPE (5% perforation)	**100 gauge**	0.00	0.30	0.55	0.79	1.34	**0.59[e]**
	150 gauge	0.00	0.49	0.73	1.00	1.23	**0.69[d]**
PP	**100 gauge**	0.00	0.25	0.91	1.91	2.45	**1.10[b]**
	150 gauge	0.00	0.45	0.74	0.95	1.52	**0.74[cd]**
PP (5% perforation)	**100 gauge**	0.00	0.28	0.51	0.53	1.03	**0.47[f]**
	150 gauge	0.00	0.49	0.74	0.94	1.46	**0.73[cd]**
Control		0.00	4.36	6.86	9.49	12.66	**6.68[a]**
Mean		**0.00[e]**	**0.85[d]**	**1.41[c]**	**1.94[b]**	**2.75[a]**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 0.078 **Days (D)** = 0.058 **D x T** = 0.17					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 29: Effect of different packaging materials and storage interval on the physiological loss in weight per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

LDPE 100 film ranged from 0.25 to 0.99 and 0.26 to 1.28 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed an abrupt decline in PLW with prolongation in storage thereby ranged from 4.06 to 12.49 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the seasons of investigation. The findings were further confirmed through pooled mean analysis of both the years (Table 29a and Fig 29). Fruits wrapped in perforated PP 100 gauge registered the lowest average PLW (0.47%) followed by perforated LDPE 100 gauge film (0.59%) whereas, control fruits recorded the maximum average PLW (6.68%). The interaction between treatments and storage interval was found to be significant. In the present study, among different packaging materials, perforated PP 100 and perforated LDPE 100 gauge films were the most efficacious wrapping material with respect to reduced weight loss; this might be due plastic covering plays an important role in preventing dehydration by creating a saturated micro-atmosphere around the fruit. Reduction in PLW of polythene packed fruits could be attributed to retention of firmness of fruits in green. Moreover, the polyethylene films have the characteristic feature of reducing the rate of transpiration by restricting the diffusion of gases and feedback mechanism.

The results are in corroboration with the findings of Nath *et al* (2012) who reported that perforated LLDPE and perforated HDPE wrapped pear fruits revealed the lowest PLW in contrast to control; this might be due to continuous loss of moisture due to transpiration from the fruit and respiration. Similar results were reported in pear (Kaur *et al* 2013) and papaya (Azene *et al* 2014). Ramayya *et al* (2012) evaluated the effect of OPP (perforated and non perforated) films and found that mangoes packed in OPP bags with 50% perforation registered the lower average weight loss in contrast to OPP bags with 25% perforation. Mahajan and Singh (2014) demonstrated the effect of packaging films on shelf-life and quality of Kinnow fruits and found that shrink film wrapped fruits registered the lower PLW than those of control. Similar findings were also reported in peach (Mahajan *et al* 2015) mango (Rao and shivshankara 2015) and apple (Sharma *et al* 2013).

4.3.2 Spoilage (%)

The data on spoilage per cent influenced by various packaging materials revealed a declining trend during storage (Table 30). In 2016-17, the lowest spoilage (3.33%) was registered by the fruits packed in perforated PP 100 gauge followed by perforated LDPE 100 gauge film where it was recorded as 5 per cent. However, Interestingly, the maximum spoilage was registered by fruits wrapped in non perforated PP 100 gauge (33.33%) even higher than that of control (11.67 %).

Table 30: Effect of different packaging materials and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

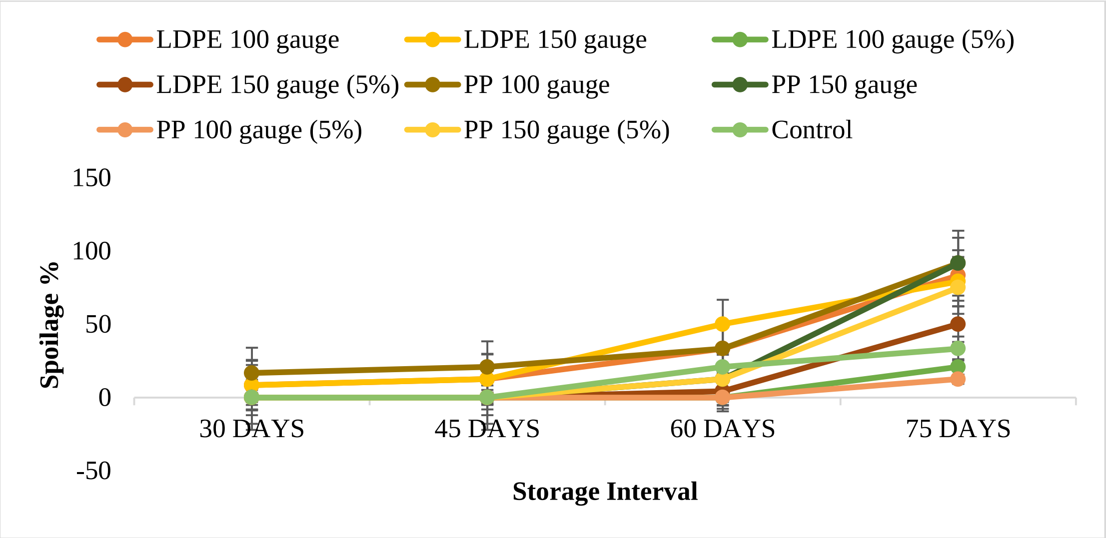
TREATMENT		Spoilage (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	0.00	16.66	25.00	33.33	75.00	**30.00^{c}**	0.00	0.00	0.00	33.33	91.66	**25.00^{c}**
	150 gauge	0.00	0.00	0.00	66.66	91.66	**31.66^{b}**	0.00	16.66	25.00	33.33	66.66	**28.33^{b}**
LDPE (5%Perforated)	**100 gauge**	0.00	0.00	0.00	0.00	25.00	**5.00^{g}**	0.00	0.00	0.00	0.00	16.66	**3.33^{g}**
	150 gauge	0.00	0.00	0.00	8.66	50.00	**11.73^{f}**	0.00	0.00	0.00	0.00	50.00	**10.00^{f}**
PP	**100 gauge**	0.00	16.66	25.00	33.33	91.66	**33.33^{a}**	0.00	16.66	16.66	33.33	91.66	**31.66^{a}**
	150 gauge	0.00	0.00	0.00	25.00	91.66	**23.33^{d}**	0.00	0.00	0.00	0.00	91.66	**18.33^{d}**
PP (5% Perforated)	**100 gauge**	0.00	0.00	0.00	0.00	16.66	**3.33^{h}**	0.00	0.00	0.00	0.00	8.33	**1.67^{h}**
	150 gauge	0.00	0.00	0.00	16.66	75.00	**18.33^{e}**	0.00	0.00	0.00	8.33	75.00	**16.67^{e}**
Control		0.00	0.00	0.00	25.00	33.33	**11.67^{f}**	0.00	0.00	0.00	16.66	33.33	**9.99^{f}**
Mean		**0.00^{e}**	**3.70^{d}**	**5.55^{c}**	**23.18^{b}**	**61.11^{a}**		**0.00^{e}**	**3.70^{d}**	**4.63^{c}**	**13.89^{b}**	**58.33^{a}**	
LSD (P≤0.05)		**Treatment (T)** = 1.20 **Days (D)** = 0.90 **D x T** = 2.69						**Treatment (T)** = 0.97 **Days (D)** = 0.72 **D x T** = 2.16					

Mean values with same alphabets are statistically similar at *p ≤ 0.05* (n =15 fruits/replication)

Table 30a: Effect of different packaging materials and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

Spoilage (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	0.00	8.33	12.50	33.33	83.33	**27.50[c]**
	150 gauge	0.00	8.33	12.50	49.99	79.16	**30.00[a]**
LDPE (5% perforation)	**100 gauge**	0.00	0.00	0.00	0.00	20.83	**4.17[g]**
	150 gauge	0.00	0.00	0.00	4.33	50.00	**10.87[f]**
PP	**100 gauge**	0.00	16.66	20.83	33.33	91.66	**32.50[a]**
	150 gauge	0.00	0.00	0.00	12.50	91.66	**20.83[d]**
PP (5% perforation)	**100 gauge**	0.00	0.00	0.00	0.00	12.49	**2.50[h]**
	150 gauge	0.00	0.00	0.00	12.49	75.00	**17.50[e]**
Control		0.00	0.00	0.00	20.83	33.33	**10.83[c]**
Mean		**0.00[d]**	**3.70[cd]**	**5.09[c]**	**18.53[b]**	**59.72[b]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.92 **Days (D)** = 0.68 **D x T** = 2.05					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 30: Effect of different packaging materials and storage interval on the spoilage per centage in Kinnow fruit stored at 5-7°C and 90-95% RH

The data further revealed that the spoilage of the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films ranged from 0 to 16.66 and 0 to 25 per cent, respectively from 30 days to 75 days of storage. On the other hand, the spoilage of fruits wrapped in non perforated PP 100 gauge films ranged from 16.66 to 91.66 per cent from 30 days to 75 days respectively. Similar trend were registered in 2017-18. Fruits wrapped in perforated PP 100 gauge film recorded the lowest decay incidence i.e. 1.67 per cent followed by perforated LDPE 100 gauge i.e. 3.33 per cent. However, fruits wrapped in non-perforated PP 100 gauge film revealed the maximum fruit spoilage (31.66%) even higher in contrast to control (16.67%). It was noticed that the spoilage of the fruits wrapped in perforated PP 100 gauge film and perforated LDPE 100 gauge film ranged from 0 to 8.33 per cent and 0 to 16.66 per cent, respectively from 30 days to 75 days of storage. On the other hand, non perforated PP 100 film registered the spoilage ranged from 16.66 to 91.66 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. It was also visualized through pooled mean analysis of both the years (Table 30a and Fig 30). Fruits wrapped in perforated PP 100 gauge film registered the lowest decay (2.50%) followed by perforated LD 100 film (4.17%) while, non perforated PP 100 gauge registered the maximum decay (32.50%) In present study, it was noticed that fruits wrapped in non-perforated PP 100 gauge packaging film recorded the maximum decay which was interestingly, even higher than that of control; this might be due to occurrence of higher decay incidence in non perforated PP 100 film might be due to accumulation of excessive water vapour inside the package, because of restricted movement of water through the film (Tijskens and Vollebregt 2003; Soliva and Martin 2003 and Mahajan *et al* 2015). These results are in conformity with the findings of Nath *et al* (2012) who evaluated the effect of different packaging materials on the shelf-life and quality of pear fruits and found that minimum cumulative decay loss was registered in fruits packed in perforated PP in contrast to non perforated and control. The LDPE film registered even higher spoilage than that of unwrapped fruits of peach (Mahajan *et al* 2015). Similar findings were reported in pear (Kaur *et al* 2013; Geason *et al* 1991 and Sandhu *et al* 2000) Sharma *et al* (2013) reported that cryovac film was most effective in reducing the decay percentage over unwrapped fruits in apple cv. ‘Royal delicious’.

4.3.3 Organoleptic sensory attributes (Hedonic scale 1-9)

The data on sensory quality of Kinnow fruit influenced by different packaging films revealed a decreasing trend during storage (Table 31). In 2016-17, the maximum mean palatability rating (7.77) was retained by fruits wrapped in perforated PP 100 gauge film followed by perforated LDPE 100 gauge film (7.64). However, fruits wrapped in non perforated LDPE 150 gauge film recorded the lowest score for sensory attributes i.e. 5.97. The data further revealed that the sensory score of the fruits wrapped in perforated PP100 gauge and perforated LDPE 100 gauge ranged from 8.60 to 6.55 and 8.45 to 6.65, respectively from 30 days to 75 days of storage. On the other hand, fruits packed in non perforated LDPE 150 gauge film followed a decline in palatability rating and thereby ranged from 8.25 to 0.00 from 30 days to 75 days of storage. Similar trends were also noticed in 2017-18. The maximum sensory score was maintained in the fruits wrapped in perforated PP 100 gauge (8.11) followed by perforated LDPE 100 gauge film(7.95). However, non perforated LD 150 gauge wrapped fruits recorded the lowest score for sensory attributes i.e. 6.17. It was noticed that the sensory attributes of the fruits wrapped in perforated PP 100 gauge and perforated LD 100 gauge film ranged from 8.85 to 6.71 and 8.70 to 6.72, respectively from 30 days to 75 days of storage. On the other hand, non perforated LDPE 150 gauge packed fruits followed a an abrupt and sharp decline in palatability rating thereby ranged from 8.40 to 0.00 from 30 days to 75 days of storage. The interaction between treatment and storage interval was found to be significant from 30 days to 75 days during both the years i.e. 2016-17 and 2017-18. The pooled mean analysis of both the years (Table 31a and Fig 31) further confirmed the findings as fruits wrapped in perforated PP 100 gauge film retained the best quality of fruits with respect to sensory score (7.94) followed by perforated LD 100 gauge film (7.79). However, non perforated LDPE150 gauge film retained the lowest sensory score (6.07). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.In the present investigation, the maximum palatability rating was retained by the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films; this might be due to their better retention of the quality parameter *viz* TSS and sugars during storage may be possibly due to retarded ripening and senescence processes which simultaneously delayed the conversion of starch into sugars.

These results are in corroboration with the findings of Ramaya *et al* (2012) who, however, evaluated the effect of OPP (perforated and non perforated) and observed that mango fruits packed in non perforated OPP film registered better quality (as compared to perforated OPP film. Mahajan and Singh (2014) reported that Kinnow fruits wrapped in shrink films registered the maximum score for sensory attributes in contrast to control. Similar findings were also reported in peach (Mahajan *et al* 2015) and apple cv. 'Red delicious' (Sharma *et al* 2013). Kudachikar *et al* (2011) reported that fruits of banana cv. 'Robusta' wrapped in MAP and MAP +GK registered the maximum scores for overall fruit quality in contrast to unwrapped fruits (7.2) at the end of storage.

Table 31: Effect of different packaging materials and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

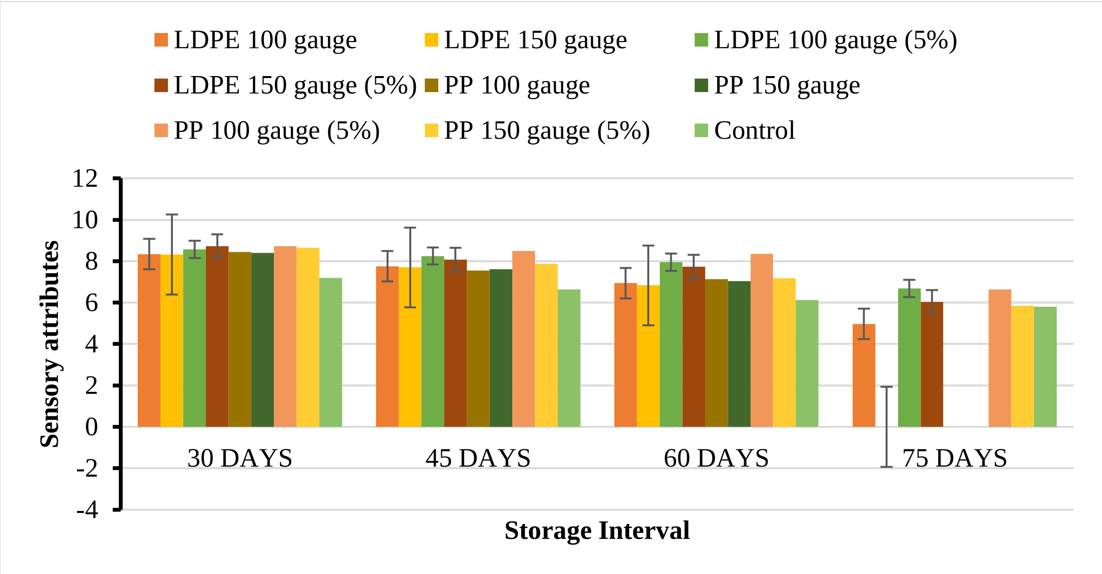
TREATMENT		Organoleptic sensory attributes (Hedonic scale 1-9)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	7.00	8.35	7.65	6.60	4.20	**6.76^{d}**	8.00	8.33	7.85	7.28	5.75	**7.44^{d}**
	150 gauge	7.00	8.25	7.70	7.18	0.00	**5.97^{g}**	8.00	8.40	7.70	6.75	0.00	**6.17^{fg}**
LDPE (5%Perforated)	**100 gauge**	7.00	8.45	8.20	7.90	6.65	**7.64^{ab}**	8.00	8.70	8.31	8.00	6.72	**7.95^{ab}**
	150 gauge	7.00	8.65	8.05	7.70	5.48	**7.38^{b}**	8.00	8.80	8.10	7.78	6.60	**7.86^{bc}**
PP	**100 gauge**	7.00	8.35	7.50	7.10	0.00	**5.99^{g}**	8.00	8.55	7.60	7.17	0.00	**6.26^{f}**
	150 gauge	7.00	8.30	7.60	7.00	0.00	**5.98^{g}**	8.00	8.50	7.63	7.08	0.00	**6.24^{f}**
PP (5% Perforated)	**100 gauge**	7.00	8.60	8.45	8.25	6.55	**7.77^{a}**	8.00	8.85	8.56	8.45	6.71	**8.11^{a}**
	150 gauge	7.00	8.60	7.80	7.15	5.45	**7.20^{c}**	8.00	8.70	7.95	7.20	6.25	**7.62^{c}**
Control		7.00	6.50	6.09	5.75	5.40	**6.15^{f}**	8.00	7.90	7.17	6.50	6.20	**7.15^{e}**
Mean		**7.00^{d}**	**8.44^{a}**	**7.87^{b}**	**7.33^{c}**	**3.54^{e}**		**8.00^{b}**	**8.60^{a}**	**7.96^{b}**	**7.46^{c}**	**4.00^{d}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.24 **Days (D)** = 0.18 **D x T** = 0.53						**Treatment (T)** = 0.24 **Days (D)** = 0.18 **D x T** = 0.54					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 31 (a): Effect of different packaging materials and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

Organoleptic sensory attributes (Hedonic scale 1-9)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	7.50	8.34	7.75	6.94	4.97	**7.10e**
	150 gauge	7.50	8.32	7.70	6.83	0.00	**6.07g**
LDPE (5% perforation)	**100 gauge**	7.50	8.57	8.25	7.95	6.68	**7.79b**
	150 gauge	7.50	8.72	8.07	7.74	6.04	**7.62c**
PP	**100 gauge**	7.50	8.45	7.55	7.13	0.00	**6.13g**
	150 gauge	7.50	8.40	7.61	7.04	0.00	**6.11g**
PP (5% perforation)	**100 gauge**	7.50	8.72	8.50	8.35	6.63	**7.94a**
	150 gauge	7.50	8.65	7.87	7.17	5.85	**7.41d**
Control		7.50	7.20	6.63	6.12	5.80	**6.65f**
Mean		**7.50**^{c}	**8.38**^{a}	**7.77**^{b}	**7.25**^{d}	**4.00**^{e}	
LSD (P≤0.05)		**Treatment (T)** = 0.14 **Days (D)** = 0.10 **D x T** = 0.31					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 31: Effect of different packaging materials and storage interval on the organoleptic sensory attributes in Kinnow fruit stored at 5-7°C and 90-95% RH

4.3.4 Firmness (Kg Force)

The data pertaining to the effect of different packaging films on firmness revealed a declining trend during storage (Table 32). In 2016-17, the mean maximum firmness (5.40 kg f) was retained by the fruits wrapped in perforated PP 100 gauge followed by perforated LDPE 100 gauge and perforated LDPE 150 gauge film (5.39 and 5.27 kg f). However, control fruits registered the lowest average firmness (4.07 kg f). The data further revealed that the firmness of the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge film ranged from 7.22 to 3.21 and 6.44 to 3.77 kg force, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed an abrupt decline and shriveling in firmness with prolongation in storage period thereby ranged from 4.40 to 2.80 kg force from 30 days to 75 days of storage. Similar trend was also noticed in 2017-18. Fruits wrapped in perforated PP 100 gauge retained the maximum firmness (5.48 kg f), whereas perforated LDPE 100 gauge was found statistically at par with perforated PP 100 gauge film (5.47 kg f). However, control fruits registered the lowest average firmness (4.36 kg f). It was noticed that the firmness of the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge film ranged from 7.36 to 3.45 and 6.56 to 3.80 kg force, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed a sharp decline in firmness at faster pace with an advancement in storage period thereby ranged from 4.69 to 3.23 kg force from 30 days to 75 days of storage. The interaction between treatments and storage period was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 33a and Fig 33). Fruits packed in perforated PP 100 gauge retained the maximum mean firmness (5.44 kg f) followed by perforated LDPE 100 gauge film (5.43 kg f). On the other hand, control fruits could maintained the lowest average firmness (4.21 kg f). The interaction between treatments and storage interval was found to be significant. The softening of flesh during storage could be due to the degradation of soluble pectin by high activity of endo-polygalacturonase enzyme in fruits (Martin-Cabrejas *et al* 1994). In the present study, fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films maintained the higher firmness throughout the storage period, this might be due to maintenance of high humidity inside the packaging films, helps in reducing the transpiration loss and respiratory activity thus retained turgidity of the cells.

These results are in corroboration with the findings of Ramayya *et al* (2012) who, however, found that OPP film did not influence firmness of mango fruit during storage. Nath *et al* (2012) observed that the maximum firmness was recorded by fruits of pear wrapped in perforated PP followed by non-perforated LDPE during 12 days of storage. Similar findings were reported in mango cv. ‘Alphonso and Banganapalli’ (Rao and Shivashankara 2015). Mahajan and Singh (2014) reported that Kinnow fruits wrapped in shrink film registered the maximum firmness than those of control at the end of the storage. Similar results were obtained in apple (Sharma *et al* 2013). Kudachikar *et al* (2011) reported that fruits of banana

Table 32: Effect of different packaging materials and storage interval on the firmness (kg f) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

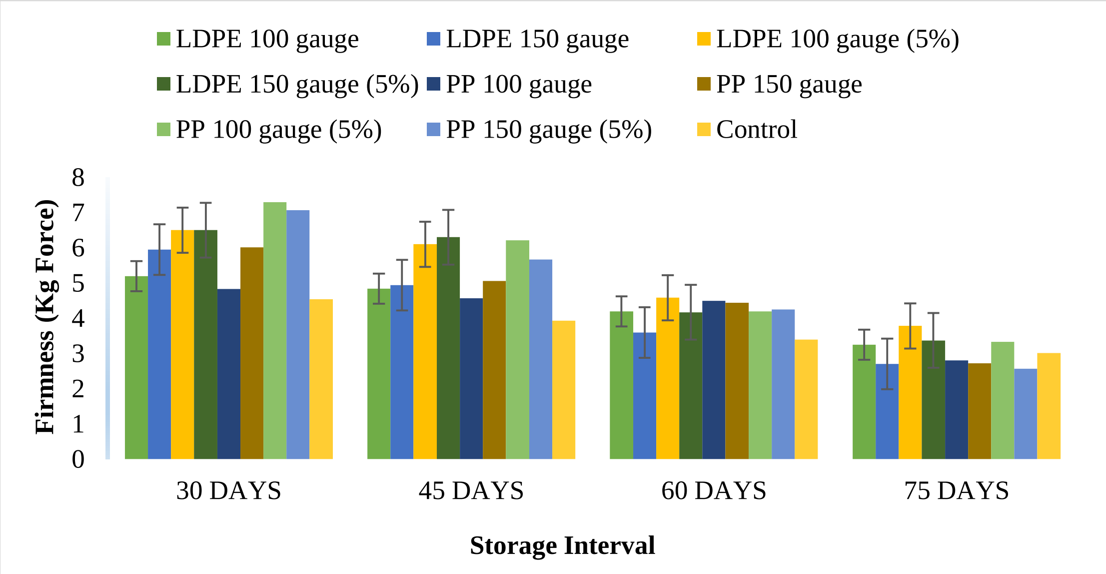
TREATMENT		Firmness (Kg Force)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	6.13	5.21	4.81	4.18	3.10	**4.69^{e}**	6.25	5.17	4.88	4.21	3.40	**4.78^{e}**
	150 gauge	6.13	5.90	4.91	3.61	2.63	**4.64^{ef}**	6.25	6.01	4.98	3.58	2.77	**4.72^{ef}**
LDPE (5%Perforated)	**100 gauge**	6.13	6.44	6.09	4.54	3.77	**5.39^{a}**	6.25	6.56	6.12	4.63	3.80	**5.47^{ab}**
	150 gauge	6.13	6.49	6.26	4.23	3.26	**5.27^{b}**	6.25	6.52	6.34	4.11	3.49	**5.34^{bc}**
PP	**100 gauge**	6.13	4.81	4.55	4.51	2.73	**4.55^{f}**	6.25	4.85	4.59	4.48	2.88	**4.61^{f}**
	150 gauge	6.13	5.98	5.12	4.41	2.59	**4.85^{d}**	6.25	6.04	5.00	4.47	2.86	**4.92^{d}**
PP (5% Perforated)	**100 gauge**	6.13	7.22	6.24	4.22	3.21	**5.40^{a}**	6.25	7.36	6.19	4.16	3.45	**5.48^{a}**
	150 gauge	6.13	6.88	5.64	4.22	2.51	**5.08^{c}**	6.25	7.26	5.70	4.28	2.63	**5.22^{c}**
Control		6.13	4.40	3.70	3.30	2.80	**4.07^{g}**	6.25	4.69	4.17	3.48	3.23	**4.36^{g}**
Mean		**6.13^{a}**	**5.92^{b}**	**5.26^{c}**	**4.13^{d}**	**2.95^{e}**		**6.25^{a}**	**6.05^{b}**	**5.33^{c}**	**4.15^{d}**	**3.17^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.11 **Days (D)** = 0.085 **D x T** = 0.26						**Treatment (T)** = 0.13 **Days (D)** = 0.10 **D x T** = 0.29					

Mean values with same alphabets are statistically similar at *$p \leq 0.05$* (n =15 fruits/replication)

Table 32a: Effect of different packaging materials and storage interval on the firmness (kg f) in Kinnow fruit stored at 5-7°C and 90-95% RH

Firmness (Kg Force)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	6.19	5.19	4.84	4.19	3.25	**4.73^{e}**
	150 gauge	6.19	5.95	4.94	3.59	2.70	**4.68^{e}**
LDPE (5% perforation)	**100 gauge**	6.19	6.50	6.10	4.58	3.78	**5.43^{a}**
	150 gauge	6.19	6.50	6.30	4.17	3.37	**5.31^{b}**
PP	**100 gauge**	6.19	4.83	4.57	4.49	2.80	**4.58^{f}**
	150 gauge	6.19	6.01	5.06	4.44	2.72	**4.88^{d}**
PP (5% perforation)	**100 gauge**	6.19	7.29	6.21	4.19	3.33	**5.44^{a}**
	150 gauge	6.19	7.07	5.67	4.25	2.57	**5.15^{c}**
Control		6.19	4.54	3.93	3.39	3.01	**4.21^{g}**
Mean		**6.19^{a}**	**5.99^{b}**	**5.29^{c}**	**4.14^{d}**	**3.06^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.096 **Days (D)** = 0.072 **D x T** = 0.21					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 32: Effect of different packaging materials and storage interval on the firmness (kg f) in Kinnow fruit stored at 5-7°C and 90-95% RH

cv. Robusta wrapped in MAP and MAP +GK registered higher fruit firmness over unwrapped during storage.

4.3.5 Juice (%)

The data pertaining to the effect of different packaging materials on juice content revealed a declining trend during storage (Table 33). In 2016-17, the mean maximum juice (46.84%) was retained by the fruits wrapped in perforated PP 100 gauge followed by perforated LD 100 gauge film (46.19%). However, the lowest average juice content was retained in the control fruits (42.12%). The data further revealed that the juice content in the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge film ranged from 48.18 to 45.19 per cent and 48.00 to 42.33 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed an abrupt and sharp decline in juice content thereby ranged from 47.77 to 34.31 per cent from 30 days to 75 days of storage. Similar trend was also noticed in 2017-18. Fruits wrapped in perforated PP 100 gauge film retained the maximum juice content (47.37%) followed by perforated LDPE 100 gauge film (47.18%). The control fruits recorded the lowest average juice content (43.14%). It was further noticed that the juice content in the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge film ranged from 48.64 to 45.61 and 49.18 to 43.19 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed a continuous decline in juice content at faster pace with an advancement in storage period thereby ranged from 46.98 to 34.65 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 33a and Fig 33). Fruits wrapped in perforated PP 100 gauge retained the maximum mean juice content (47.10%) followed by perforated LDPE 100 gauge film (46.68%) whereas, control fruits recorded the lowest average volume of juice (42.63%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge film retained the maximum juice content; this might be due to influence of packaging films on juice recovery may partly be due to differential rate of water loss from the fruit and gas permeability properties of polymeric films.

These results are in corroboration with the findings of Sharma *et al* (2013) who demonstrated the effect of heat shrink films on shelf-life and quality of apples cv. 'Royal delicious' and found that fruits wrapped in cryovac films retained the highest juice recovery. Heat shrinkable films are known to influence juice recovery in Mosambi and Kinnow, primarily due to curve on PLW over unwrapped fruits (Ladaniya and Singh 2001; Ladaniya 2003). Pandey *et al* (2006) observed a decline in juice recovery following increase in storage period in apples.

Table 33: Effect of different packaging materials and storage interval on the juice per centage in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

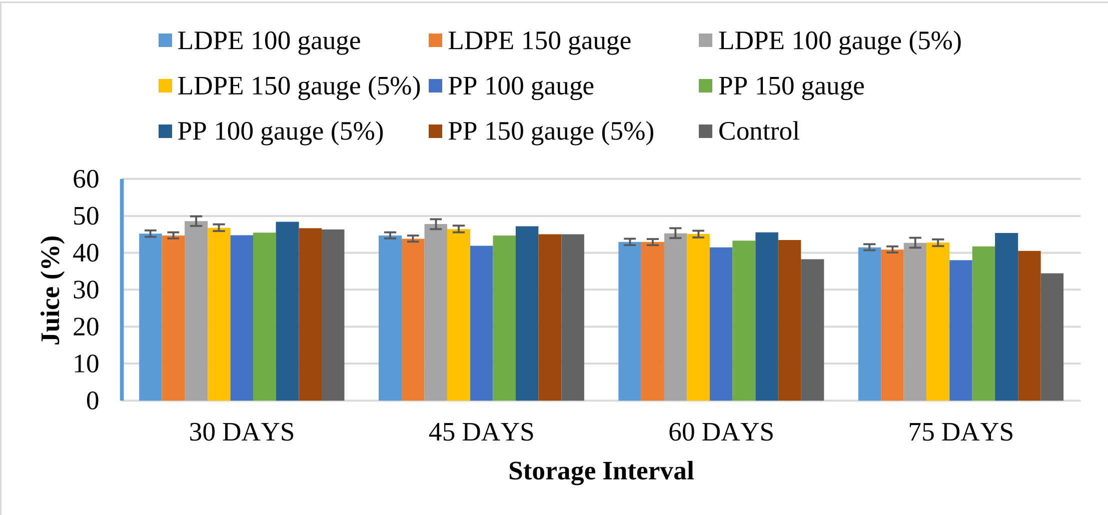
TREATMENT		Juice (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
LDPE	**100 guage**	48.50	44.25	43.91	42.33	42.08	**44.21^{b}**	49.50	46.13	45.51	43.59	40.96	**45.14^{bc}**
	150 gauge	48.50	44.36	43.29	42.67	40.82	**43.93^{b}**	49.50	45.08	44.37	43.21	40.96	**44.62^{cd}**
LDPE (5%Perforated)	**100 gauge**	48.50	48.00	47.35	44.88	42.33	**46.19^{a}**	49.50	49.18	48.24	45.77	43.19	**47.18^{a}**
	150 gauge	48.50	46.89	46.44	44.75	42.37	**45.79^{a}**	49.50	46.70	46.49	45.45	43.17	**46.26^{ab}**
PP	**100 gauge**	48.50	44.12	41.19	40.88	37.65	**42.47^{c}**	49.50	45.39	42.68	42.05	38.46	**43.62^{de}**
	150 gauge	48.50	45.71	44.64	43.19	40.14	**44.44^{b}**	49.50	45.18	44.71	43.43	43.35	**45.23^{bc}**
PP (5% Perforated)	**100 gauge**	48.50	48.18	46.94	45.38	45.19	**46.84^{a}**	49.50	48.64	47.45	45.65	45.61	**47.37^{a}**
	150 gauge	48.50	46.81	44.27	42.86	40.43	**45.57^{b}**	49.50	46.62	45.71	44.00	40.59	**45.28^{bc}**
Control		48.50	47.77	44.38	37.64	34.31	**42.12^{c}**	49.50	46.98	45.67	38.88	34.65	**43.14^{e}**
Mean		**48.50^{a}**	**46.01^{b}**	**44.71^{c}**	**42.73^{d}**	**40.58^{e}**		**49.50^{a}**	**46.66^{b}**	**45.65^{c}**	**43.56^{d}**	**41.22^{e}**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 1.20 **Days (D)** = 0.90 **D x T** = 2.69						**Treatment (T)** = 1.26 **Days (D)** = 0.94 **D x T** = 2.81					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 33a: Effect of different packaging materials and storage interval on the juice percentage in Kinnow fruit stored at 5-7°C and 90-95% RH

Juice (%)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	49.00	45.19	44.71	42.96	41.52	**44.67^{cd}**
	150 gauge	49.00	44.72	43.83	42.94	40.89	**44.27^{d}**
LDPE (5% perforation)	**100 gauge**	49.00	48.59	47.79	45.32	42.71	**46.68^{a}**
	150 gauge	49.00	46.79	46.46	45.10	42.77	**46.03^{b}**
PP	**100 gauge**	49.00	44.75	41.93	41.46	38.05	**43.04^{e}**
	150 gauge	49.00	45.44	44.67	43.31	41.74	**44.83^{cd}**
PP (5% perforation)	**100 gauge**	49.00	48.41	47.19	45.51	45.40	**47.10^{a}**
	150 gauge	49.00	46.71	44.99	43.43	40.51	**44.93^{c}**
Control		49.00	46.37	45.02	38.26	34.48	**42.63^{e}**
Mean		**49.00^{a}**	**46.33^{b}**	**45.18^{c}**	**43.14^{d}**	**40.90^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.65 **Days (D)** = 0.48 **D x T** = 1.45					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 33: Effect of different packaging materials and storage interval on the juice percentage in Kinnow fruit stored at 5-7°C and 90-95% RH

4.3.6 TSS (%)

The data pertaining to the effect of different packaging films on total soluble solids content revealed a declining trend during storage (Table 34). In 2016-17, fruits wrapped with perforated PP 100 gauge and gauge films maintained the maximum TSS content (10.67%) followed by perforated LDPE 100 gauge film (10.59%). However, control fruits recorded the lowest TSS content (9.64%). It was noticed that the TSS content in the fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge film ranged from 10.50 to 11.20 and 10.20 to 10.80 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits retained the lowest average TSS content ranged from 8.85 to 10.40 per cent from 30 days to 75 days of storage period. Similar trend was also noticed during 2017-18. Fruits wrapped in perforated PP 100 gauge film maintained the maximum TSS content (10.79%) followed by perforated LDPE 100 gauge film (10.68%). The control fruits registered the lowest TSS (9.71%) content. The data further revealed that TSS content in the fruits wrapped in perforated PP 100 and perforated LD 100 ranged from 10.65 to 11.55 and 10.35 to 10.85 per cent from 30 days to 75 days, respectively. On the other hand, with an advancement of storage period control fruits retained the TSS content ranged from 8.55 to 10.50 per cent from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during the years of 2016-17 and 2017-18. The pooled mean analysis of both the years (Table 34a and Fig 34) further confirmed the findings as fruits wrapped in perforated PP 100 gauge film registered the mean maximum TSS (10.73%) followed by the fruits packed in perforated LDPE 100 gauge film (10.63%). However, control fruits retained the lowest TSS content (9.67%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the increasing decreasing trend in TSS content during storage; might be due to hydrolysis of starch into sugars. On the completion of starch hydrolysis, no further increase occurred and subsequently the TSS content declined as the sugars act as substrate during respiration (Wills *et al* 1980). The results in the present studies are in conformity to the findings of Azene *et al* (2014) who evaluated the effect of various packaging materials on shelf-life and quality of papaya fruit and found that fruits wrapped in LDPE registered the maximum TSS content during storage. Similar findings were also reported in mango (Rao and shivashankara 2015). Nath *et al* (2012) observed higher soluble solid content in control and non perforated PP film wrapped pear fruits during storage. Mahajan *et al* (2015) found that shrink film resulted the maximum TSS content in peach fruit during storage. Similar findings were also reported in Kinnow fruit (Mahajan and Singh 2014).

Table 34: Effect of different packaging materials and storage interval on the total soluble solids per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

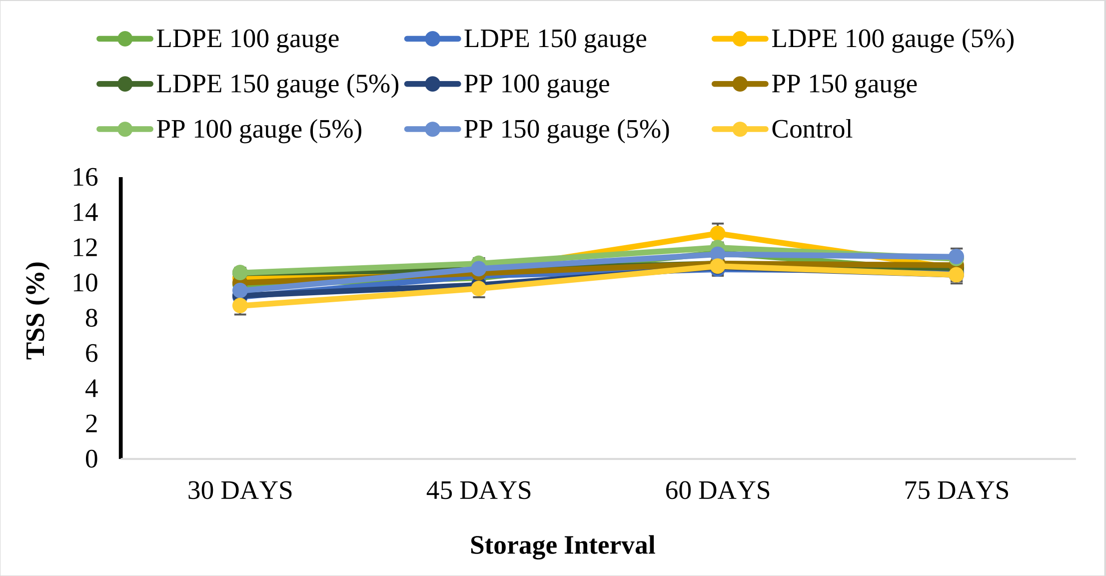
TREATMENT		Total soluble solids (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	8.75	9.80	10.20	11.00	10.80	**10.11[bc]**	8.45	10.00	10.35	12.45	10.45	**10.34[b]**
	150 gauge	8.75	9.10	10.30	10.70	10.60	**9.89[cd]**	8.45	9.30	10.50	10.85	10.75	**9.97[c]**
LDPE (5%Perforated)	**100 gauge**	8.75	10.20	10.60	12.60	10.80	**10.59[a]**	8.45	10.35	10.75	13.00	10.85	**10.68[a]**
	150 gauge	8.75	10.20	10.50	10.80	10.60	**10.17[b]**	8.45	10.90	11.00	11.40	11.10	**10.57[ab]**
PP	**100 gauge**	8.75	9.20	9.80	10.80	10.30	**9.77[d]**	8.45	9.35	9.95	11.00	10.60	**9.87[c]**
	150 gauge	8.75	10.00	10.45	10.80	10.60	**10.12[bc]**	8.45	10.00	10.65	11.40	11.40	**10.38[b]**
PP (5% Perforated)	**100 gauge**	8.75	10.50	11.00	11.90	11.20	**10.67[a]**	8.45	10.65	11.20	12.10	11.55	**10.79[a]**
	150 gauge	8.75	9.25	10.15	11.60	11.55	**10.26[b]**	8.45	9.85	11.45	11.65	11.42	**10.56[ab]**
Control		8.75	8.85	9.50	10.70	10.40	**9.64[d]**	8.45	8.55	9.85	11.20	10.50	**9.71[c]**
Mean		**8.75[e]**	**9.68[d]**	**10.28[c]**	**11.21[a]**	**10.76[b]**		**8.45[e]**	**9.88[d]**	**10.63[c]**	**11.67[a]**	**10.96[b]**	
LSD (P≤0.05)		**Treatment (T)** = 0.28 **Days (D)** = 0.21 **D x T** = 0.63						**Treatment (T)** = 0.28 **Days (D)** = 0.21 **D x T** = 0.63					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 34a: Effect of different packaging materials and storage interval on the total soluble solids per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Total soluble solids (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	8.60	9.90	10.27	11.72	10.62	**10.22[b]**
	150 gauge	8.60	9.20	10.40	10.77	10.67	**9.93[c]**
LDPE (5% perforation)	**100 gauge**	8.60	10.27	10.67	12.80	10.82	**10.63[a]**
	150 gauge	8.60	10.55	10.75	11.10	10.85	**10.37[b]**
PP	**100 gauge**	8.60	9.27	9.87	10.90	10.45	**9.82[cd]**
	150 gauge	8.60	10.00	10.55	11.10	11.00	**10.25[b]**
PP (5% perforation)	**100 gauge**	8.60	10.57	11.10	12.00	11.37	**10.73[a]**
	150 gauge	8.60	9.55	10.80	11.62	11.48	**10.41[b]**
Control		8.60	8.70	9.67	10.95	10.45	**9.67[d]**
Mean		**8.60[e]**	**9.78[d]**	**10.46[c]**	**11.44[a]**	**10.86[b]**	
LSD (P≤0.05)		**Treatment (T)** = 0.19 **Days (D)** = 0.14 **D x T** = 0.43					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 34: Effect of different packaging materials and storage interval on the total soluble solids per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

4.3.7 Reducing sugars (%)

The data pertaining to the effect of packaging materials on reducing sugars revealed an identical trends during storage (Table 35). In 2016-17, Fruits packed in perforated PP 100 gauge film recorded maximum mean reducing sugars (3.14%) followed by perforated LDPE 100 gauge film (3.10%). On the other hand, control fruits registered the lowest average reducing sugar content (2.30 %). It was noticed that fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge films revealed a gradual increase in reducing sugars content up to 60 days of the storage i.e. 5.40 and 5.00 per cent, respectively; thereafter followed a decline till the end of the storage i.e. 3.28 and 3.86 per cent, respectively. Similar trend was also noticed in 2017-18. The average maximum reducing sugars (3.19%) was observed in the fruits wrapped in perforated PP 100 gauge film followed by perforated LDPE 100 gauge film (3.16%). However, control fruits registered the lowest reducing sugars content (2.32%). The data further revealed that fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge films showed a gradual rise in reducing sugars up to 60 days of the storage i.e. 5.49 and 5.14 per cent, respectively; thereafter followed a sharp and steady decline till end of the storage i.e. 3.36 and 3.93 per cent, respectively. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 35a and Fig 35). Fruits wrapped in perforated PP 100 gauge film retained the maximum reducing sugars (3.17%) followed by perforated LDPE 100 gauge film (3.09%). On the other hand, control fruits maintained the lowest average reducing sugars (2.35%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.

4.3.8 Total sugars (%)

The data pertaining to the effect of different packaging materials on total sugars content revealed a decreasing trend during storage period (Table 36). In 2016-17, fruits wrapped in perforated PP 100 gauge film recorded the maximum mean total sugars content (7.04%) followed by fruits packed in perforated LDPE 100 gauge film where total sugars content was recorded as 6.94 per cent. However, control fruits registered the lowest total sugars (5.39%) content. It was noticed that total sugars in the fruits wrapped in perforated PP 100 and perforated LD 100 films ranged from 6.95 to 7.72 and 5.43 to 8.71 per cent, respectively from 30 days to 75 days of storage period. On the other hand the unwrapped fruits retained the total sugars content ranged from 5.04 to 5.56 per cent from 30 days to 75 days of the storage. Similar results were obtained in 2017-18. The maximum mean total sugars content (7.09%) was obtained in the fruits wrapped in perforated PP 100 gauge film followed by perforated LDPE 100 100 gauge film (6.97%), whereas control fruits retained the lowest total sugars (5.51%) content. The data further revealed that the total sugars content in the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge ranged from

Table 35: Effect of different packaging materials and storage interval on the reducing sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

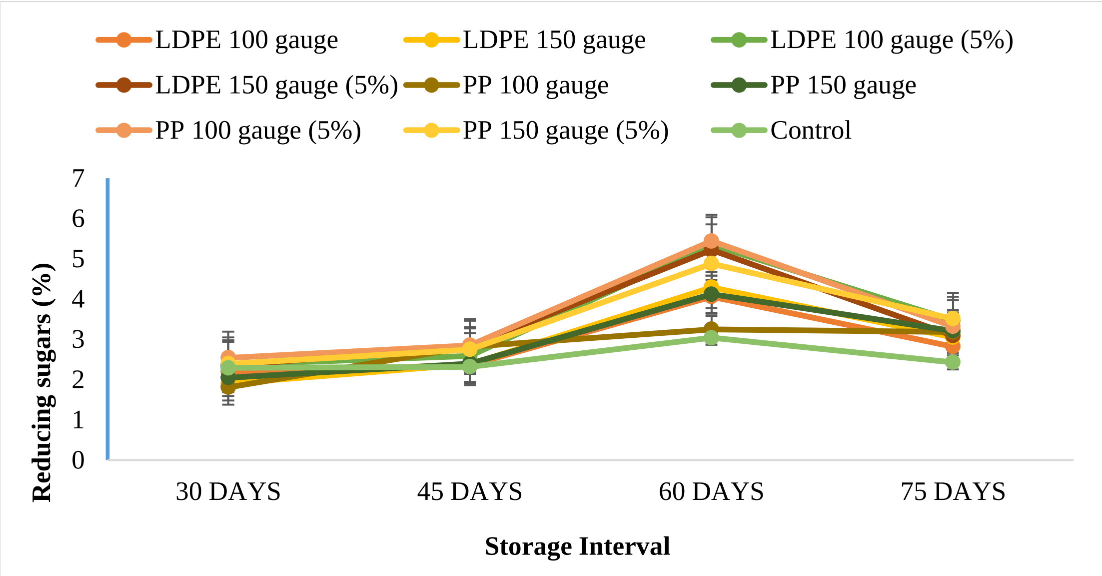
TREATMENT		Reducing sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
LDPE	**100 guage**	1.70	2.33	2.40	3.85	2.97	**2.65^{d}**	1.67	2.38	2.45	3.92	3.07	**2.69^{d}**
	150 gauge	1.70	2.13	2.37	4.21	2.70	**2.62^{d}**	1.67	2.08	2.32	4.28	2.67	**2.60^{e}**
LDPE (5%Perforated)	**100 gauge**	1.70	2.40	2.56	5.00	3.86	**3.10^{ab}**	1.67	2.48	2.88	5.14	3.93	**3.16^{c}**
	150 gauge	1.70	2.31	2.59	5.68	3.00	**3.06^{b}**	1.67	2.34	2.63	5.71	3.08	**3.08^{bc}**
PP	**100 gauge**	1.70	1.79	2.80	3.22	3.12	**2.53^{e}**	1.67	1.83	2.85	3.29	3.24	**2.58^{e}**
	150 gauge	1.70	1.73	2.36	4.32	3.36	**2.69^{d}**	1.67	1.67	2.40	4.38	3.40	**2.70^{d}**
PP (5% Perforated)	**100 gauge**	1.70	2.51	2.82	5.40	3.28	**3.14^{a}**	1.67	2.58	2.88	5.49	3.36	**3.19^{a}**
	150 gauge	1.70	2.31	2.90	4.62	3.10	**2.93^{c}**	1.67	2.38	3.08	4.77	3.18	**3.02^{bc}**
Control		1.70	2.31	2.36	3.11	2.46	**2.39^{f}**	1.67	2.28	2.29	2.97	2.40	**2.32^{f}**
Mean		**1.70^{e}**	**2.20^{d}**	**2.57^{c}**	**4.38^{a}**	**3.09^{b}**		**1.67^{e}**	**2.22^{d}**	**2.61^{c}**	**4.44^{a}**	**3.15^{b}**	
LSD (P≤0.05)		**Treatment (T)** = 0.085 **Days (D)** = 0.063 **D x T** = 0.19						**Treatment (T)** = 0.087 **Days (D)** = 0.065 **D x T** = 0.19					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 35a: Effect of different packaging materials and storage interval on the reducing sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

		Reducing sugars (%)					
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	1.68	2.20	2.36	4.06	2.82	**2.63^{e}**
	150 gauge	1.68	1.90	2.38	4.29	3.05	**2.66^{de}**
LDPE (5% perforation)	**100 gauge**	1.68	2.37	2.59	5.35	3.47	**3.09^{b}**
	150 gauge	1.68	2.34	2.83	5.22	3.09	**3.04^{c}**
PP	**100 gauge**	1.68	1.81	2.82	3.25	3.18	**2.55^{f}**
	150 gauge	1.68	2.05	2.40	4.12	3.21	**2.70^{d}**
PP (5% perforation)	**100 gauge**	1.68	2.54	2.85	5.44	3.32	**3.17^{a}**
	150 gauge	1.68	2.39	2.75	4.88	3.51	**3.04^{bc}**
Control		1.68	2.29	2.32	3.04	2.43	**2.35^{g}**
Mean		**1.68^{e}**	**2.21^{d}**	**2.59^{c}**	**4.41^{a}**	**3.12^{b}**	
LSD (P≤0.05)		**Treatment (T)** = 0.053 **Days (D)** = 0.039 **D x T** = 0.12					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 35: Effect of different packaging materials and storage interval on the reducing sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 36: Effect of different packaging materials and storage interval on the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

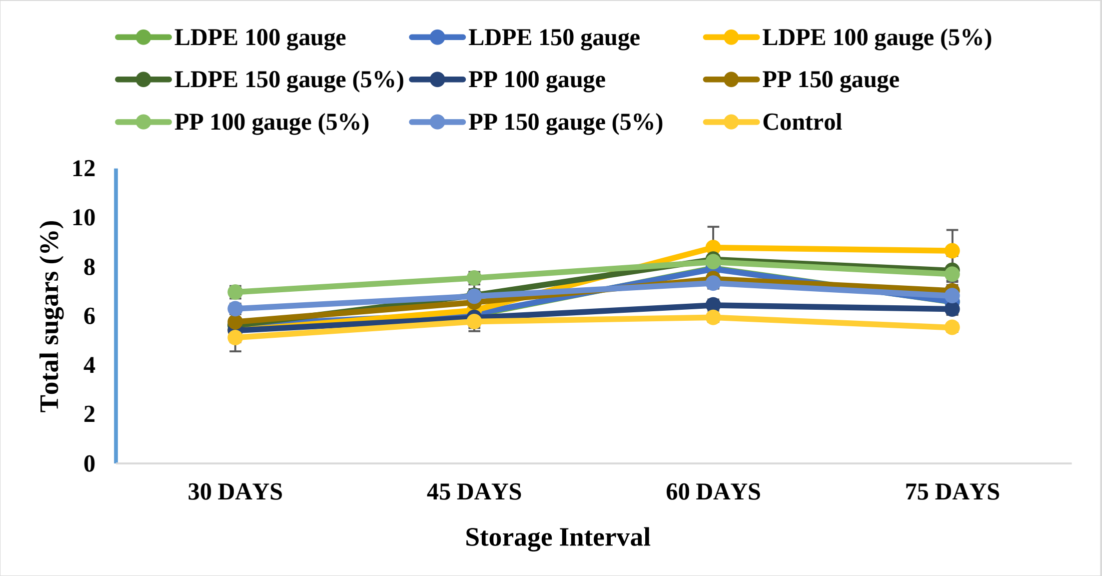
TREATMENT		Total sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	4.69	5.49	5.52	8.72	6.21	**6.13[d]**	5.10	5.70	6.55	7.18	6.94	**6.29[cd]**
	150 gauge	4.69	5.76	6.60	7.22	6.97	**6.25[cd]**	5.10	5.52	5.58	8.60	6.20	**6.20[d]**
LDPE (5%Perforated)	**100 gauge**	4.69	5.43	5.52	8.81	8.71	**6.94[a]**	5.10	5.40	6.95	8.76	8.60	**6.97[a]**
	150 gauge	4.69	5.65	6.87	8.32	7.88	**6.68[b]**	5.10	5.60	6.82	8.28	7.82	**6.72[b]**
PP	**100 gauge**	4.69	5.47	5.97	6.48	6.32	**5.78[e]**	5.10	5.35	5.90	6.40	6.25	**5.80[e]**
	150 gauge	4.69	5.74	6.52	7.53	6.97	**6.29[cd]**	5.10	5.79	6.61	7.49	7.08	**6.41[c]**
PP (5% Perforated)	**100 gauge**	4.69	6.95	7.60	8.22	7.72	**7.04[a]**	5.10	7.00	7.48	8.18	7.69	**7.09[a]**
	150 gauge	4.69	6.33	6.83	7.36	6.84	**6.41[c]**	5.10	6.25	6.78	7.30	6.81	**6.45[c]**
Control		4.69	5.04	5.77	5.91	5.56	**5.39[f]**	5.10	5.20	5.78	5.98	5.51	**5.51[f]**
Mean		**4.69e**	**5.76d**	**6.52c**	**7.62a**	**7.02b**		**5.10[e]**	**5.76[d]**	**6.49[c]**	**7.57[a]**	**6.99[b]**	
LSD (P≤0.05)		**Treatment (T)** = 0.21 **Days (D)** = 0.16 **D x T** = 0.472						**Treatment (T)** = 0.20 **Days (D)** = 0.15 **D x T** = 0.46					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 36a: Effect of different packaging materials and storage interval on the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Total sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	4.89	5.59	6.03	7.95	6.57	**6.21[e]**
	150 gauge	4.89	5.64	6.09	7.91	6.58	**6.22[de]**
LDPE (5% perforation)	**100 gauge**	4.89	5.41	6.23	8.78	8.65	**6.80[b]**
	150 gauge	4.89	5.62	6.84	8.30	7.85	**6.70[b]**
PP	**100 gauge**	4.89	5.41	5.93	6.44	6.28	**5.79[f]**
	150 gauge	4.89	5.76	6.56	7.51	7.02	**6.35[cd]**
PP (5% perforation)	**100 gauge**	4.89	6.97	7.54	8.20	7.70	**7.06[a]**
	150 gauge	4.89	6.29	6.80	7.33	6.82	**6.43[c]**
Control		4.89	5.12	5.77	5.94	5.53	**5.45[g]**
Mean		**4.89[e]**	**5.76[d]**	**6.42[c]**	**7.60[a]**	**7.00[b]**	
LSD (P≤0.05)		**Treatment (T)** = 0.14 **Days (D)** = 0.10 **D x T** = 0.31					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 36: Effect of different packaging materials and storage interval on the total sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

7.00 to 7.69 and 5.40 to 8.60 per cent respectively, from 30 days to 75 days of storage. On the other hand, control fruits retained the total sugars content from 5.20 to 5.51 from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 36a and Fig 36). Fruits wrapped in perforated PP 100 gauge film registered the maximum total sugars (7.06%) followed by the fruits packed in perforated LDPE 100 gauge film (6.80%) while, control fruits recorded the lowest total sugars (5.45%). The interaction between treatments and storage interval was found to be significant. In the present study, an increase in sugars (total and reducing sugars) might be due to breakdown of starch into sugars, as on complete hydrolysis of starch no further increase in sugars occurs and subsequently a decline in these parameter is predictable as they along with other organic acids are primary substrate for respiration (Wills *et al* 1980).

These results are in corroboration with the findings of Nath *et al* (2012) who observed that higher sugar content in the pear fruits wrapped in PP films than that of control. Azene *et al* (2014) evaluated the effects of various packaging materials on shelf-life and quality of papaya fruit and found that fruits wrapped in LDPE registered the maximum reducing sugar and total sugars content. Mahajan *et al* (2015) found that shrink film wrapped fruits of peach revealed the maximum sugar percentage over other wrapping films during storage. Sharma *et al* (2013) reported that cryovac wrapped apple cv. 'Royal delicious' registered higher sugars content than those of unwrapped fruits during storage.

4.3.9 Vitamin C (mg/100g)

The data on vitamin C content influenced by various packaging materials revealed a declining trend during storage (Table 37). In 2016-17, fruits packed in perforated PP 100 gauge film retained the mean maximum ascorbic acid (23.94 mg/100g pulp) content followed by the fruits packed in perforated LDPE 100 gauge, perforated LDPE 150 gauge, perforated PP150 gauge and non perforated PP 150 gauge where it was recorded as 23.79, 23.70, 23.62 and 23.20 mg/100g pulp. These treatments were statistically at par with each other. However, control fruits registered the lowest average ascorbic acid content (22.09 mg/100g pulp). It was noticed that the ascorbic acid content in the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films ranged from 22.34 to 19.40 and 23.69 to 18.70 mg/100g pulp from 30 days to 75 days of storage. On the other hand, control fruits followed a sharp and abrupt decline in ascorbic acid content with an advancement in storage thereby ranged from 20.68 to 17.44 mg/100g pulp, respectively. Similar trend was also noticed during 2017-18. The average maximum ascorbic acid content was registered in the fruits packed perforated PP 100 gauge film (25.85 mg/100g pulp) followed by perforated LDPE 100 gauge, perforated LDPE 150 gauge, perforated PP150 gauge and non perforated PP 150 gauge films where it was recorded as 25.40, 25.25, 25.13 and 25.10mg/100g pulp, respectively. These treatments

Table 37: Effect of different packaging materials and storage interval on the vitamin C content (mg/100g) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

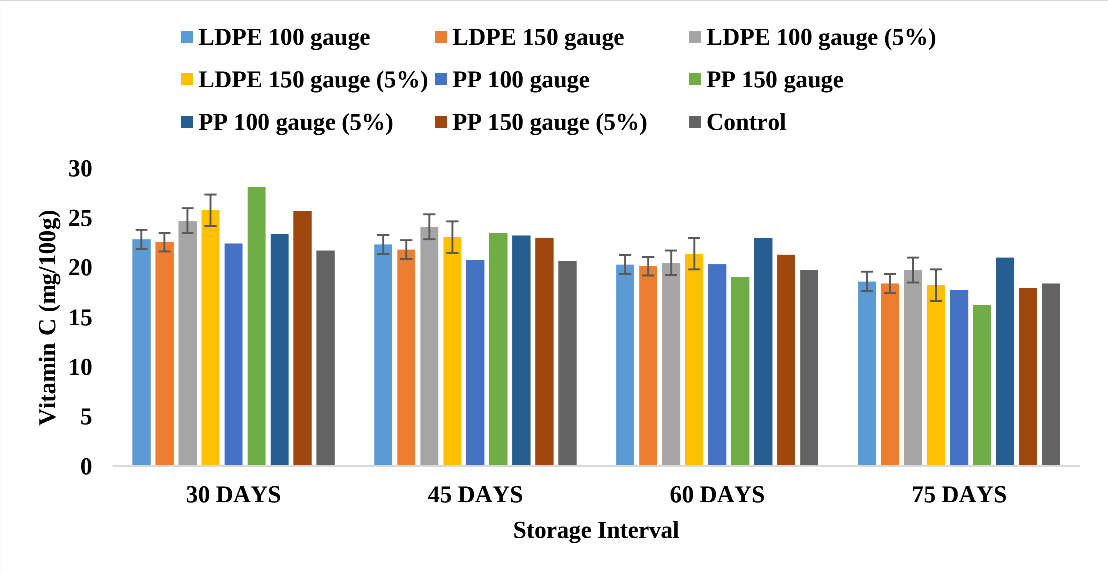
TREATMENT		Vitamin C (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
LDPE	**100 guage**	33.97	21.26	21.08	19.42	17.65	**22.68^{bc}**	33.88	24.41	23.56	21.18	19.56	**24.52^{bcd}**
	150 gauge	33.97	21.19	20.28	18.80	17.54	**22.36^{c}**	33.88	23.91	23.35	21.47	19.24	**24.37^{cd}**
LDPE (5%Perforated)	**100 gauge**	33.97	23.69	23.11	19.48	18.70	**23.79^{a}**	33.88	25.73	25.08	21.47	20.83	**25.40^{ab}**
	150 gauge	33.97	24.09	22.45	20.28	17.70	**23.70^{a}**	33.88	27.46	23.68	22.50	18.74	**25.25^{abc}**
PP	**100 gauge**	33.97	21.16	19.66	19.32	16.68	**22.16^{c}**	33.88	23.68	21.85	21.32	18.76	**23.90^{d}**
	150 gauge	33.97	27.08	22.78	17.47	14.71	**23.20^{ab}**	33.88	29.12	24.12	20.63	17.73	**25.10^{abc}**
PP (5% Perforated)	**100 gauge**	33.97	22.34	22.18	21.80	19.40	**23.94^{a}**	33.88	24.43	24.26	24.12	22.58	**25.85^{a}**
	150 gauge	33.97	25.40	21.60	20.51	16.60	**23.62^{a}**	33.88	26.03	24.41	22.06	19.26	**25.13^{abc}**
Control		33.97	20.68	19.70	18.65	17.44	**22.09^{c}**	33.88	22.79	21.62	20.88	19.35	**23.70^{d}**
Mean		**33.97^{a}**	**22.99^{b}**	**21.43^{c}**	**19.53^{d}**	**17.38^{e}**		**33.88^{a}**	**25.28^{b}**	**23.55^{c}**	**21.74^{d}**	**19.56^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.79 **Days (D)** = 0.59 **D x T** = 1.77						**Treatment (T)** = 0.98 **Days (D)** = 0.73 **D x T** = 2.18					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 37a: Effect of different packaging materials and storage interval on the vitamin C content (mg/100g) per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Vitamin C (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	33.92	22.83	22.32	20.30	18.60	**23.60[d]**
	150 gauge	33.92	22.55	21.81	20.13	18.39	**23.36[de]**
LDPE (5% perforation)	**100 gauge**	33.92	24.71	24.09	20.47	19.76	**24.59[ab]**
	150 gauge	33.92	25.77	23.06	21.39	18.22	**24.47[abc]**
PP	**100 gauge**	33.92	22.42	20.75	20.32	17.72	**23.03[ef]**
	150 gauge	33.92	28.10	23.45	19.05	16.22	**24.15[c]**
PP (5% perforation)	**100 gauge**	33.92	23.38	23.22	22.96	20.99	**24.90[a]**
	150 gauge	33.92	25.71	23.00	21.28	17.93	**24.37[bc]**
Control		33.92	21.73	20.66	19.76	18.39	**22.90[f]**
Mean		**33.92[a]**	**24.14[b]**	**22.49[c]**	**20.63[d]**	**18.47[e]**	
LSD (P≤0.05)		**Treatment (T)** = 0.43 **Days (D)** = 0.32 **D x T** = 0.97					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 37: Effect of different packaging materials and storage interval on the vitamin C content (mg/100g) per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

were statistically at par with each other However, control fruits registered the lowest average ascorbic acid (23.70 mg/100g pulp) content. The data further revealed that fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films retained the ascorbic acid content ranged from 24.43 to 22.58 and 25.73 to 20.83 mg/100g pulp, respectively from 30 days to 75 days of storage. On the other hand, control fruits followed an abrupt decline in ascorbic acid content at faster pace with prolongation in storage period thereby retained the ascorbic acid content from 22.79 to 19.35 mg/100 g pulp from 30 days to 75 days of storage. The interaction between treatments and storage interval was found to significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 37a and Fig 37). Fruits packed in perforated PP 100 gauge maintained the mean maximum ascorbic acid (24.90 mg/100g) followed by perforated LDPE 100 gauge film (24.59 mg/100g). On the other hand, control fruits retained the lowest average ascorbic acid content (22.90 mg/100g). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study decline in ascorbic acid content might be due to conversion of ascorbic acid to dehydroascorbic acid by the action of ascorbic acid oxidase (Mapson 1970).

The results are in agreement with the findings of Nath *et al* (2012) who observed the maximum retention of ascorbic acid content in the pear fruits wrapped in perforated PP film than those of non perforated and unwrapped fruits. Fruits of 'papaya' wrapped in LDPE retained the maximum ascorbic acid content (45.6 mg/100g) as compared to control (40.60 mg/100 g) after 18 days of storage (Azene *et al* 2014). Mahajan and Singh (2014) reported that fruits of Kinnow wrapped in shrink film retained the maximum ascorbic acid content over unwrapped fruits during storage. The similar findings were also reported in peach (Mahajan *et al* 2015). Sharma *et al* (2013) reported that fruits of apples cv. 'Royal delicious' wrapped in cryovac films maintained higher content of ascorbic acid over unwrapped fruits at the end of the storage.

4.3.10 Total carotenoids (mg/100g)

The data pertaining to the effect of different packaging materials on total carotenoids content revealed an identical trends during storage (Table 38). In 2016-17, the average maximum total carotenoids content was observed in the fruits wrapped in perforated PP 100 gauge (0.52 mg/100g pulp) followed by LDPE 100 gauge film (0.45 mg/100g pulp). However, control fruits registered the lowest total carotenoids content (0.37 mg/100g pulp). A gradual increase in the total carotenoids content was observed in the fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge film after 30 days of storage i.e. 0.74 and 0.64 mg/100g pulp, respectively; thereafter followed a decline till the end of the storage i.e. 0.41 and 0.23 mg per cent respectively. Similar results were also obtained in 2017-18. The average maximum total carotenoids content was observed in the fruits wrapped in

Table 38: Effect of different packaging materials and storage interval on the total carotenoids content (mg/100g) in Kinnow fruits stored at 5-7°C and 90-95% RH

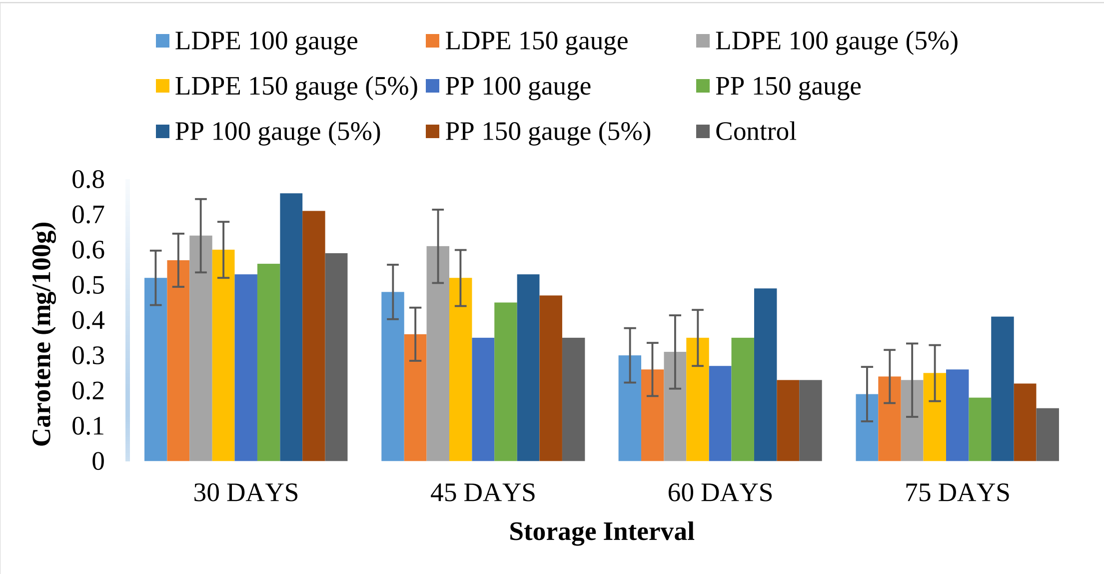
TREATMENT		Total carotenoids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	0.48	0.54	0.46	0.29	0.20	**0.394[ef]**	0.37	0.51	0.50	0.31	0.19	**0.375[f]**
	150 gauge	0.48	0.53	0.38	0.28	0.28	**0.390[f]**	0.37	0.47	0.39	0.27	0.27	**0.360[g]**
LDPE (5%Perforated)	**100 gauge**	0.48	0.64	0.60	0.30	0.23	**0.450[b]**	0.37	0.65	0.63	0.32	0.24	**0.442[b]**
	150 gauge	0.48	0.61	0.50	0.34	0.25	**0.436[c]**	0.37	0.60	0.54	0.37	0.26	**0.428[c]**
PP	**100 gauge**	0.48	0.60	0.32	0.27	0.25	**0.384[f]**	0.37	0.62	0.34	0.24	0.21	**0.354[g]**
	150 gauge	0.48	0.56	0.44	0.36	0.18	**0.404[e]**	0.37	0.57	0.47	0.35	0.19	**0.389[e]**
PP (5% Perforated)	**100 gauge**	0.48	0.74	0.51	0.48	0.41	**0.524[a]**	0.37	0.79	0.55	0.51	0.42	**0.528[a]**
	150 gauge	0.48	0.70	0.46	0.23	0.222	**0.417[d]**	0.37	0.73	0.48	0.24	0.22	**0.406[d]**
Control		0.48	0.60	0.36	0.24	0.15	**0.366[g]**	0.37	0.58	0.35	0.22	0.16	**0.336[h]**
Mean		**0.480[b]**	**0.613[a]**	**0.447[c]**	**0.310[d]**	**0.241[e]**		**0.370[c]**	**0.613[a]**	**0.470[b]**	**0.318[d]**	**0.239[e]**	
LSD (P≤0.05)		**Treatment (T)** = 0.0123 **Days (D)** = 0.00092 **D x T** = 0.0276						**Treatment (T)** = 0.0119 **Days (D)** = 0.00089 **D x T** = 0.0266					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 38a: Effect of different packaging materials and storage interval on the total carotenoids content (mg/100g) inKinnow fruit stored at 5-7°C and 90-95% RH

Total carotenoids (mg/100g)							
Storage interval (Days)							
TREATMENTS		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	0.42	0.52	0.48	0.30	0.19	**0.38[f]**
	150 gauge	0.42	0.57	0.36	0.26	0.24	**0.37[ef]**
LDPE (5% perforation)	**100 gauge**	0.42	0.64	0.61	0.31	0.23	**0.45[b]**
	150 gauge	0.42	0.60	0.52	0.35	0.25	**0.43[c]**
PP	**100 gauge**	0.42	0.53	0.35	0.27	0.26	**0.37[g]**
	150 gauge	0.42	0.56	0.45	0.35	0.18	**0.40[e]**
PP (5% perforation)	**100 gauge**	0.42	0.76	0.53	0.49	0.41	**0.53[a]**
	150 gauge	0.42	0.71	0.47	0.23	0.22	**0.41[d]**
Control		0.42	0.59	0.35	0.23	0.15	**0.35[h]**
Mean		**0.42[c]**	**0.61[a]**	**0.46[b]**	**0.31[d]**	**0.24[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.00091 **Days (D)** = 0.00068 **D x T** = 0.020					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 38: Effect of different packaging materials and storage interval on the total carotenoids content (mg/100g pulp) content in Kinnow fruit stored at 5-7°C and 90-95% RH

perforated PP 100 gauge (0.53 mg/100g pulp) followed by perforated LDPE 100 gauge film (0.44 mg/100g pulp). However, control fruits registered the lowest average carotenoids content (0.34 mg/100g pulp). The data further revealed that the carotenoids content in the fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge film registered a gradual rise in carotenoids content after 30 days of storage i.e. 0.79 and 0.65 mg/100g pulp, respectively; thereafter followed a gradual decline till the end of the storage i.e. 0.42 and 0.24 mg/100g pulp respectively. The interaction between treatments and storage interval was found to significant during both the years of investigation . The pooled mean analysis of both the years (Table 38a and Fig 38) also revealed the similar findings as fruits wrapped in perforated PP 100 gauge film maintained the mean maximum carotene content (0.53 mg/100g pulp) followed by perforated LDPE 100 gauge film (0.45 mg/100g pulp). On the other hand, control fruits retained the lowest average carotenoids content (0.35 mg/100g pulp). The interaction between treatments and storage interval was found to be significant in the poollotaed mean analysis of both the years. In the present study, the control fruits followed a continuous instability and subsequent reduction of carotenoids is because of their vulnerability to oxidation and geometric isomerization of its polyene chain during storage (Sanchez-Moreno *et al* 2003). Ethylene causes the loss of chlorophylls, produces some minor changes in carotenoids, induces carotenoid synthesis and thus has the potential to re-establish the orange colors (El-Zeftawi and Garrett, 1978).

The results are in conformity to the findings of Mahajan and Singh (2014) who reported that shrink wrapped Kinnow fruits showed gradual and steady increase in carotenoids content up to 15 days of storage. Similar findings were also noticed in mango cv. ‘Alphonso and ‘Banganapalli’ (Rao and Shivshankara 2015). Ruth *et al* (2014) who, however, reported that unwrapped fruits registered higher content of total carotenoids than those of wrapped in ordinary and active bag modified atmospheric packaging. Muftuoglu *et al* (2012) revealed no significant effects of packaging atmosphere and packaging material on total carotenoids content in apricot.

4.3.11 Pectin (Ca pectate %)

The data on pectin content influenced by different packaging material revealed a decreasing trend during storage period (Table 39). In 2016-17, the fruits wrapped in perforated PP 100 gauge film registered the mean maximum pectin content (0.50%) followed by perforated LDPE 100 gauge film (0.48%). However, control fruits registered the lowest average pectin content (0.42%). It was noticed that the pectin content in the fruits wrapped in perforated PP 100 and perforated LD 100 gauge films ranged from 0.72 to 0.18 and 0.70 to 0.15 per cent, respectively from 30 days to 75 days of the storage period. On the other hand, unwrapped fruits maintained the pectin content from 0.60 to 0.13 per cent from 30 days to 75

Table 39: Effect of different packaging materials and storage interval on the pectin content (Ca pectate %) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

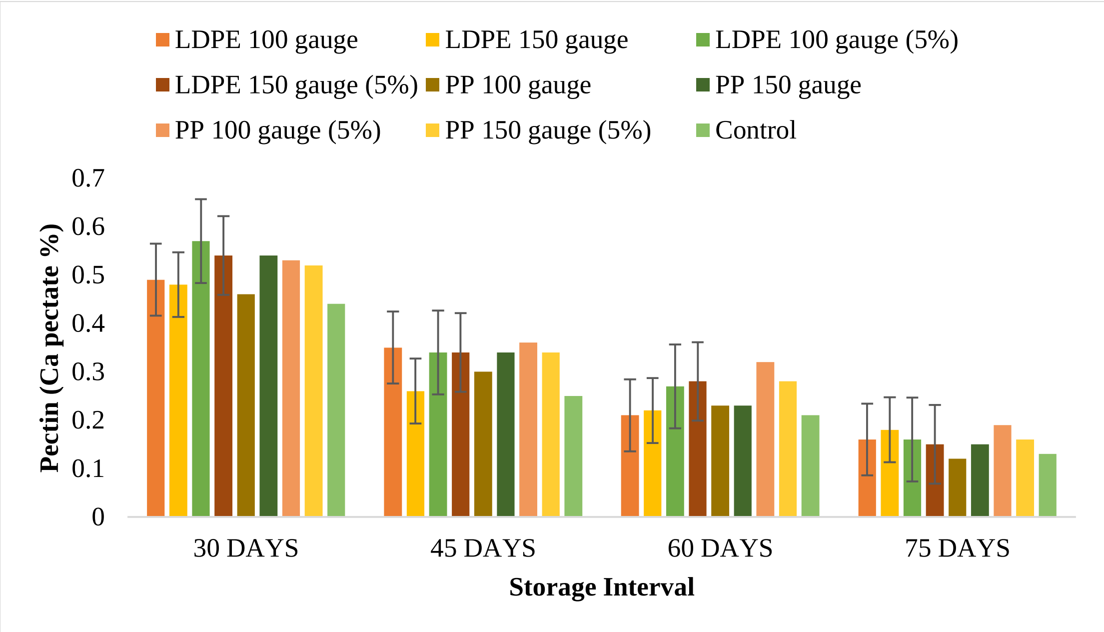
TREATMENT		Pectin (Ca pectate %)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
LDPE	**100 guage**	0.80	0.61	0.39	0.27	0.20	**0.45^e**	0.50	0.37	0.32	0.16	0.12	**0.29^d**
	150 gauge	0.80	0.70	0.30	0.23	0.19	**0.44^f**	0.50	0.27	0.22	0.22	0.18	**0.28^e**
LDPE (5%Perforated)	**100 gauge**	0.80	0.70	0.45	0.31	0.15	**0.48^b**	0.50	0.45	0.24	0.23	0.17	**0.32^{ab}**
	150 gauge	0.80	0.74	0.37	0.31	0.16	**0.47^a**	0.50	0.34	0.32	0.26	0.15	**0.31^{bc}**
PP	**100 gauge**	0.80	0.61	0.38	0.26	0.12	**0.43^g**	0.50	0.32	0.22	0.20	0.13	**0.27^e**
	150 gauge	0.80	0.72	0.44	0.25	0.10	**0.46^c**	0.50	0.36	0.25	0.22	0.20	**0.30^c**
PP (5% Perforated)	**100 gauge**	0.80	0.72	0.41	0.37	0.18	**0.50^a**	0.50	0.34	0.31	0.27	0.21	**0.33^a**
	150 gauge	0.80	0.70	0.39	0.30	0.18	**0.47^c**	0.50	0.35	0.30	0.26	0.15	**0.31^{bc}**
Control		0.80	0.60	0.33	0.26	0.13	**0.42^h**	0.50	0.28	0.18	0.16	0.14	**0.25^f**
Mean		**0.80^a**	**0.69^b**	**0.38^c**	**0.28^d**	**0.16^e**		**0.500^a**	**0.341^b**	**0.263^c**	**0.220^d**	**0.161^e**	
LSD (P≤0.05)		**Treatment (T)** = 0.00055 **Days (D)** = 0.00041 **D x T** = 0.012						**Treatment (T)** = 0.00098 **Days (D)** = 0.00073 **D x T** = 0.022					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 39a: Effect of different packaging materials and storage interval on the pectin (Ca pectate %) content in Kinnow fruit stored at 5-7°C and 90-95% RH

Pectin (Ca pectate %)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	0.65	0.49	0.35	0.21	0.16	**0.37^{d}**
	150 gauge	0.65	0.48	0.26	0.22	0.18	**0.36^{e}**
LDPE (5% perforation)	**100 gauge**	0.65	0.57	0.34	0.27	0.16	**0.40^{a}**
	150 gauge	0.65	0.54	0.34	0.28	0.15	**0.39^{b}**
PP	**100 gauge**	0.65	0.46	0.30	0.23	0.12	**0.35^{e}**
	150 gauge	0.65	0.54	0.34	0.23	0.15	**0.38^{c}**
PP (5% perforation)	**100 gauge**	0.65	0.53	0.36	0.32	0.19	**0.41^{a}**
	150 gauge	0.65	0.52	0.34	0.28	0.16	**0.39^{bc}**
Control		0.65	0.44	0.25	0.21	0.13	**0.34^{f}**
Mean		**0.65^{a}**	**0.51^{b}**	**0.32^{c}**	**0.25^{d}**	**0.16^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.00091 **Days (D)** = 0.00068 **D x T** = 0.020					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig.39: Effect of different packaging materials and storage interval on the pectin (Ca pectate %) content in Kinnow fruit stored at 5-7°C and 90-95% RH

days of storage period. Similar trend wasnoticed in 2017-18. The fruits wrapped in perforated PP 100 gauge film maintained the maximum pectin content (0.33%) followed by perforated LDPE 100 gauge film (0.32%). However, control fruits retained the lowest average pectin content (0.25%). The data further revealed that the pectin content in the fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films ranged from 0.34 to 0.21 and 0.45 to 0.17 per cent, respectively from 30 days to 75 days of storage. On the other hand, control fruits retained the pectin content ranged from 0.28 to 0.14 per cent from 30 days to 75 days of storage. The interaction between treatments and storage was found to be significant during 2016-17 and 2017-18. The findings were further confirmed through the pooled mean analysis of both the years (Table 39a and Fig 39). Perforated PP 100 gauge film was the best in terms of retaining and maintaining the maximum mean pectin content (0.41%) followed by perforated LDPE 100 gauge film (0.40%) while, control fruits retained the lowest pectin content (0.34%). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years.

In the present study, loss in pectin content might be due to degree of fruit ripening particularly affected the pectin contents, which supports the hypothesis that softening is closely related to pectin solubilisation and depolymerization (Kurz *et al* 2008 and Rosli *et al* 2004). During ripening large molecule protopectins are converted to soluble pectin which are then used as a substrate for respiration (Biale 1964). These results are in conformity to the findings of Mohamed *et al* (1996) who reported that fruits of 'sapota' wrapped in LDPE films registered higher insoluble pectin content over those wrapped in shrink film and unwrapped. Similar findings were also reported in apple (Tavakoli and Wiley 1968). OPP-Coex-film packaging (Antifog film) led to a higher content of soluble pectins in comparison to the control in radish (Schreiner *et al* (2003).

4.3.12 Total phenol (mg/100g)

The data pertaining to the effect of packaging materials on total phenol content revealed an identical trend during storage (Table 40). In 2016-17, fruits wrapped in perforated PP 100 gauge film registered the maximum mean total phenol content (126.62 mg/100g pulp) followed by perforated LDPE 100 gauge film (120.96 mg/100g pulp). On the other hand, control fruits recorded the lowest average total phenol (87.15 mg/100g pulp) content. The fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge films registered a gradual increase in total phenol content after 30 days of storage i.e. 192.15 and 185.20 mg/100 g pulp, respectively. The similar trend was also noticed in 2017-18. The highest average total phenol (126.16 mg/100g pulp) content was recorded in the fruits wrappedin perforated PP 100 gauge followed by perforated LDPE 100 gauge films (126.16 and 122.86 mg/100g pulp, respectively). On the other hand, control fruits registered the lowest average total phenol content (92.15 mg/100g pulp). It was further noticed that fruits wrapped in perforated PP 100 gauge and perforated

Table 40: Effect of different packaging materials and storage interval on the total phenol content (mg/100g) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

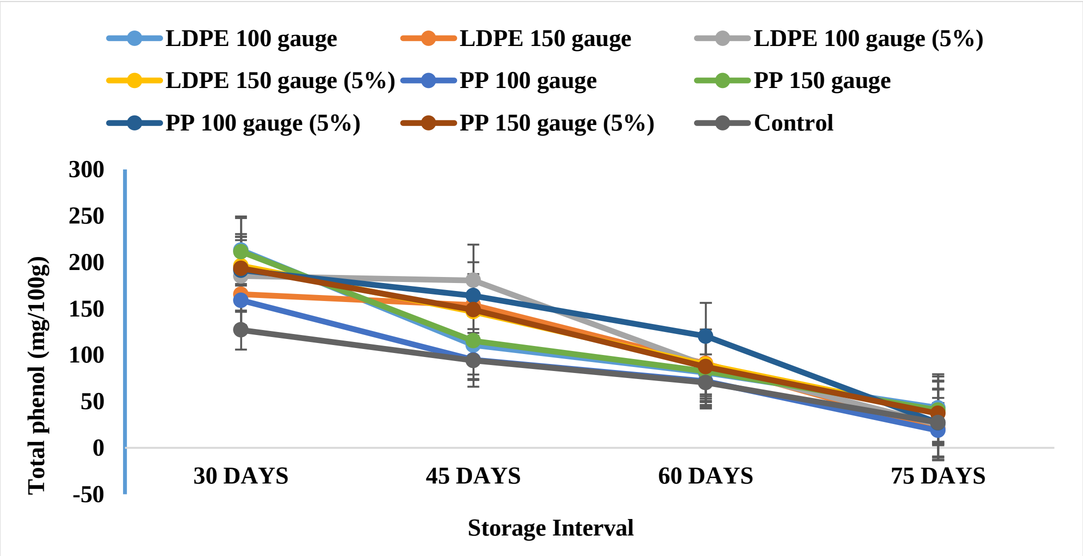
TREATMENT		Total phenols (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	128.13	189.87	110.23	86.38	47.01	**112.32^{c}**	131.84	236.06	110.74	75.40	38.80	**118.57^{b}**
	150 gauge	128.13	166.83	155.30	89.61	20.41	**112.06^{c}**	131.84	163.81	152.30	91.94	20.72	**112.12^{c}**
LDPE (5%Perforated)	**100 gauge**	128.13	185.20	179.62	87.54	24.33	**120.96^{b}**	131.84	184.91	181.20	90.54	25.83	**122.86^{ab}**
	150 gauge	128.13	209.08	134.31	90.25	43.00	**120.95^{b}**	131.84	182.99	158.81	89.25	33.50	**119.28^{b}**
PP	**100 gauge**	128.13	160.00	96.48	68.31	17.40	**96.06^{d}**	131.84	157.54	92.97	74.81	19.97	**95.43^{d}**
	150 gauge	128.13	228.00	107.20	70.68	30.75	**112.95^{c}**	131.84	194.37	123.23	94.37	50.51	**118.86^{b}**
PP (5% Perforated)	**100 gauge**	128.13	192.15	165.65	120.94	26.24	**126.62^{a}**	131.84	190.15	162.15	119.44	27.24	**126.16^{a}**
	150 gauge	128.13	184.88	163.81	86.95	33.44	**119.44^{b}**	131.84	201.79	133.34	87.51	40.41	**118.98^{b}**
Control		128.13	122.40	90.44	68.30	26.48	**87.15^{e}**	131.84	131.46	97.44	72.25	27.75	**92.15^{d}**
Mean		**128.13^{c}**	**182.05^{a}**	**133.67^{b}**	**85.44^{d}**	**29.90^{e}**		**131.84^{b}**	**182.57^{a}**	**134.69^{b}**	**88.39^{c}**	**31.64^{d}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 4.15 **Days (D)** = 3.09 **D x T** = 9.28						**Treatment (T)** = 4.33 **Days (D)** = 3.23 **D x T** = 9.68					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 40a: Effect of different packaging materials and storage interval on the total phenol content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total phenols (mg/100g)							
Storage interval (Days)							
TREATMENTS		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	129.98	212.96	110.48	80.89	42.90	**115.45[d]**
	150 gauge	129.98	165.32	153.80	90.77	20.56	**112.09[e]**
LDPE (5% perforation)	**100 gauge**	129.98	185.05	180.41	89.04	25.08	**121.91[b]**
	150 gauge	129.98	196.03	146.56	89.75	38.25	**120.12[bc]**
PP	**100 gauge**	129.98	158.77	94.72	71.56	18.68	**94.74[f]**
	150 gauge	129.98	211.18	115.21	82.52	40.63	**115.91[d]**
PP (5% perforation)	**100 gauge**	129.98	191.15	163.90	120.19	26.74	**126.39[a]**
	150 gauge	129.98	193.33	148.57	87.23	36.92	**119.21[c]**
Control		129.98	126.93	93.94	70.27	27.11	**89.65[g]**
Mean		**129.98[c]**	**182.30[a]**	**134.18[b]**	**86.91[d]**	**30.77[e]**	
LSD (P≤0.05)		**Treatment (T)** = 2.53 **Days (D)** = 1.88 **D x T** = 5.66					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The verticle bars represents standard error (SE) mean of three replicates

Fig 40: Effect of different packaging materials and storage interval on the total phenol (mg/100g) content in Kinnow fruit stored at 5-7°C and 90-95% RH

LDPE 100 gauge films registered a gradual increase in total phenols after 30 days of storage i.e. 190.15 and 184.91 mg/100g pulp, respectively; thereafter followed a continuous decline till the end of the storage 27.24 and 25.83 mg/100g pulp, respectively. The interaction between treatments and storage interval was found to be significant during both the years of investigation. The pooled mean analysis of both the years (Table 40a and Fig 40) also confirmed the findings as fruits wrapped in perforated PP 100 gauge film maintained the highest average total phenol (126.39 mg/100g) followed by perforated LDPE 100 gauge film (121.91 mg/100g) whereas, control fruits retained the lowest average total phenol content (89.65 mg/100g). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films retained the maximum phenolics compounds, which might be due to the effect of

MAP (low O_2 and high CO_2) in retarding postharvest ripening as can be inferred by the reduced ethylene production, fruit softening, colour change and acidity loss (Diaz-Mula *et al* 2011). In addition, the possible effect of low O_2 and high CO_2 on the delay in phenylalanine ammonia lyase (PAL), chalcone synthase or anthocyanidin synthase are the key enzymes in the biosynthesis pathway of phenolic compounds (Desjardins 2008) or reduced polyphenol oxidase (PPO) or peroxidase activities (Pourcel *et al* 2006), the main enzymes responsible of polyphenol degradation, should not be discounted.

The results are in agreement with the findings of Mohebbi *et al* (2015).The increase in total phenolics was delayed in cherry fruits cv. Cornelian wrapped in perforated LDPE and PP polymeric films. Rana *et al* (2015) studied the effect of cling and shrink films packaging on guava fruits and found that total phenols followed a decline with an advancement in storage period. Rao and Shivshankara (2015) who, however, reported that fruits of mango cv. ‘Alphonso’ and ‘Banganapalli’ wrapped in different packaging films registered lower content of total phenol in contrast to wrapped fruits.

4.3.13 Pectin methylesterse (PME) activity

The results pertaining to the effect of different packaging materials on PME activity (micro equi. acid produced/min/g tissue) illustrated that the enzyme activity registered significant changes over the storage intervals (Table 41). In general, the maximum PME activity with respect to storage interval was recorded after 45 days of storage (except perforated PP 100 gauge, PP 150 gauge and perforated LDPE 100 gauge and LDPE 150 gauge films) followed by a sudden decline till the end of the storage. In 2016-17, the average lowest mean PME activity (1.61 micro equi. acid produced/min/ml tissue) was noticed in the fruits wrapped in perforated PP 100 gauge film followed by (1.87 micro equi. acid produced/min/ml tissue). However, control fruits recorded the average maximum PME activity (2.44 micro equi. acid produced/min/ml tissue). It was further noticed that fruits

Table 41: Effect of different packaging materials and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

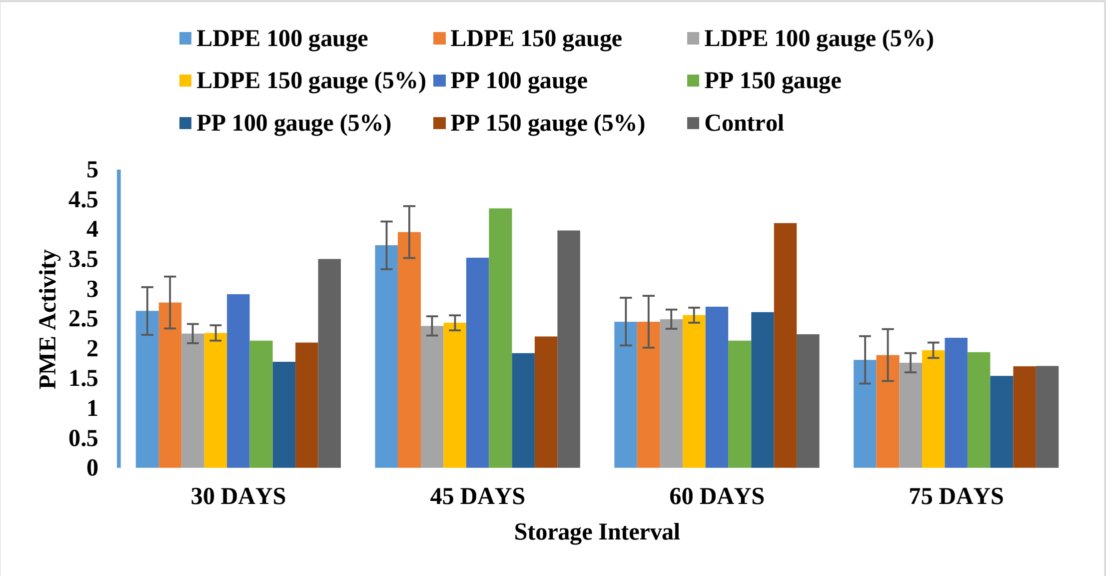
TREATMENT		**PME activity (unit/ml)**											
		2016-17						**2017-18**					
		Storage interval (Days)						**Storage interval (Days)**					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	0.56	2.43	4.16	2.21	2.12	**2.30**^{b}	0.63	2.83	3.30	2.70	1.50	**2.19**^{b}
	150 gauge	0.56	3.04	3.70	2.61	1.66	**2.31**^{b}	0.63	2.50	4.20	2.30	2.13	**2.35**^{a}
LDPE (5%Perforated)	**100 gauge**	0.56	2.17	2.36	2.52	1.72	**1.87**^{d}	0.63	2.33	2.40	2.46	1.80	**1.92**^{d}
	150 gauge	0.56	2.24	2.54	2.71	2.29	**2.07**^{c}	0.63	2.36	2.50	2.60	2.23	**2.06**^{c}
PP	**100 gauge**	0.56	3.01	3.61	2.66	2.19	**2.41**^{a}	0.63	2.81	3.44	2.75	2.17	**2.36**^{a}
	150 gauge	0.56	2.47	3.88	2.34	2.15	**2.28**^{b}	0.63	1.80	4.83	1.93	1.73	**2.18**^{b}
PP (5% Perforated)	**100 gauge**	0.56	1.81	1.98	2.49	1.23	**1.61**^{e}	0.63	1.76	1.86	2.73	1.86	**1.77**^{e}
	150 gauge	0.56	1.94	2.11	4.55	1.34	**2.10**^{c}	0.63	2.26	2.30	3.66	2.06	**2.18**^{b}
Control		0.56	3.64	4.06	2.16	1.77	**2.44**^{a}	0.63	3.36	3.90	2.33	1.65	**2.37**^{a}
Mean		**0.56**^{e}	**2.53**^{c}	**3.15**^{a}	**2.69**^{b}	**1.83**^{d}		**0.63**^{d}	**2.44**^{b}	**3.19**^{a}	**2.61**^{a}	**1.90**^{c}	
LSD (P≤0.05)		**Treatment (T)** = 0.067 **Days (D)** = 0.049 **D x T** = 0.15						**Treatment (T)** = 0.080 **Days (D)** = 0.051 **D x T** = 0.15					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 41a: Effect of different packaging materials and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

PME activity (unit/ml)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	0.59	2.63	3.73	2.45	1.81	**2.24**[c]
	150 gauge	0.59	2.77	3.95	2.45	1.89	**2.33**[b]
LDPE (5% perforation)	**100 gauge**	0.59	2.25	2.38	2.49	1.76	**1.89**[f]
	150 gauge	0.59	2.26	2.43	2.56	1.97	**1.96**[e]
PP	**100 gauge**	0.59	2.91	3.52	2.70	2.18	**2.38**[a]
	150 gauge	0.59	2.13	4.35	2.13	1.94	**2.23**[c]
PP (5% perforation)	**100 gauge**	0.59	1.78	1.92	2.61	1.54	**1.69**[g]
	150 gauge	0.59	2.10	2.20	4.10	1.70	**2.14**[d]
Control		0.59	3.50	3.98	2.24	1.71	**2.41**[a]
Mean		**0.59**[e]	**2.48**[c]	**3.16**[a]	**2.64**[b]	**1.83**[d]	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.046 **Days (D)** = 0.034 **D x T** = 0.10					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 41: Effect of different packaging materials and storage interval on the PME activity (unit/ml) in Kinnow fruit stored at 5-7°C and 90-95% RH

wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films delayed the initiation of peak in PME activity till 60 days of storage i.e. 2.49 and 2.52 micro equi. acid produced/min/ml tissue, respectively. On the other hand, control fruits initiated an earliest peak in PME activity after 45 days of storage i.e. 4.06 micro equi. acid produced/min/ml tissue. Similar trend was also noticed in 2017-18. The average lowest mean PME activity was observed in the fruits wrapped in perforated PP 100 gauge film (1.77 micro equi. acid produced/min/ml tissue) followed by perforated LDPE 100 gauge film (1.92 micro equi. acid produced/min/ml tissue). On the other hand control fruits recorded the average maximum PME activity (2.37 micro equi. acid produced/min/ml tissue). The data further revealed that fruits wrapped in perforated PP 100 gauge and perforated LDPE 100 gauge films revealed a delayed initiation of peak in PME activity till 60 days of storage i.e. 2.73 and 2.46 micro equi. acid produced/min/ml tissue, respectively. However, control fruits initiated an earliest peak in PME activity after 45 days of storage i.e. 3.90 micro equi. Acid produced/min/ml tissue. The interaction between treatments and storage interval was found to be significant during both the years of investigationin. The findings were further confirmed through the pooled mean analysis of the both the years (Table 41a and Fig 41). Fruits wrapped in perforated PP 100 gauge registered the lowest PME activity (1.69 micro equi. acid produced/min/ml tissue) followed by perforated LDPE 100 gauge film (1.89 micro equi. acid produced/min/ml tissue). On the other hand, control fruits recorded the maximum PME activity (2.41 micro equi. acid produced/min/ml tissue). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. In the present study, the perforated PP 100 and perforated LDPE 100 gauge films registered the average lowest PME activity may be due to slower respiratory activity occurring inside the package due to creation of modified atmospheric conditions (Sen *et al* 2012 and Giacalone and Chiabrando 2013).

The results are in corroboration with the findings of Mahajan *et al* (2015) who demonstrated the effect of various packaging films and found that the packaging films influenced the PME activity in peach fruit and this might be attributed to the difference in gaseous conditions generated inside the packages. Similar findings were also reported by Kaur *et al* (2014) who reported that unwrapped pear fruits registered the maximum PME activity over wrapped fruits inside different packaging films. Fruit of plum cv 'Tegan blue' stored in MAP alone also showed reduction in the activities of exo-PG, endo-PG, PE, and EGase enzymes as compared with control fruit (Khan and Singh 2008). Similar findings were also reported in nacterine (Ozkayaa *et al* 2016) pears (Ortiz *et al* 2011 and Pedreschi *et al* 2008) and papaya (Lazan *et al* 1993).

4.3.14 Cellulase activity

The data on cellulase activity influenced by different packaging materials revealed an identical trend during storage (Table 42). In general, Irrespective of the wrapping material (except

Table 42: Effect of different packaging materials and storage interval on the cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$) in Kinnow fruit stored at 5-7°C and 90-95% RH

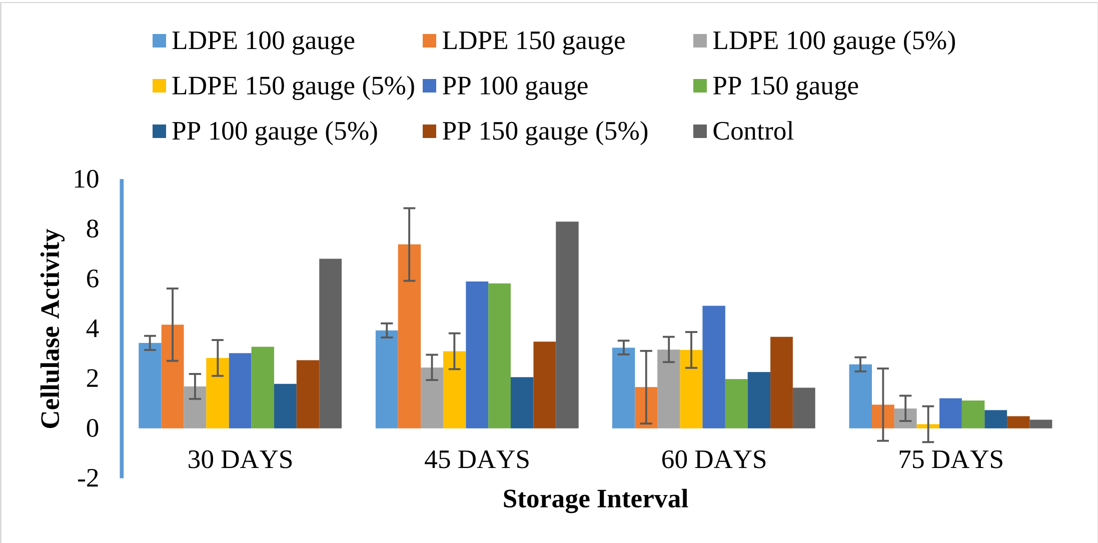
TREATMENT		Cellulase activity (mg glucose per min^{-1} mg $protein^{-1}$)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	0.85	2.88	3.41	2.70	2.14	**2.40^{d}**	1.68	3.98	4.45	3.79	3.00	**3.38^{b}**
	150 gauge	0.85	4.10	6.33	1.75	0.77	**2.76^{c}**	1.68	4.22	8.43	1.55	1.14	**3.40^{b}**
LDPE (5%Perforated)	**100 gauge**	0.85	1.66	2.25	3.59	0.48	**1.77^{f}**	1.68	1.70	2.63	2.73	1.12	**1.97^{f}**
	150 gauge	0.85	2.40	2.70	2.81	0.19	**1.79^{f}**	1.68	3.24	3.49	3.49	0.13	**2.40^{e}**
PP	**100 gauge**	0.85	2.90	5.77	4.60	1.16	**3.06^{b}**	1.68	3.12	6.01	5.24	1.24	**3.46^{b}**
	150 gauge	0.85	2.88	5.18	1.84	0.81	**2.31^{d}**	1.68	3.67	6.45	2.10	1.41	**3.06^{c}**
PP (5% Perforated)	**100 gauge**	0.85	1.82	1.86	2.12	0.74	**1.48^{g}**	1.68	1.75	2.25	2.40	0.72	**1.76^{g}**
	150 gauge	0.85	2.57	3.19	3.40	0.40	**2.08^{e}**	1.68	2.89	3.78	3.94	0.59	**2.57^{d}**
Control		0.85	6.22	7.38	1.70	0.33	**3.30^{a}**	1.68	7.40	9.23	1.56	0.38	**4.05^{a}**
Mean		**0.85^{d}**	**3.05^{b}**	**4.23^{a}**	**2.72^{c}**	**0.78^{d}**		**1.68^{d}**	**3.55^{b}**	**5.19^{a}**	**2.98^{c}**	**1.08^{e}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.10 **Days (D)** = 0.08 **D x T** = 0.23						**Treatment (T)** = 0.09 **Days (D)** = 0.07 **D x T** = 0.200					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 42a: Effect of different packaging materials and storage interval on the cellulase activity (mg glucose per min^{-1} mg protein^{-1}) of Kinnow fruit stored at 5-7^{o}C and 90-95% RH

Cellulase activity (mg glucose per min^{-1} mg protein^{-1})							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	1.26	3.43	3.93	3.24	2.57	**2.89^{d}**
	150 gauge	1.26	4.16	7.38	1.65	0.95	**3.08^{c}**
LDPE (5% perforation)	**100 gauge**	1.26	1.68	2.44	3.16	0.80	**1.87^{h}**
	150 gauge	1.26	2.82	3.09	3.15	0.16	**2.10^{g}**
PP	**100 gauge**	1.26	3.01	5.89	4.92	1.20	**3.26^{b}**
	150 gauge	1.26	3.27	5.81	1.97	1.11	**2.69^{e}**
PP (5% perforation)	**100 gauge**	1.26	1.78	2.05	2.26	0.73	**1.62^{i}**
	150 gauge	1.26	2.73	3.48	3.67	0.49	**2.33^{f}**
Control		1.26	6.81	8.30	1.63	0.35	**3.67^{a}**
Mean		**1.26^{d}**	**3.30^{b}**	**4.71^{a}**	**2.85^{c}**	**0.93^{e}**	
LSD ($P\leq0.05$)		**Treatment (T)** = 0.064 **Days (D)** = 0.048 **D x T** = 0.14					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

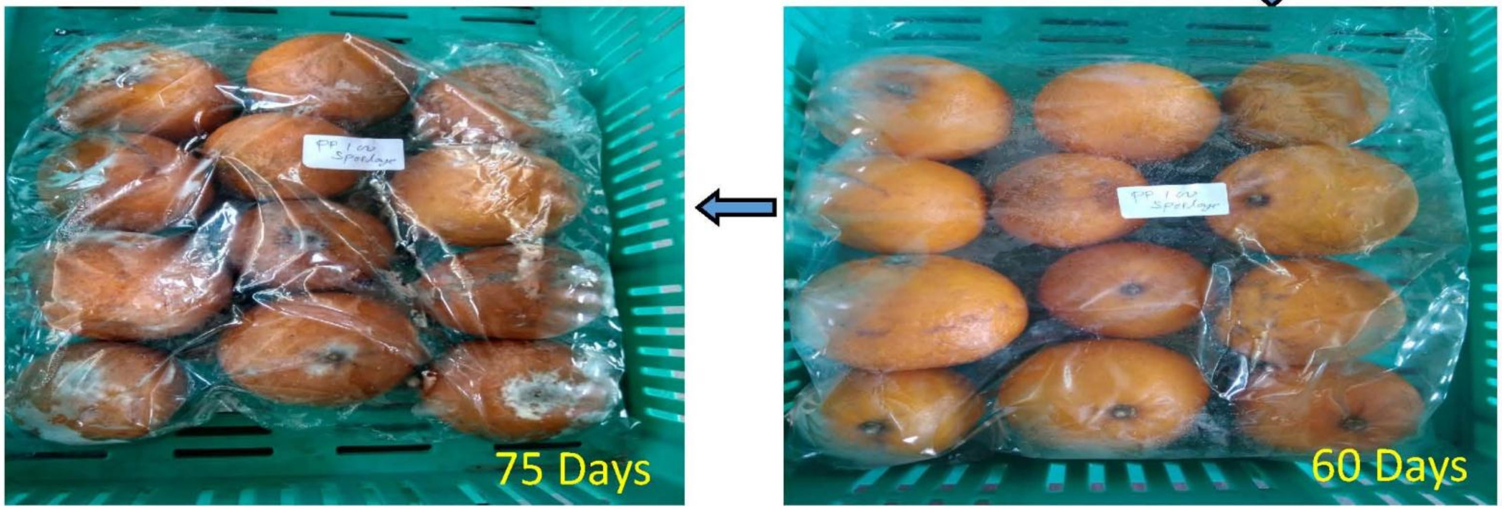
Fig 42: Effect of different packaging materials and storage interval on the cellulase activity (mg glucose per min^{-1} mg protein^{-1}) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

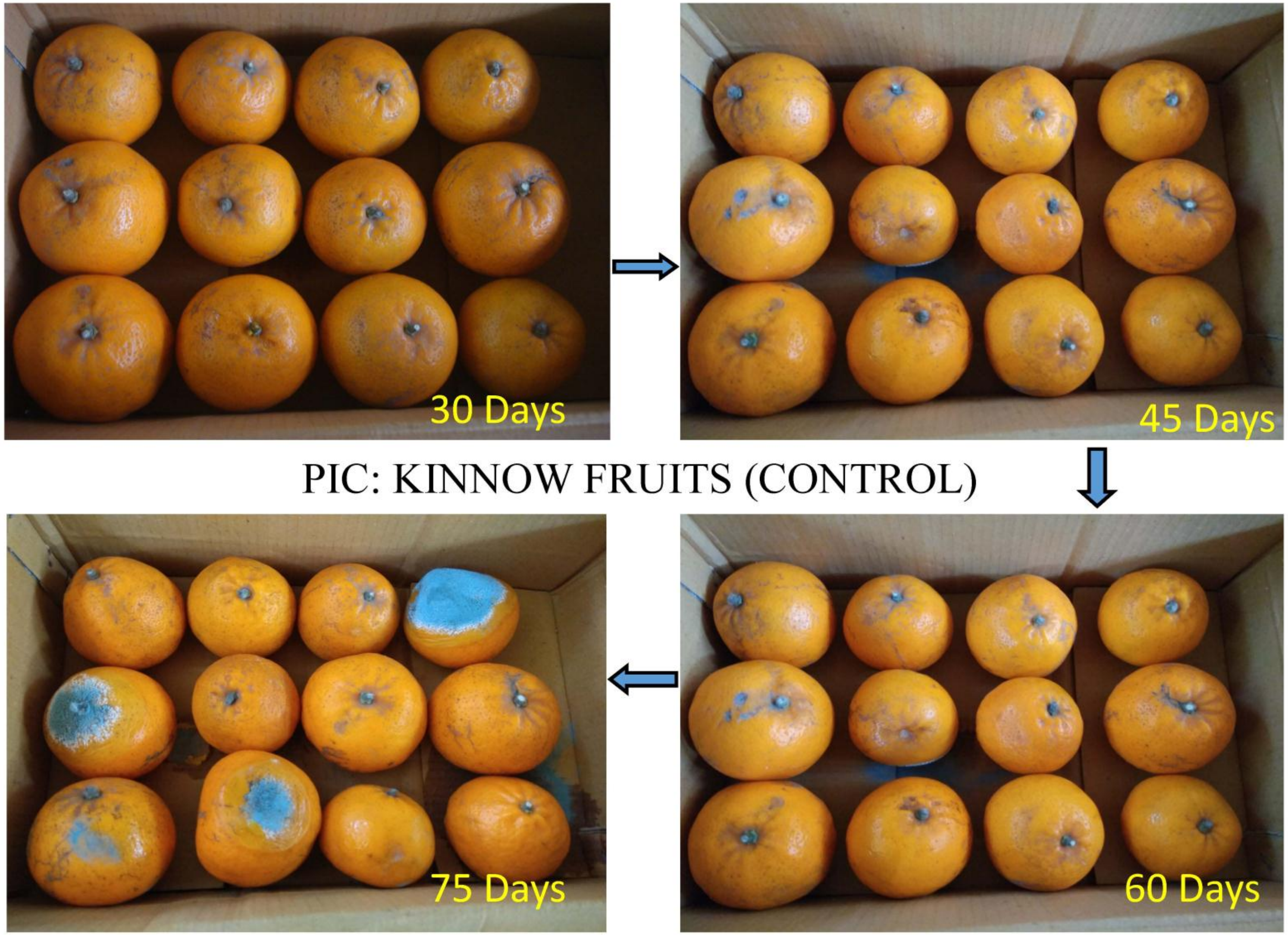
perforated PP 100 gauge, PP 150 gauge, perforated LDPE 100 gauge and perforated LDPE 150 gauge films) the maximum cellulase activity with respect to storage interval was recorded after 45 days of the storage followed by a sudden decline till the end of the storage. In 2016-17, the average lowest average cellulase activity (1.48 mg glucose per min^{-1} mg $protein^{-1}$)was recorded in the fruits wrapped in perforated PP 100 gauge followed by perforated LDPE 100 guage film (1.77 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, control fruits showed the maximum mean cellulase activity (3.30 mg glucose per min^{-1} mg $protein^{-1}$). The data further revealed that fruits wrapped in perforated PP 100 delayed the peak in cellulase activity till 60 days of storage i.e. 2.12 mg glucose per min^{-1} mg $protein^{-1}$ followed by perforated LDPE 100 gauge film (3.59 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, control fruits registered an earliest peak in cellulase activity after 45 days of storage period i.e. 7.38 mg glucose per min^{-1} mg $protein^{-1}$. The similar trend was also noticed in 2017-18. Fruits wrapped in perforated PP 100 gauge film registered the lowest cellulase activity (1.76 mg glucose per min^{-1} mg $protein^{-1}$) followed by perforated LDPE 100 gauge (1.97 mg glucose per min^{-1} mg $protein^{-1}$). However, control fruits recorded the highest average cellulase activity (4.05 mg glucose per min^{-1} mg $protein^{-1}$). It was noticed that fruits wrapped in perforated PP 100 gauge film delayed the cellulase activity till 60 days of storage period i.e. 2.40 mg glucose per min^{-1} mg $protein^{-1}$ followed by perforated LDPE 100 gauge film (2.73 mg glucose per min^{-1} mg $protein^{-1}$). On the other hand, control fruits revealed an earliest peak in cellulase activity after 45 days of storage period i.e. 9.23 mg glucose per min^{-1} mg $protein^{-1}$). The interaction between treatments and storage interval was found to be significant during both the years of investigation. The findings were further confirmed through the pooled mean analysis of both the years (Table 42a and Fig 42). Perforated PP 100 gauge film registered the lowest average cellulase activity (1.62 mg glucose per min^{-1} mg $protein^{-1}$) followed by perforated LDPE 100 gauge film (1.87 mg glucose per min^{-1} mg $protein^{-1}$). However, control fruits recorded the maximum cellulase activity (3.67 mg glucose per min^{-1} mg $protein^{-1}$). The interaction between treatments and storage interval was found to be significant in the pooled mean analysis of both the years. Fruit softening is associated with cell wall disassembly (Seymour and Gross 1996) and modifications to the pectin fraction are some of the most apparent changes that take place in the cell wall during ripening (Marin-Rodriguez *et al* 2002). The general observation is that softening is accompanied by solubilization of pectin, involving the action of enzymes pectinesterase (PE), polygalacturonase (PG) and pectate lyases (PL) (White 2002).

The results are in corroboration with the findings of (Khan and Singh 2008) who reported that fruit of plum cv ‘Tegan blue’ stored in MAP alone also showed reduction in the activities of exo-PG, endo-PG and EGase enzymes as compared to control fruit. Similar findings were reported in nacterine (Ozkaya *et al* 2016) pears (Ortiz *et al* 2011 and Pedreschi *et al* 2008) and papaya (Lazan *et al* 1993).

PIC: KINNOW FRUIT PACKED IN PP 100 (5%)

PIC: KINNOW FRUITS PACKED IN PP 100





PIC: KINNOW FRUITS (CONTROL)

CHAPTER V

SUMMARY

The present investigations entitled “Effect of post-harvest treatments and packagings on storage-life and quality of Kinnow fruit” were conducted in the Department of Fruit science and Punjab Horticultural Post-harvest Technology Centre (PHPTC), PAU campus, Ludhiana during 2016-17 and 2017-18. Kinnow fruit were harvested in mid-january at physiological maturity stage to evaluate performance of different edible coatings on enhancing storage life and quality retention, to study effect of different anti-senescence compounds on storage life and to examine the effect of modified atmospheric packaging with various packing materials of different thicknesses on enhancement of storage life. The fruit of uniform size, apparently free from disease and bruises were sorted, washed with chlorinated water (100 mg L^{-1}). Thereafter, the fruit were divided into requisite lots for further handling. The first lot of fruit was coated with varied concentration of different edible coatings *viz* CMC (1, 1.5 and 2 per cent), chitosan (0.5, 1 and 1.5 per cent, respectively) and bees-wax (5, 10 and 15 per cent, respectively). The second lot of fruit was treated with different concentrations of anti-senescence compounds *viz* 1-MCP (500, 1000 and 1500 ppb), methyl jasmonates (1, 2 and 3 mM) and salicylic acid (1, 2 and 3mM). In the third lot, the fruit were individually seal wrapped with different packaging films commercially available in the market *viz.*,perforated and non perforated low density polyethylene film (100 and 150 gauge films) and perforated and non perforated polypropylene (100 and 150 gauge films, respectively). The control fruit were kept uncoated, untreated and unpacked. The fruit treated with different treatments were stored under modified atmospheric storage conditions *viz* 5-7^{o}C and 90-95% RH. The fruit were analyzed for various physico-chemical parameters at 0, 30, 45, 60 and 75 days interval after storage. The results of present study are summarized below:

The physiological loss in weight of Kinnow fruit increased during storage irrespective of different coating treatments. In both the seasons of investigation, the fruit coated with CMC 2 per cent registered the lowest PLW i.e. 2.98 and 2.68 per cent, respectively followed by CMC (1.5), chitosan (1%) and bees-wax (10%) in contrast to control fruit (7.57 and 6.43 per cent, respectively. In the second experiment, the fruit treated with MeJA (1mM) exhibited the lowest PLW in the both the seasons of study i.e. 4.02 and 2.35 per cent, respectively followed by 1-MCP (1500 ppb and SA 2mM). The control fruit showed the highest PLW during both the seasons i.e. 10.31 and 6.43 per cent, respectively. In the third experiment, fruit packed in perforated PP 100 gauge resulted the lowest PLW (0.50 and 0.44 per cent) followed by perforated LDPE 100 gauge film. The control fruit exhibited the highest PLW (6.93 and 6.43 per cent), respectively during both the season of investigation.

The lowest spoilage percentage was recorded in the fruit coated with CMC (2%) i.e. 1.67 and 0 per cent followed by CMC (1.5%), chitosan (1%) and bees wax (10%) in contrast to uncoated fruits (18.33 and 10.00 per cent) during the seasons of 2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) showed the lowest spoilage (1.67 and 0 per cent) followed by 1-MCP 1500 (ppb) as compared to control (13.33 and 10.00 per cent), respectively during both the seasons of study. In the third experiment, the fruit wrapped in perforated PP 100 gauge film registered the lowest spoilage (3.33 and 1.67 per cent) followed by perforated LDPE 100 gauge film than those of fruit wrapped in non perforated packaging films (33.33 and 31.66 per cent) during both the seasons of investigation.

The highest sensory rating was noted in the fruit coated with CMC 2% (7.53 and 8.37) followed by CMC (1.5%), chitosan (1%) and bees-wax (10%) as comparedto uncoated fruits (6.76 and 7.15) during the season of2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) maintained the highest sensory score (7.65 and 8.38) than that of untreated fruit (6.15 and 7.15 per cent), respectively during both the seasons of investigation. In the third experiment, the fruit packed in perforated PP 100 gauge film registered the maximum sensory score i.e. 7.70 and 8.11 per cent, respectively followed by perforated LDPE 100 gauge film. However, unpacked control fruit exhibited the lowest sensory rating (6.15 and 7.15 per cent, respectively) during 2016-17 and 2017-18, respectively.

Fruit firmness followed a gradual decline with an advancement in storage period. However, CMC (2%) maintained the highest firmness (4.94 and 5.29 kg force) followed byCMC (1.5%), chitosan (1%) and bees-wax (10%) than those of uncoated fruit (4.06 and 5.29 kg force) during the season of 2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) retained the highest firmness (5.01 and 5.34 kg force) followed by 1-MCP (1500 ppb) than those of untreated fruit (4.07 and 4.36 kg force) during 2016-17 and 2017-18, respectively. In the third experiment, the fruit wrapped in perforated PP 100 gauge film maintained the maximum firmness (5.40 and 5.48 kg force) followed by perforated LDPE 100 gauge film as compared to unwrapped fruits (4.07 and 4.36 kg force) in the season of 2016-17 and 2017-18, respectively.

Juice content declined with prolongation in storage period. However, the fruit coated with CMC (2%) maintained the highest juice content (38.48 and 46.45 per cent, respectively) followed by CMC (1.5%), chitosan (1%) and bees-wax (10%) in contrast to uncoated fruit (33.98 and 43.14 per cent, respectively) during 2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) retained the maximum juice content (38.02 and 46.03 per cent, respectively) followed by 1-MCP (1500 ppb) than those of untreated fruits (34.38 and 41.14 per cent, respectively) during both the season of study. In the third experiment, the fruit wrapped in perforated PP 100 gauge film retained the maximum juice content (46.84 and 47.37 per cent, respectively) followed by perforated LDPE 100 gauge film. The unwrapped fruit resulted in lowest juice content (42.12 and 43.14 per cent, respectively) during the season of 2016-17 and 2017-18, respectively.

The TSS, reducing sugars and total sugars increased irrespective of the coating treatments in the fruits up to 60 days under cold storage conditions. The maximum TSS, reducing sugars and total sugars were recorded in the fruits coated with CMC (2%) i.e. 11.06, 4.21 and 8.61 per cent, respectively during 2016-17 and 11.06, 3.41 and 6.92 per cent, respectively during 2017-18. The uncoated fruits registered the lowest TSS, reducing sugars and total sugars content i.e. 10.03, 3.36 and 6.93 percent, respectively during 2016-17 and 10.27, 2.66 and 5.80 per cent, respectively during 2017-18. In the second experiment, the fruit treated with MeJA (1mM) registered the maximum TSS, reducing sugars and total sugars (11.00, 4.06 and 7.87 per cent, respectively during 2016-17 and 10.97, 3.28 and 7.87 per cent, respectively during 2017-18. The untreated fruits recorded the lowest TSS, reducing sugars and total sugars (10.07, 3.38 and 7.02 percent, respectively during first season of investigation and 10.27, 2.66 and 6 per cent, respectively during second season of investigation. In third experiment, the fruit wrapped in perforated PP 100 gauge film registered the maximum TSS, reducing sugars and total sugars (10.67, 3.14 and 7.04 per cent, respectively in 2016-17 and 10.79, 3.19 and 7.09 per cent in 2017-18, respectively). The unwrapped fruits registered the lowest TSS, reducing sugars and total sugars (9.64, 2.30 and 5.39 per cent in 2016-17 and 9.71, 2.32 and 5.51 per cent in 2017-18 respectively.

The vitamin C content of the Kinnow fruits followed a declining trend with an advancement in storage period. Fruits coated with CMC (2%) maintained the highest ascorbic acid (23.95 and 27.84 mg/100g pulp) content followed by CMC (1.5%), chitosan (1%) and bees-wax (10%) as compared to control (19.72 and 21.72 mg/100 g pulp) in 2016-17 and 2017-18, respectively. In the experiment-2, the fruit treated with MeJA (1mM) maintained the highest (22.67 and 28.19 mg/100g pulp, respectively) ascorbic acid content as compared to control (19.72 and 21.80 mg/100g pulp) during both the seasons of investigation. In the third experiment, the fruit packed in perforated PP 100 gauge film retained the maximum (23.94 and 25.85 mg/100g pulp) followed by perforated LDPE 100 gauge film in contrast to unwrapped fruits (22.09 and 23.70 mg/100g pulp, respectively) during 2016-17 and 2017-18, respectively.

The fruits coated with CMC (2%) maintained the maximum total carotenoids content (0.62 and 0.53 mg/100g pulp) followed by CMC (1.5%), chitosan (1%) and bee wax (10%) in contrast to control (0.47 and 0.33 mg/100g pulp, respectively) during 2016-17 and 2017-18. In the second experiment, the fruit treated with MeJA (1mM) maintained the maximum total carotenoids content (0.66 and 0.59 mg/100g pulp) followed by 1-MCP (1500 ppb) in contrast to control (0.45 and 0.34 mg/100g pulp), respectively during 2016-17 and 2017-18, respectively. In the third experiment, fruits packed in perforated PP 100 gauge maintained the maximum total carotenoids (0.52 and 0.53 mg/100g pulp) content followed by perforated LDPE 100 gauge than that of unwrapped fruits (0.37 and 0.34 mg/100g pulp, respectively) during 2016-17 and 2017-18, respectively.

The highest pectin content (0.56 and 0.34 %) was retained in the fruits coated with CMC (2%) followed by its 1.5 per cent concentration, chitosan (1%) and bee wax (10%) in contrast to uncoated (0.46 and 0.28%) during 2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) maintained the maximum pectin content (0.56 and 0.38%) followed by 1-MCP (1500 ppb) than those of untreated fruits (0.46 and 0.27%, respectively) during 2016-17 and 2017-18, respectively. In the third experiment, the fruit wrapped in perforated PP 100 gauge film maintained the maximum pectin content (0.50 and 0.33%) followed by perforated LDPE 100 gauge as compared to unwrapped fruit (0.42 and 0.25 per cent), during 2016-17 and 2017-18, respectively.

The maximum total phenolics content (143.26 and 147.08 mg/100g pulp) was maintained in the fruits coated with CMC (2%) followed by CMC (1.5%), chitosan (1%) and bee wax (10%) than those of uncoated fruits (110.31 and 118.57 mg/100g pulp, respectively) during 2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) retained the maximum total phenolics content (137.30 and 128.57 mg/100g pulp) than those of untreated fruits (110.31 and 128.57 mg/100g pulp) followed by 1-MCP (1500 ppb) during 2016-17 and 2017-18, respectively. In the third experiment, the fruit packed in perforated PP 100 gauge film followed by perforated LDPE 100 gauge film maintained the highest total phenolics content (126.62 and 126.16 mg/100g pulp) content in contrast to unwrapped fruits (87.15 and 92.15 mg/100g pulp) during 2016-17 and 2017-18, respectively.

The lowest PME activity (0.26 and 1.58 micro equi acid produced/min/ml juice) was recorded in the fruit coated with CMC (2%) followed by its 1.5 per cent concentration, chitosan (1%) and bee wax (10%) in contrast to uncoated fruit (0.33 and 2.37 micro equi acid produced/min/ml juice) during 2016-17 and 2017-18, respectively. In the second experiment, the lowest mean PME activity (0.26 and 1.42 micro equi acid produced/min/ml juice) was registered in the fruits treated with MeJA (1mM) followed by 1-MCP (1500 ppb). However, untreated fruits recorded the maximum PME activity (0.45 and 2.37 micro equi acid produced/min/ml juice) during 2016-17 and 2017-18, respectively. In the third experiment, the fruit wrapped in perforated PP 100 gauge film maintained lowest PME activity (1.61 and 1.77 micro equi acid produced/min/ml juice) followed by perforated LDPE 100 gauge film than those of unwrapped fruits (2.44 and 2.37 micro equi acid produced/min/ml juice) during 2016-17 and 2017-18, respectively.

The lowest cellulase activity (1.75 and 2.19 mg glucose per min^{-1} mg $protein^{-1}$) was recorded in the fruit coated with CMC (2%) followed by its 1.5 per cent concentration and chitosan (1%) as compared to uncoated fruit (2.92 and 5.20 mg glucose per min^{-1} mg $protein^{-1}$) during 2016-17 and 2017-18, respectively. In the second experiment, the fruit treated with MeJA (1mM) recorded the lowest mean cellulase activity (1.74 and 2.37 mg glucose per min^{-1} mg $protein^{-1}$) followed by 1-MCP (1500 ppb) in contrast to untreated fruit (3.49 and 5.69 mg glucose per min^{-1} mg $protein^{-1}$) during 2016-17 and 2017-18, respectively. In the third experiment, the fruit wrapped in perforated PP 100 gauge film recorded the lowest mean cellulase activity (1.48 and 1.76 mg glucose per min^{-1} mg $protein^{-1}$) followed by perforated LDPE 100 gauge film in contrast to unwrapped fruits (3.30 and 4.05 mg glucose per min^{-1} mg $protein^{-1}$) during 2016-17 and 2017-18, respectively.

From the present studies, it can be concluded that in experiment-1, CMC 2 per cent and 1.5 per cent coatings were most effective in retaining and maintaining physical and physico-chemical attributes up to 60 days in contrast to control (uncoated) where fruits remained acceptable only up to 45 days

In experiment-2, MeJA 1mM and 1-MCP 1500 ppb were the best among anti-senescence compounds in terms of retaining and maintaining desirable fruit quality up to 60 days than those of control (untreated) where fruits remained fit for consumption only up to 45 days

In experiment-3, perforated PP 100, LDPE 100, LDPE 150 and PP 150 gauge packaging films maintained the best quality of fruits even after 60 days of storage while, non perforated PP 100, PP 150, LDPE 100, LDPE 150 gauge films and control (unwrapped) fruits remained acceptable only up to 45 days with respect to overall fruit quality.

From the present study it is observed that in all three experiments CMC with 2 per cent formulation is the best treatment to enhance the storage life and quality retention of Kinnow fruit due to its cost effectiveness and ease of application therefore, can be recommended among growers.

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APPENDIX-I

Following physio-chemical attributes were studied in addition to the scheduled work in present study entitled, "Effect of edible coatings, anti-senescence compounds and packaging materials on the stored fruits:

Sr no	**Observation**	**Table No**		
		Expt`1	**Expt 2**	**Expt 3**
1	**Titratable Acidity (%)**	1 and 1a	7 and 7a	13 and 13a
2	**Non-Reducing sugars (%)**	2 and 2a	8 and 8a	14 and 14a
3	**Total Flavonoids (mg/100g)**	3 and 3a	9 and 9a	15 and 15a
4	**Total Antioxidants (%)**	4 and 4a	10 and 10a	16 and 16a
5	**Protein (mg/100g)**	5 and 5a	11 and 11a	17 and 17a
6	**Total Free Amino Acids (mg/100g)**	6 and 6a	12 and 12a	18 and 18a

Table 1: Effect of different edible coatings and storage interval on the titratable acidity (%) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

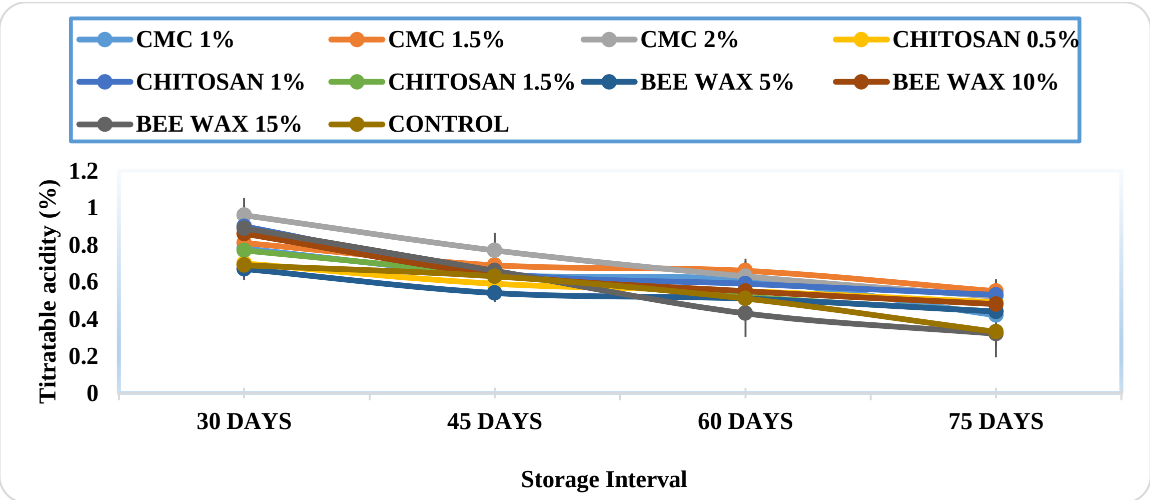
TREATMENT		Titratable acidity (Days)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	0.780	0.520	0.500	0.476	0.323	**0.520^{e}**	1.33	1.036	0.786	0.736	0.520	**0.882^{de}**
	1.5%	0.780	0.650	0.526	0.526	0.483	**0.593^{b}**	1.33	1.230	0.800	0.666	0.590	**0.923^{b}**
	2%	0.780	0.700	0.630	0.483	0.453	**0.609^{a}**	1.33	1.220	0.910	0.770	0.600	**0.966^{a}**
Chitosan	**0.5%**	0.780	0.496	0.450	0.436	0.386	**0.510^{ef}**	1.33	0.910	0.736	0.670	0.590	**0.847^{f}**
	1%	0.780	0.566	0.513	0.506	0.483	**0.570^{c}**	1.33	0.970	0.856	0.800	0.620	**0.915^{bc}**
	1.5%	0.780	0.516	0.503	0.426	0.330	**0.511^{ef}**	1.33	1.030	0.786	0.606	0.550	**0.860^{ef}**
Bee wax	**5%**	0.780	0.513	0.476	0.386	0.356	**0.503^{f}**	1.33	0.856	0.653	0.606	0.490	**0.787^{g}**
	10%	0.780	0.566	0.506	0.466	0.420	**0.548^{d}**	1.33	1.160	0.780	0.640	0.550	**0.892^{cd}**
	15%	0.780	0.600	0.530	0.350	0.280	**0.508^{ef}**	1.33	1.180	0.800	0.506	0.370	**0.837^{f}**
Control		0.780	0.490	0.436	0.416	0.386	**0.502^{f}**	1.33	0.863	0.786	0.640	0.300	**0.784^{g}**
Mean		**0.780^{a}**	**0.562^{b}**	**0.507^{c}**	**0.447^{d}**	**0.390^{e}**		**1.33^{a}**	**1.045^{b}**	**0.789^{c}**	**0.664^{d}**	**0.518^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.0141 **Days (D)** = 0.00099 **D x T**= 0.0316						**Treatment (T)** = 0.0289 **Days (D)** = 0.0204 **D x T** = 0.0645					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 1(a): Effect of different edible coatings and storage interval on the titratable acidity (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

		Titratable acidity (%)					
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	1.05	0.78	0.64	0.61	0.42	**0.70[d]**
	1.5%	1.05	0.81	0.69	0.66	0.55	**0.75[b]**
	2%	1.05	0.96	0.77	0.63	0.52	**0.79[a]**
Chitosan	**0.5%**	1.05	0.70	0.59	0.55	0.49	**0.68[e]**
	1%	1.05	0.90	0.65	0.59	0.53	**0.74[b]**
	1.5%	1.05	0.77	0.64	0.52	0.44	**0.69[e]**
Bee Wax	**5%**	1.05	0.67	0.54	0.51	0.44	**0.64[f]**
	10%	1.05	0.86	0.64	0.55	0.48	**0.72[c]**
	15%	1.05	0.89	0.66	0.43	0.32	**0.67[e]**
Control		1.05	0.69	0.63	0.51	0.33	**0.64[f]**
Mean		**1.05[a]**	**0.80[b]**	**0.65[c]**	**0.56[d]**	**0.45[e]**	
LSD (P≤0.05)		**Treatment (T)** = 0.015 **Days (D)** =0.010 **D x T** = 0.033					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bars represents standard error (SE) mean of three replicates

Fig 1: Effect of different edible coatings and storage interval on the titratable acidity (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 2: Effect of different edible coatings and storage interval on the non reducing sugars per centag in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

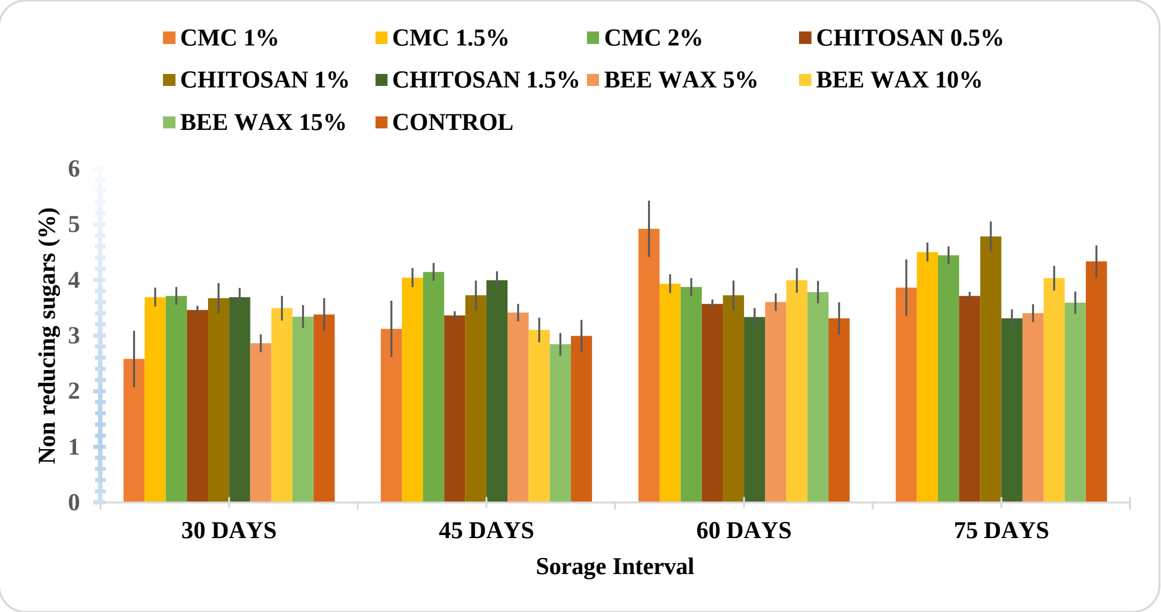
TREATMENT		Non reducing sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	2.41	2.66	4.03	4.85	4.30	**3.65^{c}**	2.83	2.50	2.21	5.00	3.42	**3.19^{cd}**
	1.5%	2.41	4.17	3.95	4.71	4.68	**3.98^{b}**	2.83	3.20	4.13	3.14	4.32	**3.52^{a}**
	2%	2.41	4.52	4.28	4.84	4.86	**4.18^{a}**	2.83	2.90	4.00	2.91	4.02	**3.33^{b}**
Chitosan	**0.5%**	2.41	4.00	3.43	3.73	4.27	**3.57^{d}**	2.83	2.92	3.29	3.40	3.16	**3.12^{d}**
	1%	2.41	4.34	3.81	4.66	4.92	**4.03^{b}**	2.83	3.00	3.63	2.54	4.64	**3.33^{b}**
	1.5%	2.41	4.12	3.81	3.66	3.91	**3.58^{cd}**	2.83	3.27	4.16	3.00	2.71	**3.19^{cd}**
Bee wax	**5%**	2.41	2.95	3.78	3.67	4.08	**3.38^{f}**	2.83	2.76	3.04	3.53	2.73	**2.97^{e}**
	10%	2.41	3.48	2.73	4.96	4.69	**3.65^{c}**	2.83	3.50	3.48	3.03	3.37	**3.24^{bc}**
	15%	2.41	3.82	3.12	3.40	4.56	**3.46^{e}**	2.83	2.87	2.56	4.15	2.63	**3.00^{e}**
Control		2.41	3.72	3.07	3.77	4.39	**3.47^{e}**	2.83	3.05	2.91	2.85	4.28	**3.18^{cd}**
Mean		**2.41^{e}**	**3.78^{c}**	**3.60^{d}**	**4.22^{b}**	**4.47^{a}**		**2.83^{d}**	**3.00^{c}**	**3.34^{b}**	**3.35^{b}**	**3.53^{a}**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 0.081 **Days (D)** = 0.057 **D x T** = 0.18						**Treatment (T)** = 0.10 **Days (D)** = 0.073 **D x T** = 0.23					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 2a: Effect of different edible coatings and storage interval on the non reducing sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Non reducing sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	2.62	2.58	3.12	4.92	3.86	**3.42[c]**
	1.5%	2.62	3.69	4.04	3.93	4.50	**3.75[a]**
	2%	2.62	3.71	4.14	3.87	4.44	**3.76[a]**
Chitosan	**0.5%**	2.62	3.46	3.36	3.57	3.71	**3.34[d]**
	1%	2.62	3.67	3.72	3.72	4.78	**3.68[b]**
	1.5%	2.62	3.69	3.99	3.33	3.31	**3.39[cd]**
Bee Wax	**5%**	2.62	2.86	3.41	3.60	3.40	**3.18[e]**
	10%	2.62	3.49	3.10	3.99	4.03	**3.45[c]**
	15%	2.62	3.34	2.84	3.78	3.59	**3.23[e]**
Control		2.62	3.38	2.99	3.31	4.33	**3.33[d]**
Mean		**2.62[e]**	**3.39[d]**	**3.47[c]**	**3.79[b]**	**4.00[a]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.075 **Days (D)** =0.053 **D x T** = 0.17					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 2: Effect of different edible coatings and storage interval on the non reducing sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 3: Effect of different edible coatings and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

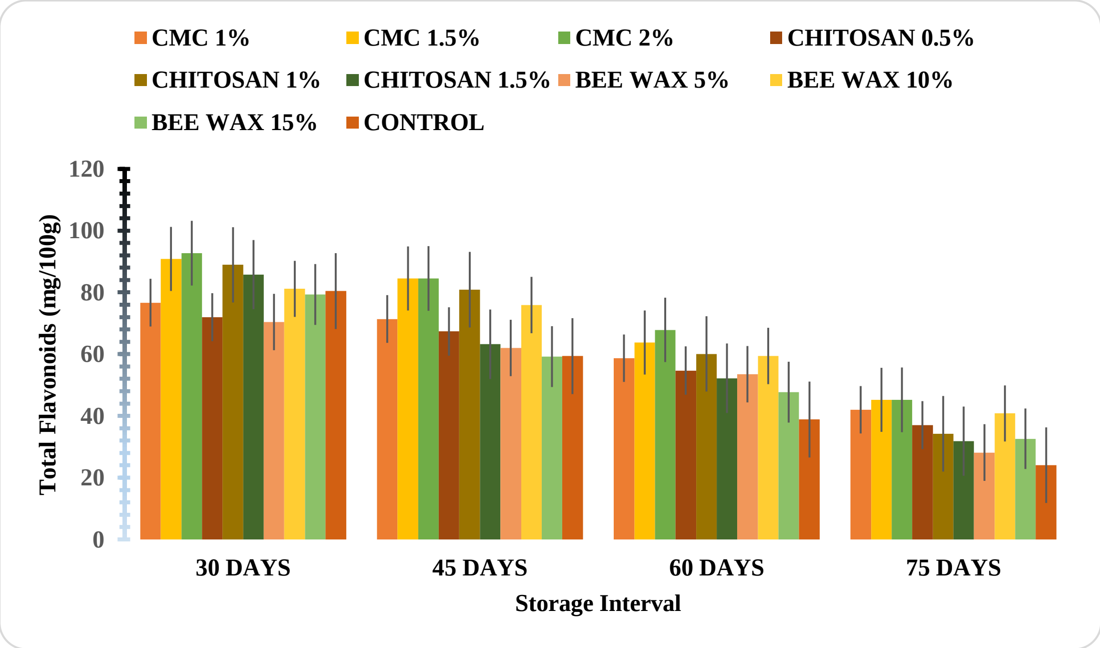
TREATMENT		Total flavonoids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	55.40	69.56	64.24	51.30	46.78	**57.46[d]**	60.50	83.75	78.49	66.07	37.23	**65.21[b]**
	1.5%	55.40	80.48	71.00	65.80	43.60	**63.26[b]**	60.50	101.16	97.95	61.70	46.87	**73.63[a]**
	2%	55.40	88.40	82.67	56.70	36.46	**63.93[a]**	60.50	96.96	86.52	79.02	55.54	**75.71[a]**
Chitosan	**0.5%**	55.40	65.00	58.68	54.90	32.50	**53.30[f]**	60.50	78.93	76.08	56.97	41.52	**61.34[ef]**
	1%	55.40	86.80	74.56	56.48	37.50	**62.15[c]**	60.50	91.07	87.23	63.67	30.98	**66.69[b]**
	1.5%	55.40	74.60	66.50	47.38	31.23	**55.02[e]**	60.50	96.88	59.91	54.46	32.43	**61.34[cd]**
Bee wax	**5%**	55.40	68.50	54.60	41.24	27.45	**49.44[g]**	60.50	72.33	69.37	65.72	28.84	**59.35[g]**
	10%	55.40	72.68	68.40	60.23	41.74	**59.69[d]**	60.50	89.65	83.39	58.58	39.91	**66.40[b]**
	15%	55.40	87.40	52.00	31.48	22.80	**49.82[g]**	60.50	71.25	66.34	63.93	42.41	**60.89[cd]**
Control		55.40	70.40	52.40	36.78	21.45	**47.29[h]**	60.50	90.45	66.40	40.91	26.65	**56.98[e]**
Mean		**55.40[c]**	**76.38[a]**	**64.50[b]**	**50.23[d]**	**34.15[e]**		**60.50[c]**	**87.24[a]**	**77.17[b]**	**61.10[c]**	**38.24[d]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 1.60 **Days (D)** = 1.13 **D x T** = 3.59						**Treatment (T)** = 2.56 **Days (D)** = 1.81 **D x T** = 5.73					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 3a: Effect of different edible coatings and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

Total flavonoids (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	57.95	76.65	71.36	58.68	42.00	**61.33^c**
	1.5%	57.95	90.82	84.47	63.75	45.24	**68.45^a**
	2%	57.95	92.68	84.47	67.86	45.24	**69.82^a**
Chitosan	**0.5%**	57.95	71.96	67.38	54.68	37.01	**57.80^d**
	1%	57.95	88.93	80.89	60.07	34.24	**64.42^b**
	1.5%	57.95	85.74	63.20	52.17	31.83	**58.18^d**
Bee Wax	**5%**	57.95	70.41	61.99	53.48	28.14	**54.39^{ef}**
	10%	57.95	81.16	75.89	59.40	40.82	**63.05^{bc}**
	15%	57.95	79.32	59.17	47.70	32.60	**55.35^{de}**
Control		57.95	80.42	59.40	38.84	24.05	**52.13^f**
Mean		**57.95^c**	**81.81^a**	**70.84^b**	**55.66^d**	**39.20^e**	
LSD (P≤0.05)		**Treatment (T)** = 3.02 **Days (D)** = 2.13 **D x T** = 6.75					

Mean values with same alphabates are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 3: Effect of different edible coatings and storage interval on the total flavonoids (mg/100g) in Kinnow fruits stored at 5-7^{o}C and 90-95% RH

Table 4: Effect of different edible coatings and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

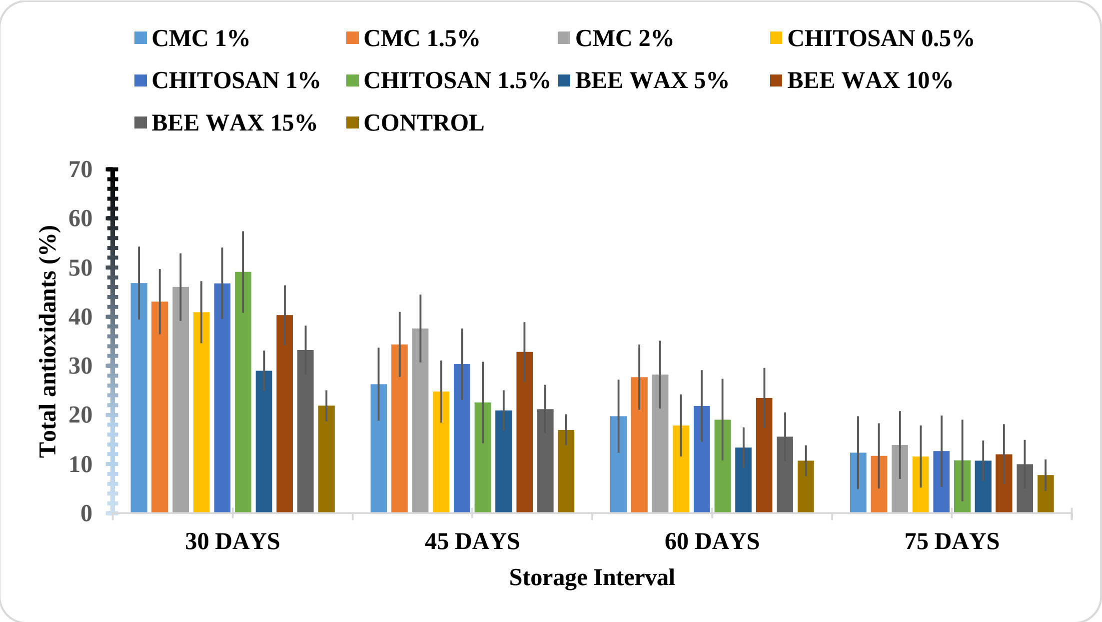
TREATMENT		STORAGE INTERVAL (Days)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	24.78	46.60	25.64	21.28	12.87	**26.07^{c}**	28.43	46.97	26.78	18.99	11.73	**26.58^{c}**
	1.5%	24.78	41.28	32.68	26.30	12.44	**27.50^{b}**	28.43	44.82	35.91	28.99	10.83	**29.80^{a}**
	2%	24.78	47.49	38.22	27.38	14.78	**30.53^{a}**	28.43	44.51	36.90	29.01	12.95	**30.36^{a}**
Chitosan	**0.5%**	24.78	42.58	22.68	16.66	11.98	**23.74^{e}**	28.43	39.17	26.72	19.00	11.07	**24.88^{d}**
	1%	24.78	42.26	33.44	22.39	11.23	**26.82^{bc}**	28.43	51.29	27.21	21.21	13.99	**28.43^{b}**
	1.5%	24.78	48.76	21.46	19.25	10.67	**24.98^{d}**	28.43	49.36	23.52	18.82	10.73	**26.17^{c}**
Bee wax	**5%**	24.78	29.44	20.56	14.56	11.29	**20.13^{g}**	28.43	31.77	21.24	12.10	10.00	**20.05^{e}**
	10%	24.78	40.34	31.62	20.44	13.34	**26.72^{c}**	28.43	40.21	33.95	25.56	10.65	**27.76^{b}**
	15%	24.78	34.60	22.68	16.56	10.78	**21.88^{f}**	28.43	31.77	19.65	14.53	9.13	**20.70^{e}**
Control		24.78	22.33	17.65	11.27	8.76	**16.96^{h}**	28.43	21.35	16.23	10.00	6.70	**16.54^{f}**
Mean		**24.78^{c}**	**39.57^{a}**	**26.66^{b}**	**19.61^{d}**	**11.81^{e}**		**28.43^{b}**	**39.79^{a}**	**26.81^{c}**	**19.82^{d}**	**10.78^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.94 **Days (D)** = 0.66 **D x T** = 2.096						**Treatment (T)** = 0.87 **Days (D)** = 0.61 **D x T** = 1.94					

Mean values with same alphabets are statistically similar at $p \le 0.05$ (n =15 fruits/replication)

Table 4a: Effect of different edible coatings and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total antioxidants (%)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	26.60	46.79	26.21	19.71	12.30	**26.32[e]**
	1.5%	26.60	43.05	34.30	27.64	11.63	**28.65[b]**
	2%	26.60	46.00	37.56	28.19	13.86	**30.44[a]**
Chitosan	**0.5%**	26.60	40.88	24.70	17.83	11.52	**24.31[g]**
	1%	26.60	46.77	30.32	21.80	12.61	**27.62[c]**
	1.5%	26.60	49.06	22.49	19.03	10.70	**25.58[f]**
Bee Wax	**5%**	26.60	28.96	20.90	13.33	10.65	**20.09[i]**
	10%	26.60	40.27	32.78	23.42	11.99	**27.02[d]**
	15%	26.60	33.18	21.16	15.54	9.95	**21.29[h]**
Control		26.60	21.84	16.94	10.64	7.73	**16.75[j]**
Mean		**26.60[b]**	**39.68[a]**	**26.74[b]**	**19.71[c]**	**11.30[d]**	
LSD ($P \leq 0.05$)		**Treatment (T)** =0.53 **Days (D)** =0.38 **D x T** =1.19					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 4: Effect of edible coating and storage interval on the total antioxidants (%) of Kinnow fruits stored at 5-7°C and 90-95% RH

Table 5: Effect of different edible coatings and storage interval on the protein (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

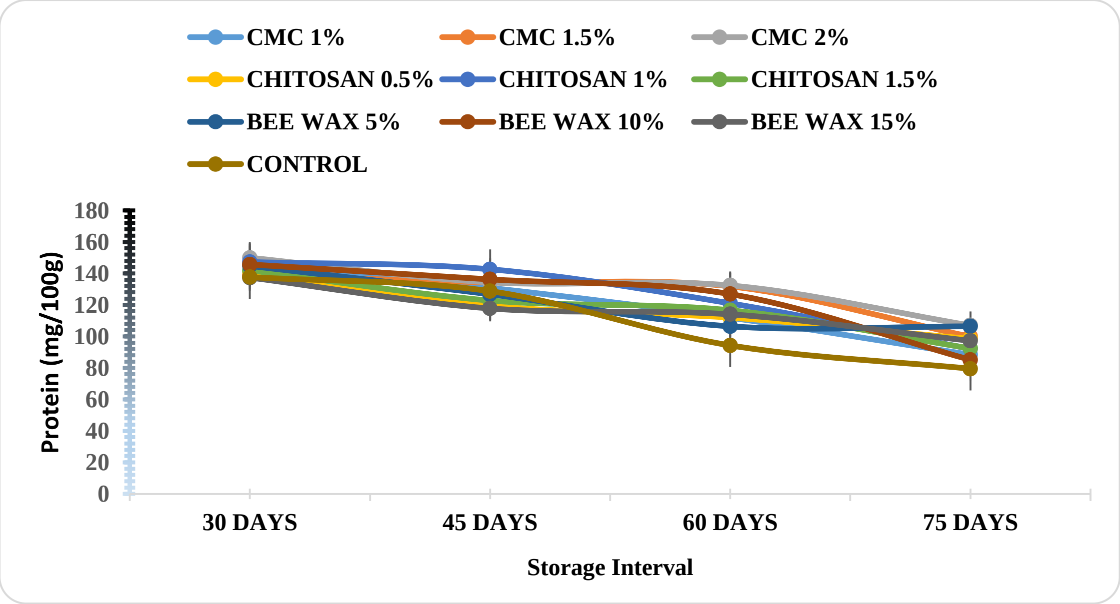
TREATMENT		Protein (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	1%	131.54	146.64	132.22	98.77	86.35	**119.10[bcd]**	140.64	144.14	129.36	124.96	90.34	**125.89[cd]**
	1.5%	131.54	133.66	127.68	126.71	96.55	**123.23[ab]**	140.64	143.91	140.98	136.86	103.08	**133.09[ab]**
	2%	131.54	146.92	128.80	125.55	102.33	**127.03[a]**	140.64	152.93	139.85	139.17	111.54	**136.83[a]**
Chitosan	0.5%	131.54	132.32	116.46	110.18	98.22	**117.74[cd]**	140.64	149.66	122.45	113.68	98.57	**125.00[cd]**
	1%	131.54	142.33	136.57	114.31	88.66	**122.68[ab]**	140.64	152.14	148.65	127.67	95.53	**132.93[ab]**
	1.5%	131.54	140.24	120.26	108.44	91.12	**118.32[cd]**	140.64	143.61	125.30	124.74	93.61	**125.58[cd]**
Bee wax	5%	131.54	135.56	114.64	110.70	87.33	**115.95[de]**	140.64	153.95	138.84	102.07	84.53	**124.00[de]**
	10%	131.54	139.88	130.47	122.45	82.31	**121.33[bc]**	140.64	151.47	141.96	131.28	87.95	**130.66[bc]**
	15%	131.54	133.12	113.89	113.89	84.68	**115.98[d]**	140.64	141.55	118.87	114.14	109.74	**124.99[cd]**
Control		131.54	134.56	123.39	90.35	78.24	**111.62[e]**	140.64	140.75	134.10	98.20	80.73	**118.88[e]**
Mean		**131.54[b]**	**138.52[a]**	**124.71[c]**	**112.13[d]**	**89.58[e]**		**140.64[b]**	**147.41[a]**	**134.04[c]**	**121.28[d]**	**95.56[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 4.35 **Days (D)** = 3.07 **D x T** = 9.72						**Treatment (T)** = 5.75 **Days (D)** = 4.07 **D x T** = 12.87					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 5a: Effect of different edible coatings and storage interval on the protein (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Protein (mg/100g)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	136.09	145.39	130.79	111.87	88.35	**122.50**[cd]
	1.5%	136.09	138.79	134.33	131.79	99.82	**128.16**[b]
	2%	136.09	149.93	134.33	132.36	106.94	**131.93**[a]
Chitosan	**0.5%**	136.09	140.99	119.46	111.93	98.40	**121.37**[d]
	1%	136.09	147.24	142.61	120.99	92.10	**127.80**[b]
	1.5%	136.09	141.93	122.78	116.59	92.37	**121.95**[d]
Bee Wax	**5%**	136.09	144.75	126.74	106.39	106.39	**119.98**[d]
	10%	136.09	145.67	136.22	126.87	85.13	**125.99**[bc]
	15%	136.09	137.34	117.76	114.02	97.21	**120.48**[d]
Control		136.09	137.66	128.74	94.28	79.49	**115.25**[e]
Mean		**136.09**[b]	**142.97**[a]	**129.37**[c]	**116.71**[d]	**92.57**[e]	
LSD (P≤0.05)		**Treatment (T)** = 3.71 **Days (D)** =2.62 **D x T** = 8.30					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 5: Effect of different edible coatings and storage interval on the protein (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 7: Effect of different edible coatings and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

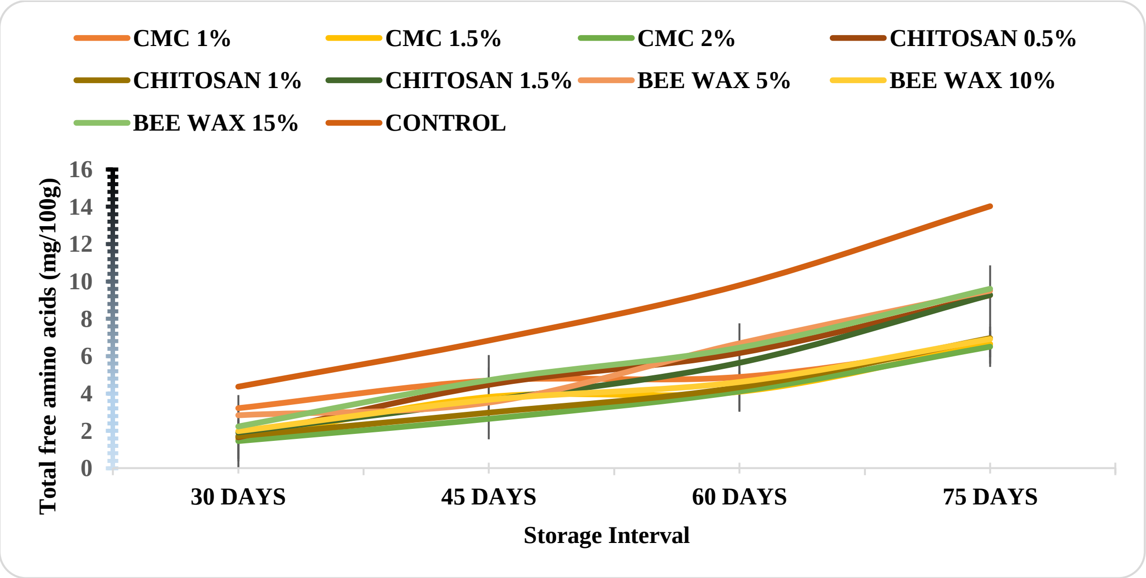
TREATMENT		Total free amino acids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
CMC	1%	81.45	63.20	47.88	68.11	98.77	**71.88^{de}**	86.33	68.46	41.67	70.11	109.00	**75.11^{c}**
	1.5%	81.45	72.20	68.31	75.33	109.21	**81.30^{b}**	86.33	79.28	70.93	82.16	129.34	**89.61^{a}**
	2%	81.45	76.41	70.34	83.49	110.00	**84.34^{a}**	86.33	80.51	79.48	86.38	119.09	**90.36^{a}**
Chitosan	0.5%	81.45	52.28	37.76	78.08	96.63	**69.24^{g}**	86.33	52.90	42.08	89.48	98.23	**73.80^{c}**
	1%	81.45	50.60	44.66	84.07	114.18	**74.99^{c}**	86.33	54.50	41.88	86.11	133.93	**80.55^{b}**
	1.5%	81.45	53.22	41.08	82.22	94.57	**70.51^{ef}**	86.33	57.07	33.79	84.48	108.17	**73.97^{c}**
Bee wax	5%	81.45	56.67	49.83	61.22	87.98	**67.43^{g}**	86.33	56.20	41.17	68.20	95.27	**69.43^{d}**
	10%	81.45	58.96	46.54	84.48	98.77	**73.61^{cd}**	86.33	61.51	49.86	88.34	108.59	**78.92^{b}**
	15%	81.45	56.24	46.56	74.22	82.39	**68.17^{g}**	86.33	60.89	54.60	69.44	95.45	**73.34^{c}**
Control		81.45	42.12	49.98	90.44	72.98	**67.39^{g}**	86.33	44.61	52.08	92.33	68.28	**68.73^{d}**
Mean		**81.45^{b}**	**59.19^{d}**	**50.29^{e}**	**78.17^{c}**	**96.33^{a}**		**86.33^{b}**	**61.59^{d}**	**50.75^{e}**	**81.70^{c}**	**106.53^{a}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 2.28 **Days (D)** = 1.61 **D x T**= 5.11						**Treatment (T)** = 2.71 **Days (D)** = 1.92 **D x T** = 6.06					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 6a: Effect of different edible coatings and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

Total free amino acids (mg/100g)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
CMC	**1%**	83.89	65.83	44.78	69.11	103.88	**73.50^c**
	1.5%	83.89	75.74	69.62	78.75	119.28	**85.45^a**
	2%	83.89	78.46	74.91	84.94	114.54	**87.35^a**
Chitosan	**0.5%**	83.89	52.59	39.92	83.78	97.43	**71.52^{cd}**
	1%	83.89	52.55	43.27	85.09	124.06	**77.77^b**
	1.5%	83.89	55.15	37.44	83.35	101.37	**72.24^{cd}**
Bee Wax	**5%**	83.89	56.44	45.50	64.71	91.63	**68.43^e**
	10%	83.89	60.23	48.20	86.41	102.61	**76.27^b**
	15%	83.89	58.56	50.58	71.83	88.92	**70.76^d**
Control		83.89	43.36	51.03	91.39	70.63	**68.06^e**
Mean		83.89^b	**59.89^d**	**50.52^e**	**79.93^c**	**101.43^a**	
LSD (P≤0.05)		**Treatment (T)** = 2.23 **Days (D)** = 1.58 **D x T** = 4.99					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 6: Effect of different edible coatings and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

Table 7: Effect of different anti-senescence compounds and storage interval on the titratable acidity (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

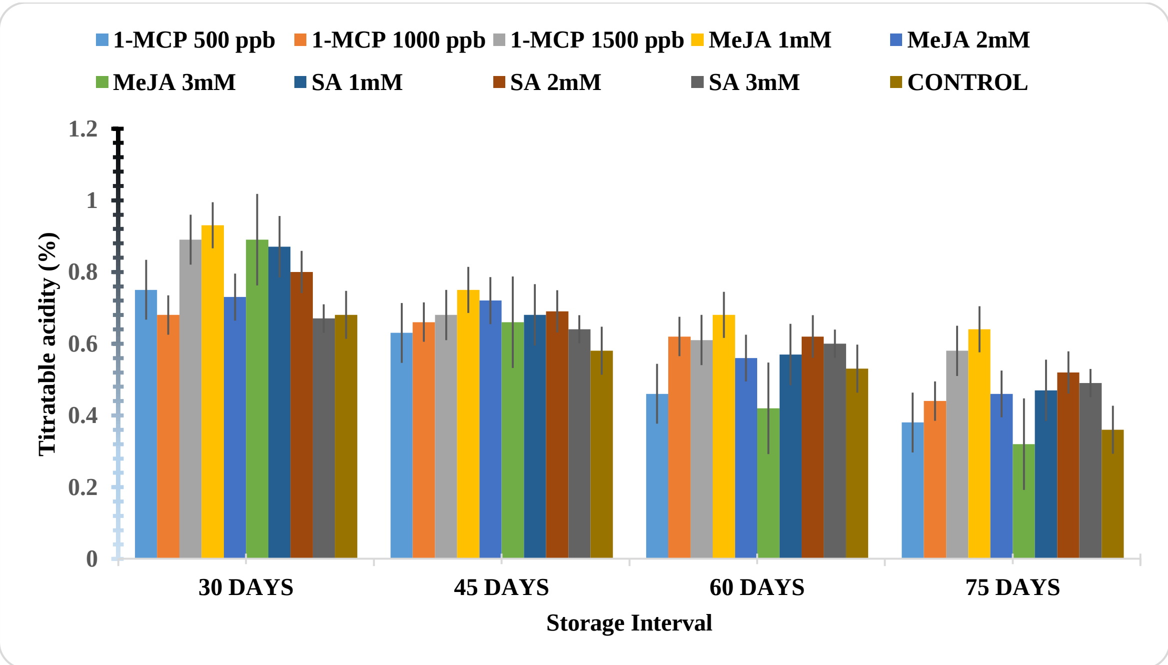
TREATMENT		STORAGE INTERVAL (Days)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	0.780	0.530	0.430	0.347	0.337	**0.482**^{e}	1.330	0.980	0.846	0.576	0.430	**0.832**^{f}
	1000 ppb	0.780	0.510	0.480	0.460	0.373	**0.520**^{d}	1.330	0.863	0.843	0.786	0.520	**0.868**^{de}
	1500 ppb	0.780	0.680	0.530	0.500	0.460	**0.590**^{a}	1.330	1.106	0.836	0.720	0.700	**0.938**^{b}
Methyl Jasmonates	**1 mM**	0.780	0.627	0.570	0.516	0.510	**0.600**^{a}	1.330	1.246	0.930	0.840	0.770	**1.023**^{a}
	2 mM	0.780	0.566	0.540	0.463	0.386	**0.547**^{c}	1.330	0.910	0.910	0.666	0.550	**0.873**^{de}
	3 mM	0.780	0.600	0.530	0.350	0.280	**0.508**^{d}	1.330	1.180	0.800	0.506	0.370	**0.837**^{f}
Salicylic acid	**1mM**	0.780	0.580	0.576	0.540	0.366	**0.568**^{b}	1.330	1.160	0.800	0.600	0.596	**0.897**^{cd}
	2mM	0.780	0.740	0.530	0.456	0.346	**0.570**^{b}	1.330	0.863	0.850	0.790	0.700	**0.906**^{c}
	3mM	0.780	0.510	0.490	0.430	0.396	**0.521**^{d}	1.330	0.843	0.800	0.773	0.590	**0.867**^{e}
Control		0.780	0.440	0.440	0.346	0.323	**0.466**^{f}	1.330	0.930	0.720	0.720	0.400	**0.820**^{f}
Mean		**0.780**^{a}	**0.578**^{b}	**0.510**^{c}	**0.441**^{d}	**0.377**^{e}		**1.330**^{a}	**1.008**^{b}	**0.833**^{c}	**0.697**^{d}	**0.563**^{e}	
LSD (P≤0.05)		**Treatment (T) =** 0.016 **Days (D) =** 0.011 **D x T =** 0.036						**Treatment (T) =** 0.029 **Days (D) =** 0.021 **D x T =** 0.066					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 7a: Effect of different anti-senescence compounds and storage interval on the titratable acidity (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Titratable acidity (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	1.05	0.75	0.63	0.46	0.38	**0.66[g]**
	1000 ppb	1.05	0.68	0.66	0.62	0.44	**0.69[e]**
	1500 ppb	1.05	0.89	0.68	0.61	0.58	**0.76[b]**
Methyl Jasmonates	**1mM**	1.05	0.93	0.75	0.68	0.64	**0.81[a]**
	2mM	1.05	0.73	0.72	0.56	0.46	**0.71[d]**
	3mM	1.05	0.89	0.66	0.42	0.32	**0.67[f]**
Salicylic acid	**1mM**	1.05	0.87	0.68	0.57	0.47	**0.73[c]**
	2mM	1.05	0.80	0.69	0.62	0.52	**0.74[c]**
	3mM	1.05	0.67	0.64	0.60	0.49	**0.69[e]**
Control		1.05	0.68	0.58	0.53	0.36	**0.64[h]**
Mean		**1.05[a]**	**0.79[b]**	**0.67[c]**	**0.57[d]**	**0.47[e]**	
LSD (P≤0.05)		**Treatment (T)** =0.014 **Days (D)** = 0.00096 **D x T** = 0.030					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 7: Effect of different anti-senescence compounds and storage interval on the titratable acidity (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 8: Effect of different anti-senescence compounds and storage interval on the non reducing sugars (%) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

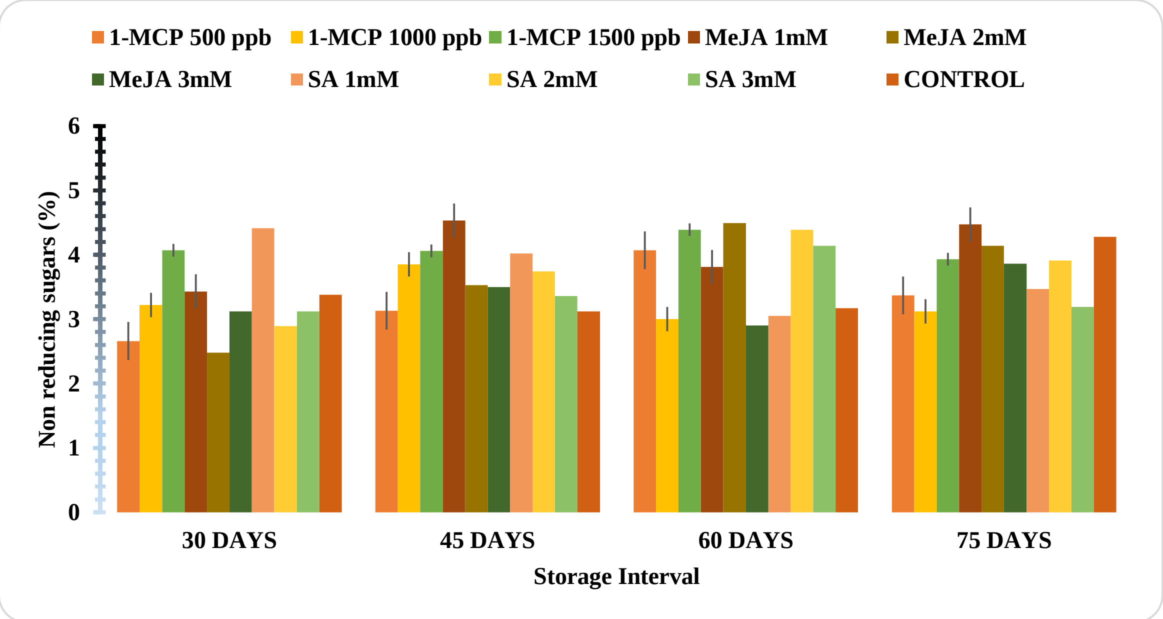
TREATMENT		Non reducing sugars (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	2.41	2.69	3.51	4.42	4.09	**3.42^{cde}**	2.83	2.64	2.76	3.73	2.66	**2.92^{e}**
	1000 ppb	2.41	2.95	3.62	4.01	3.95	**3.39^{de}**	2.83	3.49	4.08	1.99	2.29	**2.94^{e}**
	1500 ppb	2.41	3.84	3.90	4.86	3.83	**3.77^{a}**	2.83	4.30	4.22	3.93	4.03	**3.86^{a}**
Methyl Jasmonates	**1 mM**	2.41	2.97	3.48	4.77	4.46	**3.62^{b}**	2.83	3.89	5.59	2.85	4.48	**3.93^{a}**
	2 mM	2.41	2.54	3.18	4.62	4.03	**3.35^{e}**	2.83	2.42	3.89	4.36	4.26	**3.29^{c}**
	3 mM	2.41	3.10	3.68	3.79	4.30	**3.46^{cd}**	2.83	3.15	3.32	2.02	3.42	**2.95^{e}**
Salicylic acid	**1mM**	2.41	3.54	3.57	3.94	3.98	**3.49^{c}**	2.83	5.28	4.48	2.17	2.97	**3.55^{b}**
	2mM	2.41	2.86	3.50	5.07	3.70	**3.51^{c}**	2.83	2.93	3.98	3.71	4.13	**3.52^{b}**
	3mM	2.41	2.47	2.83	4.87	4.33	**3.38^{de}**	2.83	3.78	3.89	3.42	2.05	**3.20^{d}**
Control		2.41	3.72	3.34	3.50	4.28	**3.45^{cd}**	2.83	3.05	2.91	2.85	4.28	**3.18^{d}**
Mean		**2.41^{e}**	**3.07^{d}**	**3.46^{c}**	**4.38^{a}**	**4.09^{b}**		**2.83^{d}**	**3.49^{b}**	**3.78^{a}**	**3.10^{c}**	**3.46^{b}**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 0.093 **Days (D) =** 0.066 **D x T =** 0.21						**Treatment (T) =** 0.092 **Days (D) =** 0.065 **D x T =** 0.20					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 8a: Effect of different anti-senescence compounds and storage interval on the non reducing sugars per cent of Kinnow fruits stored at 5-7°C and 90-95% RH

Non reducing sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	2.62	2.66	3.13	4.07	3.37	**3.17**^{b}
	1000 ppb	2.62	3.22	3.85	3.00	3.12	**3.16**^{b}
	1500 ppb	2.62	4.07	4.06	4.39	3.93	**3.81**^{a}
Methyl Jasmonates	**1mM**	2.62	3.43	4.53	3.81	4.47	**3.77**^{ab}
	2mM	2.62	2.48	3.53	4.49	4.14	**3.45**^{ab}
	3mM	2.62	3.12	3.50	2.90	3.86	**3.20**^{ab}
Salicylic acid	**1mM**	2.62	4.41	4.02	3.05	3.47	**3.51**^{ab}
	2mM	2.62	2.89	3.74	4.39	3.91	**3.51**^{ab}
	3mM	2.62	3.12	3.36	4.14	3.19	**3.29**^{ab}
Control		2.62	3.38	3.12	3.17	4.28	**3.32**^{ab}
Mean		**2.62**^{c}	**3.28**^{b}	**3.69**^{ab}	**3.74**^{a}	**3.78**^{a}	
LSD ($P \leq 0.05$)		**Treatment (T)** =0.63 **Days (D)** =0.44 **D x T** =1.40					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 8: Effect of different anti-senescence compounds and storage interval on the non reducing sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 9: Effect of different anti-senescence compounds and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

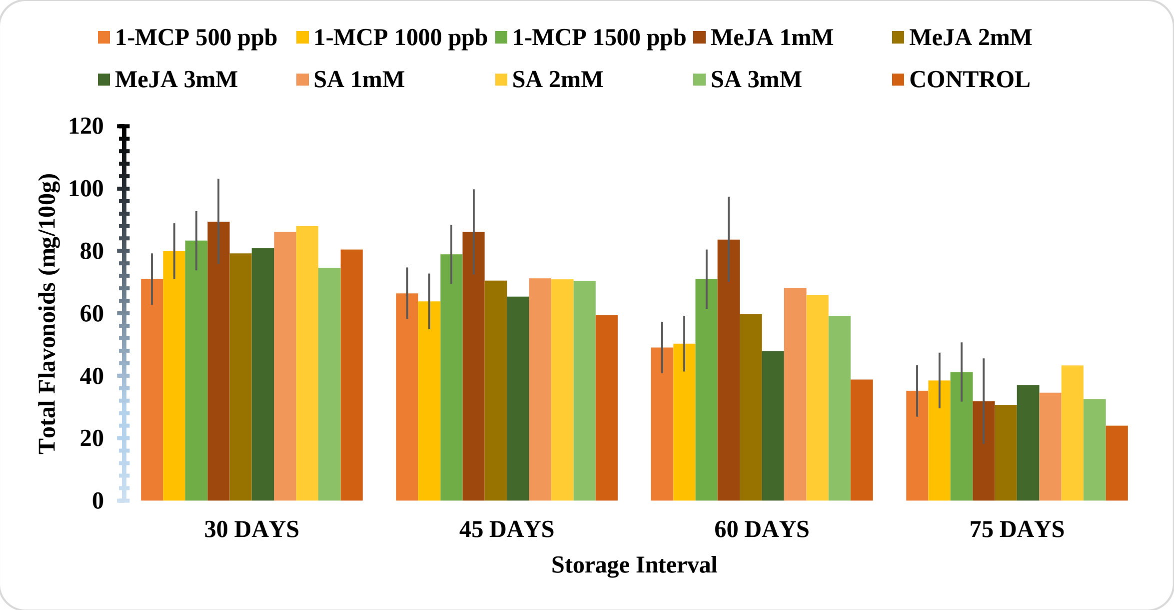
TREATMENT		Total flavonoids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	55.40	70.29	64.30	47.20	35.56	**54.55^{d}**	60.50	71.70	68.58	50.90	34.82	**57.30^{fg}**
	1000 ppb	55.40	74.14	62.37	50.22	41.18	**56.66^{c}**	60.50	85.72	65.27	50.45	35.89	**59.56^{ef}**
	1500 ppb	55.40	81.34	74.90	66.56	42.28	**64.10^{b}**	60.50	85.27	82.86	75.45	40.09	**68.83^{b}**
Methyl Jasmonates	1mM	55.40	87.78	83.44	80.66	33.49	**68.15^{a}**	60.50	91.07	88.75	86.70	30.27	**71.46^{a}**
	2mM	55.40	78.66	67.35	51.38	32.88	**57.13^{c}**	60.50	79.83	73.66	68.12	28.48	**62.12^{d}**
	3mM	55.40	82.74	61.40	47.00	36.19	**56.55^{cd}**	60.50	79.11	69.37	48.93	38.04	**59.19^{efg}**
Salicylic acid	1mM	55.40	83.46	69.77	65.54	36.17	**62.07^{b}**	60.50	88.66	72.68	70.80	33.12	**65.15^{c}**
	2mM	55.40	86.60	68.00	61.87	44.85	**63.34^{b}**	60.50	89.20	73.84	70.00	41.79	**67.06^{bc}**
	3mM	55.40	74.81	70.00	53.88	31.40	**57.10^{c}**	60.50	74.37	70.80	64.65	33.75	**60.81^{de}**
Control		55.40	70.40	52.40	36.78	21.45	**47.29^{e}**	60.50	90.45	66.40	40.91	26.65	**56.98^{g}**
Mean		**55.40^{e}**	**79.02^{a}**	**67.39^{b}**	**56.11^{c}**	**35.54^{d}**		**60.50^{d}**	**83.54^{a}**	**73.22^{b}**	**62.69^{c}**	**34.29^{e}**	
LSD ($P\leq0.05$)		**Treatment (T) =** 2.08 **Days (D) =** 1.47 **D x T =** 4.65						**Treatment (T) =** 2.28 **Days (D) =** 1.61 **D x T =** 5.11					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 9a: Effect of different anti-senescence compounds and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total flavonoids (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	57.95	70.99	66.44	49.05	35.19	**55.92^{g}**
	1000 ppb	57.95	79.93	63.82	50.33	38.53	**58.11^{f}**
	1500 ppb	57.95	83.30	78.88	71.00	41.18	**66.46^{b}**
Methyl Jasmonates	**1mM**	57.95	89.42	86.09	83.68	31.88	**69.81^{a}**
	2mM	57.95	79.24	70.50	59.75	30.68	**59.63^{e}**
	3mM	57.95	80.92	65.38	47.96	37.11	**57.87^{f}**
Salicylic acid	**1mM**	57.95	86.06	71.22	68.17	34.64	**63.61^{d}**
	2mM	57.95	87.90	70.92	65.93	43.32	**65.20^{c}**
	3mM	57.95	74.59	70.40	59.26	32.57	**58.96^{ef}**
Control		57.95	80.42	59.40	38.84	24.05	**52.13^{h}**
Mean		**57.95^{d}**	**81.28^{a}**	**70.31^{b}**	**59.40^{c}**	**34.92^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 1.21 **Days (D)** = 0.86 **D x T** = 2.72					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 9: Effect of different anti-senescence compounds and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 10: Effect of different anti-senescence compounds and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

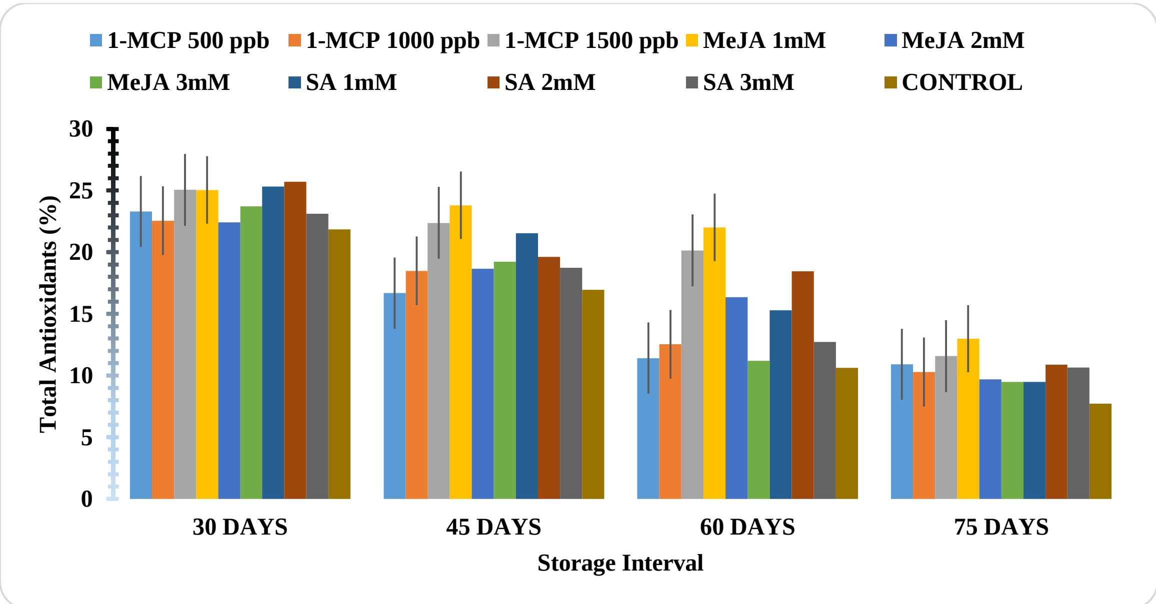
TREATMENT		Total antioxidants (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	24.78	23.00	15.88	12.00	11.15	**17.36[fg]**	28.43	23.60	17.48	10.83	10.67	**18.20[f]**
	1000 ppb	24.78	23.19	16.11	12.33	12.20	**17.72[f]**	28.43	21.94	20.88	12.74	8.38	**18.47[ef]**
	1500 ppb	24.78	23.96	20.55	18.72	12.70	**20.14[b]**	28.43	26.17	24.21	21.56	10.44	**22.16[b]**
Methyl Jasmonates	1mM	24.78	23.30	21.88	20.77	13.60	**20.87[a]**	28.43	26.81	25.72	23.25	12.37	**23.31[a]**
	2mM	24.78	21.15	19.20	16.69	10.80	**18.52[de]**	28.43	23.71	18.15	16.04	8.60	**18.99[e]**
	3mM	24.78	23.66	18.39	11.40	10.30	**17.71[f]**	28.43	23.77	20.10	10.98	8.64	**18.38[f]**
Salicylic acid	1mM	24.78	23.40	20.48	15.70	10.55	**18.98[cd]**	28.43	27.27	22.61	14.87	8.44	**20.32[d]**
	2mM	24.78	23.28	20.68	18.60	10.56	**19.58[bc]**	28.43	28.16	18.54	18.28	11.20	**20.92[c]**
	3mM	24.78	22.55	18.67	13.44	10.45	**17.98[ef]**	28.43	23.68	18.82	10.84	10.84	**18.76[ef]**
Control		24.78	22.33	17.65	11.27	8.76	**16.96[g]**	28.43	21.35	16.23	10.00	6.70	**16.54[g]**
Mean		**24.78[a]**	**22.98[b]**	**18.95[c]**	**15.09[d]**	**11.11[e]**		**28.43[a]**	**24.64[b]**	**20.27[c]**	**15.06[d]**	**9.63[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 0.72 **Days (D)** = 0.51 **D x T** = 1.60						**Treatment (T)** = 0.58 **Days (D)** = 0.41 **D x T** = 1.29					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 10a: Effect of different anti-senescence compounds and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total antioxidants (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	26.60	23.30	16.68	11.41	10.91	**17.78^{g}**
	1000 ppb	26.60	22.56	18.49	12.53	10.29	**18.10^{fg}**
	1500 ppb	26.60	25.06	22.38	20.14	11.57	**21.15^{ab}**
Methyl Jasmonates	**1mM**	26.60	25.05	23.80	22.01	12.98	**22.09^{a}**
	2mM	26.60	22.43	18.67	16.36	9.70	**18.75^{e}**
	3mM	26.60	23.71	19.24	11.19	9.47	**18.04^{fg}**
Salicylic acid	**1mM**	26.60	25.33	21.54	15.28	9.49	**19.65^{d}**
	2mM	26.60	25.72	19.61	18.44	10.88	**20.25^{c}**
	3mM	26.60	23.11	18.74	12.73	10.64	**18.37^{ef}**
Control		26.60	21.84	16.94	10.63	7.73	**16.75^{h}**
Mean		**26.60^{a}**	**23.81^{b}**	**19.61^{c}**	**15.07^{d}**	**10.37^{e}**	
LSD (P≤0.05)		**Treatment (T)** =0.40 **Days (D)** =0.28 **D x T** =0.89					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 10: Effect of different anti-senescence compounds and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 11: Effect of different anti-senescence compounds and storage interval on the protein (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

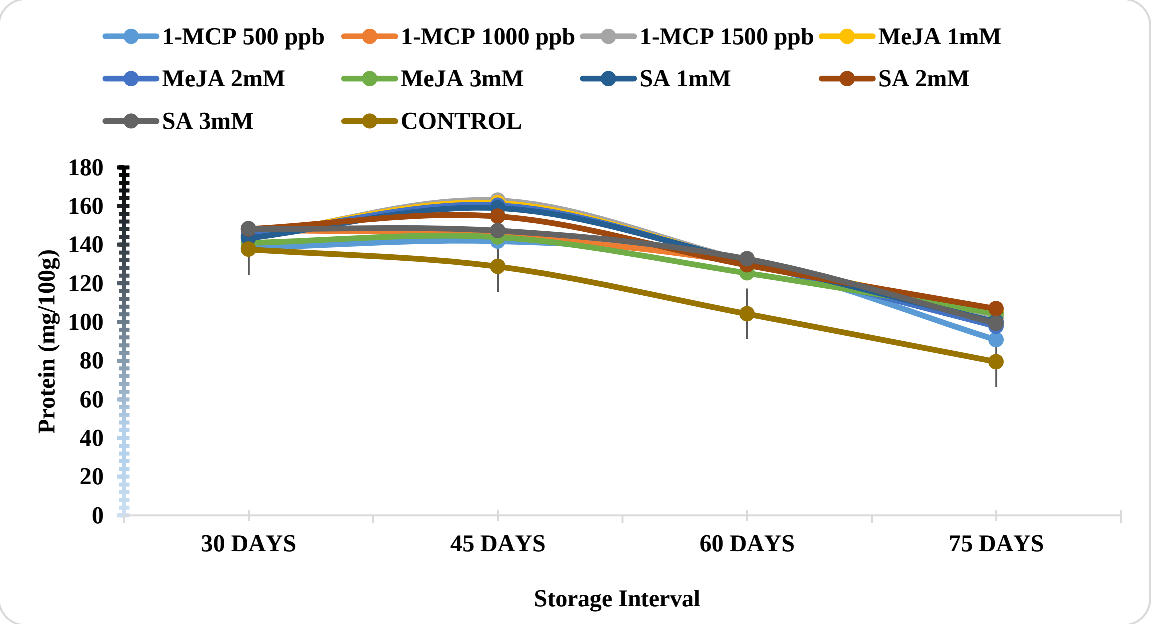
TREATMENT		Protein (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
1-MCP	500 ppb	131.54	135.61	139.71	128.68	92.39	**125.59[c]**	140.64	141.21	144.02	132.52	89.21	**129.52[d]**
	1000 ppb	131.54	148.24	151.34	124.19	93.46	**129.75[ab]**	140.64	147.41	137.93	136.58	111.43	**134.80[bc]**
	1500 ppb	131.54	134.46	157.40	131.18	108.24	**132.56[a]**	140.64	153.61	168.50	132.11	97.45	**138.46[ab]**
Methyl Jasmonates	1 mM	131.54	147.36	160.28	126.33	98.00	**132.70[a]**	140.64	141.99	162.97	136.42	112.38	**138.88[a]**
	2 mM	131.54	138.64	158.41	124.55	101.22	**130.87[a]**	140.64	150.57	162.41	137.03	94.40	**137.01[abc]**
	3 mM	131.54	137.66	140.48	123.40	102.34	**127.08[bc]**	140.64	144.36	147.41	127.33	106.36	**133.22[cd]**
Salicylic acid	1mM	131.54	140.50	154.68	130.55	97.67	**130.99[a]**	140.64	146.39	163.31	132.41	102.41	**137.03[abc]**
	2mM	131.54	143.18	151.23	128.50	104.50	**131.79[a]**	140.64	153.16	158.16	130.49	109.29	**138.35[ab]**
	3mM	131.54	140.11	136.18	134.54	108.78	**130.23[ab]**	140.64	156.28	158.42	130.83	89.89	**135.21[abc]**
Control		131.54	134.56	123.39	90.35	78.24	**111.62[d]**	140.64	140.75	134.10	118.20	80.73	**122.88[e]**
Mean		**131.54[c]**	**140.03[b]**	**147.31[a]**	**124.23[d]**	**98.48[e]**		**140.64[c]**	**147.57[b]**	**140.64[c]**	**131.39[d]**	**99.35[e]**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 3.78 **Days (D) =** 2.67 **D x T =** 8.45						**Treatment (T) =** 4.06 **Days (D) =** 2.87 **D x T =** 9.08					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 11a: Effect of different anti-senescence compounds and storage interval on the protein (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Protein (mg/100g)							
		Storage interval (Days)					
TREATMENTS		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	136.09	138.41	141.86	130.60	90.80	**127.55^{e}**
	1000 ppb	136.09	147.82	144.63	130.38	102.44	**132.28^{cd}**
	1500 ppb	136.09	144.03	162.95	131.64	102.84	**135.51^{a}**
Methyl Jasmonates	**1mM**	136.09	144.67	161.62	131.37	105.19	**135.79^{a}**
	2mM	136.09	144.60	160.41	130.79	97.81	**133.94^{abc}**
	3mM	136.09	141.01	143.94	125.36	104.35	**130.15^{de}**
Salicylic acid	**1mM**	136.09	143.44	158.99	131.48	100.04	**134.01^{abc}**
	2mM	136.09	148.17	154.69	129.49	106.89	**135.07^{ab}**
	3mM	136.09	148.19	147.30	132.68	99.33	**132.72^{bcd}**
Control		136.09	137.65	128.74	104.27	79.48	**117.25^{f}**
Mean		**136.09^{c}**	**143.80^{b}**	**150.52^{a}**	**127.81^{d}**	**98.92e**	
LSD (P≤0.05)		**Treatment (T)** = 2.62 **Days (D)** = 1.85 **D x T** =5.86					

Meanvalues with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 11: Effect of different anti-senescence compounds and storage interval on the protein (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 12: Effect of different anti-senescence compounds and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

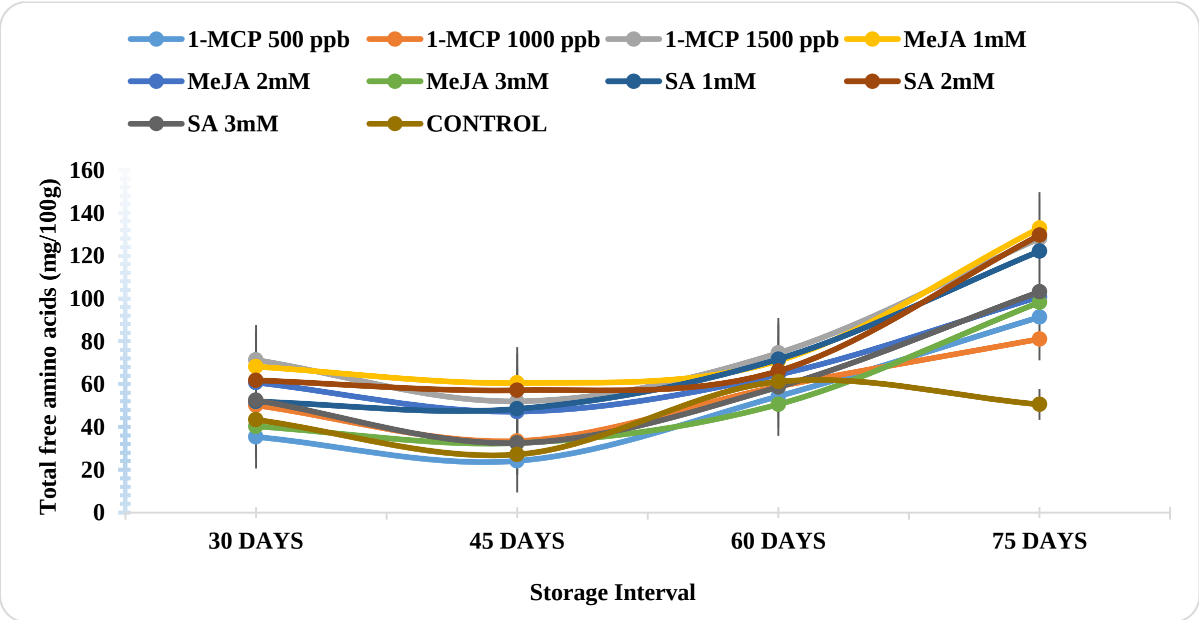
TREATMENT		**Total free amoni acids (mg/100g)**											
		2016-17						**2017-18**					
		Storage interval (Days)						**Storage interval (Days)**					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	81.45	34.44	23.12	52.46	85.88	**55.47^f**	86.33	36.26	25.19	56.20	96.74	**60.14^f**
	1000 ppb	81.45	49.86	20.38	51.21	93.23	**59.23^e**	86.33	50.33	46.46	66.60	68.92	**63.73^e**
	1500 ppb	81.45	70.48	52.34	76.56	125.56	**81.28^a**	86.33	72.12	51.62	72.53	130.53	**82.62^{ab}**
Methyl Jasmonates	**1 mM**	81.45	67.36	59.44	71.23	128.89	**81.67^a**	86.33	68.98	61.61	70.57	136.90	**84.88^a**
	2 mM	81.45	58.74	45.50	65.22	102.31	**70.64^d**	86.33	62.79	48.83	63.67	99.31	**72.19^d**
	3 mM	81.45	41.18	31.20	48.76	90.65	**58.65^e**	86.33	39.35	33.79	52.34	105.76	**63.51^e**
Salicylic acid	**1mM**	81.45	52.31	47.74	71.11	120.00	**74.52^c**	86.33	51.41	49.15	72.27	124.25	**76.68^c**
	2mM	81.45	60.28	56.42	65.57	126.66	**78.08^b**	86.33	63.36	57.85	66.71	132.44	**81.34^b**
	3mM	81.45	52.33	47.61	63.31	96.52	**68.24^d**	86.33	52.64	17.36	53.99	109.77	**64.02^e**
Control		81.45	42.12	26.00	60.00	48.98	**51.71^g**	86.33	44.61	28.28	62.33	52.08	**54.73^g**
Mean		**81.45^b**	**52.91^b**	**40.98^e**	**62.54^c**	**101.87^a**		**86.33^b**	**54.18^d**	**42.01^e**	**63.72^c**	**105.67^a**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 2.46 **Days (D)** = 1.74 **D x T** = 5.50						**Treatment (T)** = 2.52 **Days (D)** = 1.78 **D x T** = 5.65					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 12a: Effect of different anti-senescence compounds and storage interval on the free amino acids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total free amino acids (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
1-MCP	**500 ppb**	83.89	35.35	24.15	54.33	91.31	**57.81^{g}**
	1000 ppb	83.89	50.09	33.42	58.90	81.07	**61.48^{f}**
	1500 ppb	83.89	71.30	51.98	74.54	128.04	**81.95^{a}**
Methyl Jasmonates	**1mM**	83.89	68.17	60.52	70.90	132.89	**83.28^{a}**
	2mM	83.89	60.76	47.16	64.44	100.81	**71.41^{d}**
	3mM	83.89	40.26	32.49	50.55	98.20	**61.08^{f}**
Salicylic acid	**1mM**	83.89	51.86	48.44	71.69	122.12	**75.60^{c}**
	2mM	83.89	61.82	57.13	66.14	129.55	**79.71^{b}**
	3mM	83.89	52.48	32.48	58.65	103.14	**66.13^{e}**
Control		83.89	43.36	27.14	61.16	50.53	**53.22^{h}**
Mean		**83.89^{b}**	**53.55^{d}**	**41.49^{e}**	**63.13^{c}**	**103.77^{a}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 1.46 **Days (D)** =1.03**D x T** = 3.27					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 12: Effect of different anti-senescence compounds and storage interval on the free amino acids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 13: Effect of different packaging materials and storage interval on the titratable acidity per cent (%) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

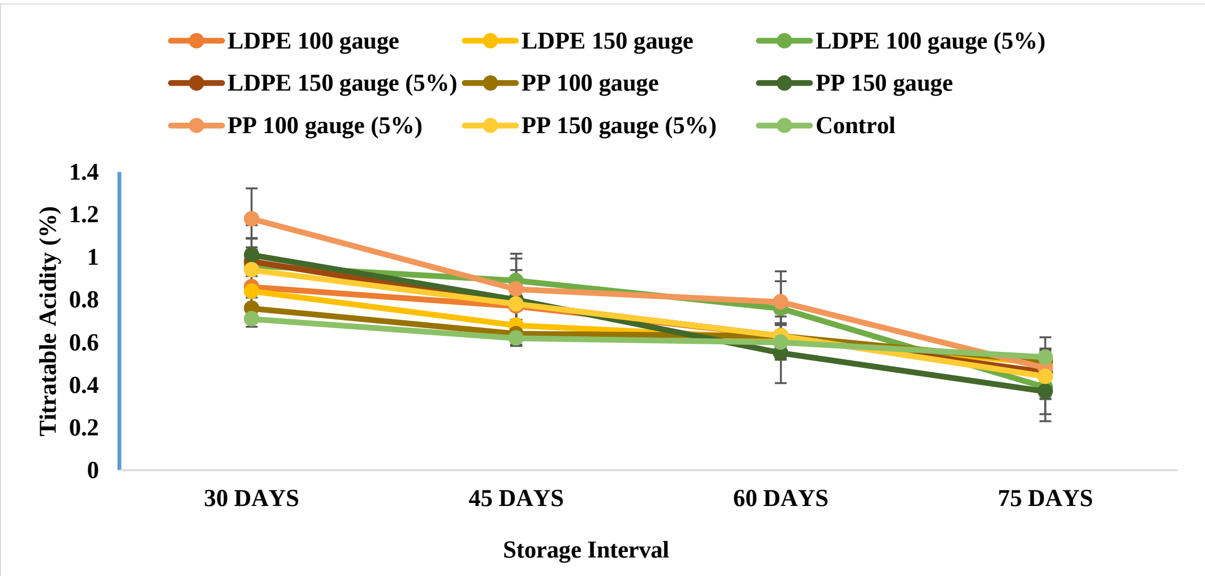
TREATMENT		Titratable acidity (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	1.150	0.810	0.680	0.610	0.490	**0.748^{def}**	1.330	0.910	0.863	0.653	0.400	**0.831^{d}**
	150 gauge	1.150	0.800	0.640	0.600	0.470	**0.732^{ef}**	1.330	0.880	0.720	0.653	0.530	**0.822^{d}**
LDPE (5%Perforated)	**100 gauge**	1.150	0.900	0.860	0.740	0.380	**0.806^{b}**	1.330	1.030	0.930	0.786	0.400	**0.895^{b}**
	150 gauge	1.150	0.880	0.740	0.670	0.430	**0.774^{c}**	1.330	1.093	0.833	0.586	0.490	**0.866^{c}**
PP	**100 gauge**	1.150	0.680	0.650	0.630	0.520	**0.726^{f}**	1.330	0.853	0.636	0.640	0.500	**0.792^{e}**
	150 gauge	1.150	0.850	0.800	0.590	0.380	**0.754^{cde}**	1.330	1.180	0.800	0.506	0.370	**0.837^{d}**
PP (5% Perforated)	**100 gauge**	1.150	1.080	0.840	0.800	0.480	**0.870^{a}**	1.330	1.293	0.863	0.786	0.490	**0.952^{a}**
	150 gauge	1.150	0.950	0.780	0.540	0.420	**0.768^{cd}**	1.330	0.930	0.780	0.720	0.470	**0.846^{cd}**
Control		1.150	0.720	0.576	0.546	0.546	**0.737^{ef}**	1.330	0.700	0.660	0.653	0.530	**0.774^{e}**
Mean		**1.150^{b}**	**0.852^{a}**	**0.745^{c}**	**0.636^{d}**	**0.457^{e}**		**1.330^{a}**	**0.985^{b}**	**0.787^{c}**	**0.665^{d}**	**0.464^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.025 **Days (D)** = 0.019 **D x T** = 0.055						**Treatment (T)** = 0.028 **Days (D)** = 0.021 **D x T** = 0.063					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 13a: Effect of different packaging materials and storage interval on the titratable acidity per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Titratable acidity (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	1.24	0.86	0.77	0.63	0.44	**0.79[ef]**
	150 gauge	1.24	0.84	0.68	0.62	0.50	**0.78[f]**
LDPE (5% perforation)	**100 gauge**	1.24	0.96	0.89	0.76	0.39	**0.85[b]**
	150 gauge	1.24	0.98	0.78	0.63	0.46	**0.82[c]**
PP	**100 gauge**	1.24	0.76	0.64	0.63	0.51	**0.76[g]**
	150 gauge	1.24	1.01	0.80	0.55	0.37	**0.80[de]**
PP (5% perforation)	**100 gauge**	1.24	1.18	0.85	0.79	0.48	**0.91[a]**
	150 gauge	1.24	0.94	0.78	0.63	0.44	**0.81[cd]**
Control		1.24	0.71	0.62	0.60	0.53	**0.74[h]**
Mean		**1.24[a]**	**0.92[b]**	**0.76[c]**	**0.65[d]**	**0.46[e]**	
LSD (P≤0.05)		**Treatment (T)** =0.017 **Days (D)** =0.013 **D x T** = 0.038					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 13: Effect of different packaging materials and storage interval on the titratable acidity per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 14: Effect of different packaging materials and storage interval on the non reducing sugar per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

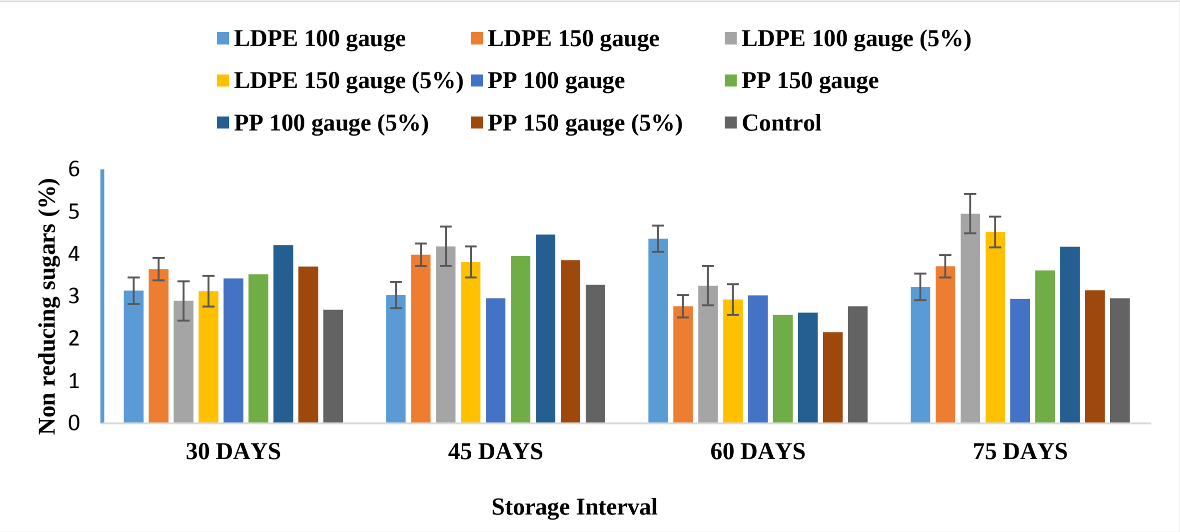
TREATMENT		**Non reducing sugars (%)**											
		2016-17						**2017-18**					
		Storage interval (Days)						**Storage interval (Days)**					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	3.23	3.03	3.02	4.51	3.07	**3.37^{cd}**	2.87	3.24	3.04	4.22	3.37	**3.35^{c}**
	150 gauge	3.23	3.39	3.97	2.82	4.03	**3.49^{bc}**	2.87	3.89	3.99	2.70	3.39	**3.37^{c}**
LDPE (5%Perforated)	**100 gauge**	3.23	2.85	4.17	3.57	4.55	**3.67^{a}**	2.87	2.93	2.93	2.94	5.35	**3.66^{a}**
	150 gauge	3.23	3.13	4.02	2.47	4.58	**3.49^{bc}**	2.87	3.11	3.60	3.37	4.47	**3.48^{b}**
PP	**100 gauge**	3.23	3.38	2.95	3.02	2.97	**3.11^{e}**	2.87	3.46	2.96	3.03	2.92	**3.05^{d}**
	150 gauge	3.23	3.86	4.04	3.01	3.53	**3.53^{b}**	2.87	3.19	3.87	3.43	3.70	**3.41^{bc}**
PP (5% Perforated)	**100 gauge**	3.23	4.27	4.43	2.64	4.19	**3.75^{a}**	2.87	4.15	4.49	2.59	4.15	**3.65^{a}**
	150 gauge	3.23	3.74	3.69	2.55	3.52	**3.35^{d}**	2.87	3.66	4.01	2.11	2.76	**3.08^{d}**
Control		3.23	2.75	3.25	2.73	2.90	**2.97^{f}**	2.87	2.62	3.30	2.80	3.01	**2.92^{e}**
Mean		**3.23^{c}**	**3.37^{b}**	**3.72^{a}**	**3.03^{d}**	**3.70^{a}**		**2.87^{d}**	**3.36^{b}**	**3.72^{a}**	**3.02^{c}**	**3.68^{a}**	
LSD (P≤0.05)		**Treatment (T)** = 0.11 **Days (D)** = 0.086 **D x T** = 0.26						**Treatment (T)** = 0.11 **Days (D)** = 0.084 **D x T** = 0.25					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 14a: Effect of different packaging materials and storage interval on the non reducing sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Non reducing sugars (%)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	3.05	3.13	3.03	4.36	3.22	**3.36[c]**
	150 gauge	3.05	3.64	3.98	2.76	3.71	**3.43[b]**
LDPE (5% perforation)	**100 gauge**	3.05	2.89	4.18	3.25	4.95	**3.67[a]**
	150 gauge	3.05	3.12	3.81	2.92	4.52	**3.48[b]**
PP	**100 gauge**	3.05	3.42	2.95	3.02	2.94	**3.08[e]**
	150 gauge	3.05	3.52	3.95	2.56	3.61	**3.34[c]**
PP (5% perforation)	**100 gauge**	3.05	4.21	4.46	2.61	4.17	**3.70[a]**
	150 gauge	3.05	3.70	3.85	2.15	3.14	**3.18[d]**
Control		3.05	2.68	3.27	2.76	2.95	**2.95[f]**
Mean		**3.05[c]**	**3.37[b]**	**3.72[a]**	**2.93[d]**	**3.69[a]**	
LSD (P≤0.05)		**Treatment (T)** =0.067 **Days (D)** =0.050 **D x T** = 0.15					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 14: Effect of different packaging materials and storage interval on the non reducing sugars per cent in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 15: Effect of packaging materials and storage interval on the total flavanoids content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

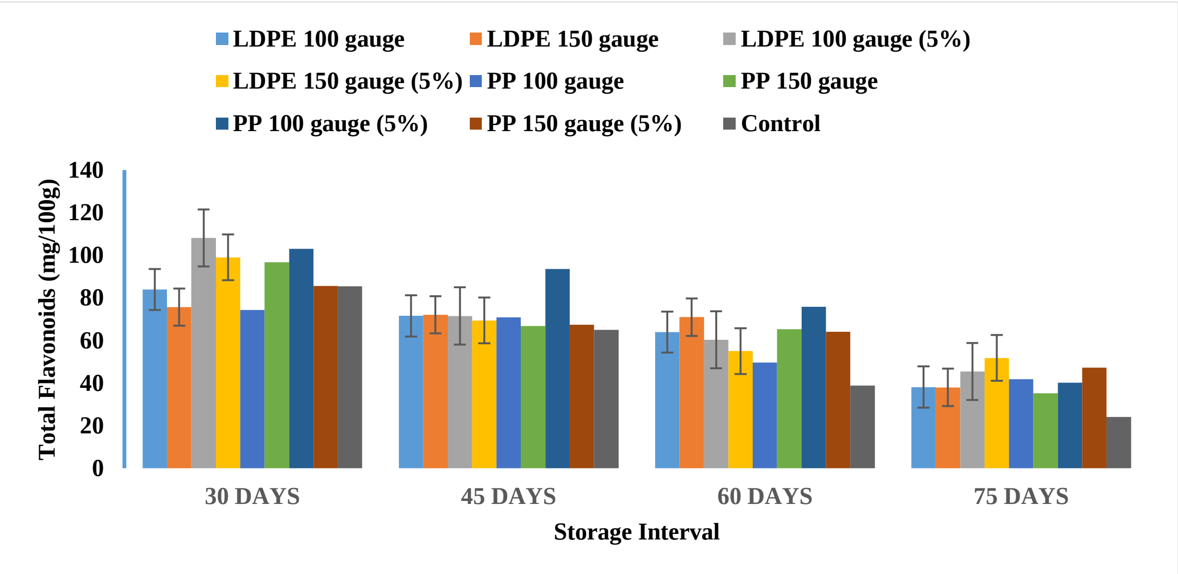
TREATMENT		Total flavonoids (mg/100g))											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	55.40	81.46	70.35	60.22	40.24	**61.53^{d}**	60.50	86.34	72.68	67.59	35.89	**64.60^{de}**
	150 gauge	55.40	74.28	70.56	69.44	37.00	**61.34^{d}**	60.50	76.97	73.48	72.41	38.93	**64.46^{e}**
LDPE (5%Perforated)	**100 gauge**	55.40	104.20	70.66	58.16	46.45	**66.97^{b}**	60.50	112.06	72.32	62.41	44.29	**70.31^{b}**
	150 gauge	55.40	94.16	67.44	52.60	50.80	**64.08^{c}**	60.50	103.84	71.25	57.32	52.77	**69.14^{b}**
PP	**100 gauge**	55.40	73.11	69.58	48.23	41.88	**57.64^{e}**	60.50	75.36	72.05	50.98	41.79	**60.13^{f}**
	150 gauge	55.40	92.40	66.00	63.58	33.49	**62.17^{d}**	60.50	100.81	67.59	66.97	36.87	**66.55^{cd}**
PP (5% Perforated)	**100 gauge**	55.40	97.40	88.66	76.20	38.78	**71.29^{a}**	60.50	108.48	98.31	75.27	41.52	**76.81^{a}**
	150 gauge	55.40	81.22	66.45	62.12	46.30	**62.30^{cd}**	60.50	90.00	68.30	65.98	48.24	**69.14^{b}**
Control		55.40	80.40	63.46	36.78	21.45	**51.50^{f}**	60.50	90.45	66.40	40.91	26.65	**66.60^{c}**
Mean		**55.40^{d}**	**86.51^{a}**	**70.35^{b}**	**58.59^{c}**	**39.60^{e}**		**60.50^{e}**	**93.81^{a}**	**73.60^{b}**	**62.20^{c}**	**40.77^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 1.84 **Days (D)** = 1.37 **D x T** = 4.12						**Treatment (T)** = 1.97 **Days (D)** = 1.47 **D x T** = 4.41					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 15a: Effect of different packaging materials and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total flavonoids (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	57.95	83.90	71.51	63.90	38.06	**63.07[de]**
	150 gauge	57.95	75.62	72.02	70.92	37.96	**62.90[e]**
LDPE (5% perforation)	**100 gauge**	57.95	108.13	71.49	60.28	45.37	**68.64[b]**
	150 gauge	57.95	99.00	69.34	54.96	51.78	**66.61[c]**
PP	**100 gauge**	57.95	74.23	70.81	49.60	41.83	**58.89[f]**
	150 gauge	57.95	96.60	66.79	65.27	35.18	**64.36[d]**
PP (5% perforation)	**100 gauge**	57.95	102.94	93.48	75.73	40.15	**74.05[a]**
	150 gauge	57.95	85.61	67.37	64.05	47.27	**64.45[d]**
Control		57.95	85.42	64.93	38.84	24.05	**54.24[g]**
Mean		**57.95[d]**	**90.16[a]**	**71.97[b]**	**60.40[c]**	**40.19[e]**	
LSD ($P \leq 0.05$)		**Treatment (T) =** 1.39 **Days (D) =** 1.03 **D x T =** 3.10					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 15: Effect of different packaging materials and storage interval on the total flavonoids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 16: Effect of different packaging materials and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7°C and 90-95% RH

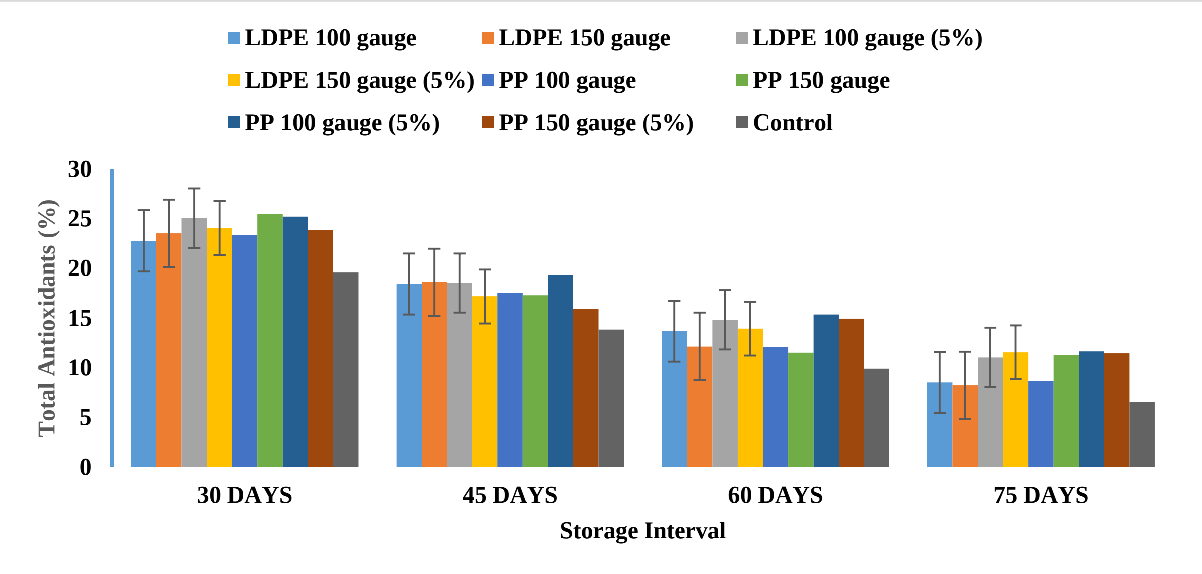
TREATMENT		Total antioxidants (%)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	24.78	23.54	16.00	12.40	8.60	**17.06^{cde}**	28.43	21.99	20.82	14.92	8.42	**18.92^{d}**
	150 gauge	24.78	20.86	18.62	12.38	7.80	**16.89^{de}**	28.43	26.18	18.54	11.89	8.64	**18.73^{d}**
LDPE (5%Perforated)	**100 gauge**	24.78	22.44	17.60	14.60	10.55	**17.99^{ab}**	28.43	27.62	19.43	15.00	11.52	**20.40^{ab}**
	150 gauge	24.78	23.60	15.68	12.28	11.24	**17.52^{bc}**	28.43	24.48	18.65	15.57	11.82	**19.79^{bc}**
PP	**100 gauge**	24.78	20.60	17.88	11.64	8.50	**16.68^{e}**	28.43	26.15	17.15	12.51	8.76	**18.60^{d}**
	150 gauge	24.78	23.32	16.30	11.10	10.75	**17.25^{cd}**	28.43	27.60	18.26	11.92	11.81	**19.60^{c}**
PP (5% Perforated)	**100 gauge**	24.78	22.58	18.48	14.80	11.20	**18.37^{a}**	28.43	27.79	20.15	15.90	12.06	**20.92^{a}**
	150 gauge	24.78	19.72	16.50	15.12	10.80	**17.38^{cd}**	28.43	27.98	15.31	14.75	12.06	**19.70^{c}**
Control		24.78	17.84	11.40	9.80	6.30	**14.02^{f}**	28.43	21.35	16.23	10.00	6.70	**16.54^{e}**
Mean		**24.78^{a}**	**21.61^{b}**	**16.50^{c}**	**12.68^{d}**	**9.53^{e}**		**28.43^{a}**	**25.68^{b}**	**18.28^{c}**	**13.61^{d}**	**10.23^{e}**	
LSD (P≤0.05)		**Treatment (T)** = 0.55 **Days (D)** = 0.41 **D x T** = 1.22						**Treatment (T)** = 0.62 **Days (D)** = 0.46 **D x T** = 1.40					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 16a: Effect of different packaging materials and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	26.60	22.76	18.41	13.66	8.51	**17.99^{d}**
	150 gauge	26.60	23.52	18.58	12.13	8.22	**17.81^{de}**
LDPE (5% perforation)	**100 gauge**	26.60	25.03	18.51	14.80	11.03	**19.20^{b}**
	150 gauge	26.60	24.04	17.16	13.92	11.53	**18.65^{c}**
PP	**100 gauge**	26.60	23.37	17.51	12.07	8.63	**17.64^{e}**
	150 gauge	26.60	25.46	17.28	11.51	11.28	**18.43^{c}**
PP (5% perforation)	**100 gauge**	26.60	25.18	19.31	15.35	11.63	**19.62^{a}**
	150 gauge	26.60	23.85	15.90	14.93	11.43	**18.54^{c}**
Control		26.60	19.59	13.81	9.90	6.50	**15.28^{f}**
Mean		**26.60^{a}**	**23.65^{b}**	**17.39^{c}**	**13.14^{d}**	**9.86^{e}**	
LSD (**P≤0.05**)		**Treatment (T)** =0.33 **Days (D)** = 0.24 **D x T** = 0.73					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig.16: Effect of different packaging materials and storage interval on the total antioxidants (%) in Kinnow fruit stored at 5-7^{0}C and 90-95% RH

Table 17: Effect of different packaging materials and storage interval on the protein content (mg/100g) in Kinnow fruit stored at 5-7^{o}C and 90-95% RH

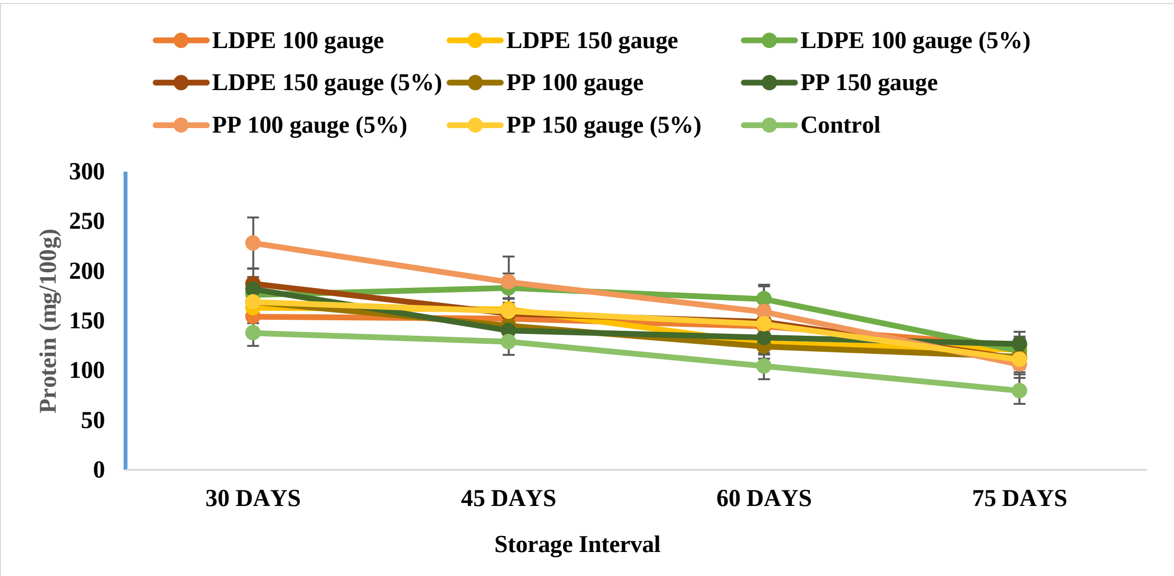
TREATMENT		Protein content (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	**30**	**45**	**60**	**75**	**Mean**	**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 guage**	131.54	155.38	152.68	140.00	121.09	**140.14^{d}**	140.64	152.82	151.35	148.42	128.35	**144.32^{de}**
	150 gauge	131.54	161.29	159.22	125.87	119.77	**139.54^{de}**	140.64	164.55	163.87	128.35	121.92	**143.87^{de}**
LDPE (5%Perforated)	**100 gauge**	131.54	168.76	183.44	168.76	117.88	**156.29^{b}**	140.64	183.27	182.26	174.92	121.13	**160.44^{b}**
	150 gauge	131.54	186.34	154.23	148.22	110.32	**146.13^{c}**	140.64	188.01	159.92	149.55	113.01	**150.23^{c}**
PP	**100 gauge**	131.54	166.44	142.12	122.89	112.81	**135.16^{e}**	140.64	170.98	147.97	125.19	114.59	**139.87^{e}**
	150 gauge	131.54	180.18	138.22	130.20	124.56	**140.94^{d}**	140.64	182.93	141.88	135.79	128.46	**145.94^{cd}**
PP (5% Perforated)	**100 gauge**	131.54	224.65	190.19	156.38	104.46	**161.44^{a}**	140.64	231.54	187.44	161.39	107.59	**165.72^{a}**
	150 gauge	131.54	166.67	156.78	144.11	108.34	**141.49^{d}**	140.64	170.86	161.95	149.10	113.46	**147.20^{cd}**
Control		131.54	134.56	123.39	90.35	78.24	**111.62^{f}**	140.64	140.75	134.10	118.20	80.73	**122.88^{f}**
Mean		**131.54^{d}**	**172.81^{a}**	**155.59^{b}**	**136.31^{c}**	**110.83^{e}**		**140.64^{c}**	**176.19^{a}**	**158.97^{b}**	**143.43^{c}**	**114.36^{d}**	
LSD ($P \leq 0.05$)		**Treatment (T)** = 4.46 **Days (D)** = 3.33 **D x T** = 9.98						**Treatment (T)** = 4.98 **Days (D)** = 3.71 **D x T** = 11.14					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 17a: Effect of different packaging materials and storage interval on the protein content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Protein (mg/100g)							
Storage interval (Days)							
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	136.09	154.10	152.01	144.21	124.72	**142.23[d]**
	150 gauge	136.09	162.92	161.54	127.11	120.84	**141.70[d]**
LDPE (5% perforation)	**100 gauge**	136.09	176.01	182.85	171.84	119.50	**157.26[b]**
	150 gauge	136.09	187.17	157.07	148.88	111.66	**148.18[c]**
PP	**100 gauge**	136.09	168.71	145.04	124.04	113.70	**137.52[e]**
	150 gauge	136.09	181.55	140.05	132.99	126.51	**143.44[d]**
PP (5% perforation)	**100 gauge**	136.09	228.09	188.81	158.88	106.02	**163.58[a]**
	150 gauge	136.09	168.76	159.36	146.60	110.90	**144.35[d]**
Control		136.09	137.65	128.74	104.27	79.48	**117.25[f]**
Mean		**136.09[d]**	**173.89[a]**	**157.28[b]**	**139.87[c]**	**112.59[e]**	
LSD ($P \leq 0.05$)		**Treatment (T)** =2.85 **Days (D)** = 2.12 **D x T** = 6.37					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 17: Effect of different packaging materials and storage interval on the protein content (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Table 18: Effect of different packaging materials and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

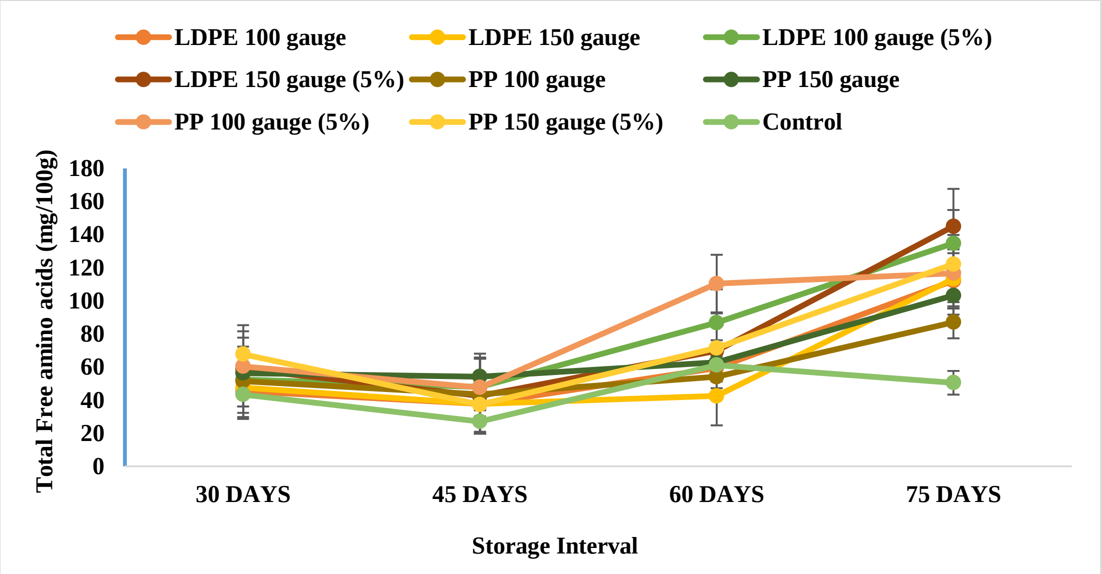
TREATMENT		Total free amino acids (mg/100g)											
		2016-17						2017-18					
		Storage interval (Days)						Storage interval (Days)					
		0	30	45	60	75	Mean	0	30	45	60	75	Mean
LDPE	**100 guage**	81.45	46.48	39.24	60.29	110.31	**67.55^{e}**	86.33	44.45	36.01	58.41	113.79	**67.80^{e}**
	150 gauge	81.45	46.33	38.29	43.31	110.27	**63.93^{f}**	86.33	48.73	37.14	41.62	116.26	**66.02^{ef}**
LDPE (5%Perforated)	**100 gauge**	81.45	53.41	46.84	87.38	133.40	**80.50^{b}**	86.33	51.20	48.94	86.18	135.99	**81.73^{b}**
	150 gauge	81.45	58.14	44.56	70.18	141.28	**79.12^{b}**	86.33	59.50	40.38	69.39	148.61	**80.84^{b}**
PP	**100 gauge**	81.45	50.38	44.21	55.22	84.21	**63.09^{f}**	86.33	52.49	42.60	52.95	89.78	**64.83^{f}**
	150 gauge	81.45	54.31	50.16	64.66	104.02	**70.92^{d}**	86.33	58.21	58.10	60.83	102.40	**73.17^{d}**
PP (5% Perforated)	**100 gauge**	81.45	61.22	48.08	108.78	114.21	**82.75^{a}**	86.33	59.50	47.13	111.93	118.99	**84.78^{a}**
	150 gauge	81.45	68.19	38.11	70.65	119.88	**75.66^{c}**	86.33	67.17	36.52	72.37	124.45	**77.37^{c}**
Control		81.45	42.12	26.00	60.00	48.98	**51.70^{g}**	86.33	44.61	28.28	62.33	52.08	**54.73^{g}**
Mean		**81.45^{b}**	**53.40^{d}**	**41.72^{e}**	**68.94^{c}**	**107.40^{a}**		**86.33^{b}**	**53.98^{d}**	**41.68^{e}**	**68.45^{c}**	**111.37^{a}**	
LSD **($P \leq 0.05$)**		**Treatment (T)** = 2.09 **Days (D)** = 1.56 **D x T** = 4.67						**Treatment (T)** = 2.61 **Days (D)** = 1.94 **D x T** = 5.83					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)

Table 18a: Effect of different packaging materials and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

Total free amino acids (mg/100g)							
		Storage interval (Days)					
TREATMENT		**0**	**30**	**45**	**60**	**75**	**Mean**
LDPE	**100 gauge**	83.89	45.46	37.62	59.35	112.05	**67.68^{e}**
	150 gauge	83.89	47.53	37.71	42.46	113.26	**64.97^{f}**
LDPE (5% perforation)	**100 gauge**	83.89	52.30	47.89	86.78	134.69	**81.11^{b}**
	150 gauge	83.89	58.82	42.47	69.78	144.94	**79.98^{b}**
PP	**100 gauge**	83.89	51.43	43.40	54.08	86.99	**63.96^{f}**
	150 gauge	83.89	56.26	54.13	62.74	103.21	**72.05^{d}**
PP (5% perforation)	**100 gauge**	83.89	60.36	47.60	110.35	116.60	**83.76^{a}**
	150 gauge	83.89	67.68	37.31	71.51	122.16	**76.51^{c}**
Control		83.89	43.36	27.14	61.16	50.53	**53.22^{g}**
Mean		**83.89^{b}**	**53.69^{d}**	**41.70^{e}**	**68.69^{c}**	**109.38^{a}**	
LSD ($P \leq 0.05$)		**Treatment (T)** =1.42 **Days (D)** =1.06 **D x T** = 3.17					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15 fruits/replication)



The vertical bar represents standard error (SE) mean of three replicates

Fig 18: Effect of different packaging materials and storage interval on the total free amino acids (mg/100g) in Kinnow fruit stored at 5-7°C and 90-95% RH

LIST OF SUBMITTED/ PUBLISHED/ ACCEPTED RESEARCH PAPERS

S. No.	Title	Journal	NAAS	Status
1.	Effect of polymeric packaging films to extend the storagelife and quality of Kinnow (*Citrus nobilis* x *Citrus deliciosa*) fruit	Journal of Food Processing and Preservation	6.79	Submitted
2.	Comparative efficacy of packaging films for retaining the bioactive compounds and antioxidants in Kinnow fruits under cold storage	Journal of Food Science and Technology	7.26	Submitted

Gmail

Rakesh Kumar <rakeshcomputers08@gmail.com>

Fwd: JFST-D-18-02824 - Submission Confirmation

arvind baswal <baswal.arvind0@gmail.com> Sat, Dec 22, 2018 at 8:02 PM
To: Rakesh Kumar <rakeshcomputers08@gmail.com>

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Effect of polymeric packaging films to extend the storage-life and quality of Kinnow (Citrus nobilis x Citrus deliciosa) fruit

Journal:	*Journal of Food Processing and Preservation*
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Keywords:	KINNOW, PACKAGING, SHELF-LIFE, POST-HARVEST QUALITY

Effect of polymeric packaging films to extend the storage-life and quality of Kinnow (*Citrus nobilis* x *Citrus deliciosa*) fruit

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Abstract

Freshly-harvested mature Kinnow fruits were packed into different commercially available packaging films viz. low density polyethylene (LDPE) 100 and 150 gauge film with 5% perforation and without perforation and polypropylene (PP) 100 gauge and 150 gauge film with 5% perforation and without perforation. The packed and unpacked fruits were stored under cold storage conditions (5-7^{0}C and 90-95% RH) to study the efficacy of MAP films and storage conditions to enhance the storage-life and quality of Kinnow fruit. Changes in fruit quality attributes were assessed periodically. Fruits packed in perforated PP 100 and perforated LDPE 100 gauge film minimized the loss in spoilage despite maintaining organoleptic sensory attributes, juice content and various physico-chemical attributes like titratable acidity, vitamin C, TSS, sugars, protein and total free amino acids content effectively over unpacked fruits. The data revealed that perforated PP 100 gauge film emerged as best with respect to prolonging and maintaining shelf-life and quality of Kinnow mandarin up to 60 days in contrast to control i.e. 45 days.

Practical application

According to previous investigations done by various workers; Kinnow fruits can be successfully stored up to 45 days by using different modified atmospheric packaging conditions. Results in the present study suggests that shelf-life of the fruits packed in perforated PP 100 and perforated LDPE 100 gauge films can be extended successfully up to 60 days at 5-7^{0}C and 90-95% RH, without much of change in physical and biochemical attributes.

Keywords: Kinnow, Packaging films, Storage conditions and Quality

1 | INTRODUCTION

Kinnow mandarin, a hybrid of King (*Citrus nobilis* L.) and Willow leaf (*Citrus deliciosa* L) leading fruit among citrus fruits grown in India. It is commercially grown in Punjab, Haryana, south western part of Rajasthan, foot hills of Himachal Pradesh and western Uttar Pradesh. Kinnow mandarins are cherished around the globe due to their nutritional value, pleasant flavor and refreshing taste. Due to these quality traits, Kinnow is in high demand not only in Indian markets but also in abroad (Dhatt and Mahajan 2011). In India, Punjab ranks first with respect to area and production under Kinnow mandarin (Anonymous 2018). The Kinnow fruits matures during mid January for commercial harvesting and these months often witness arrival of large number truck loads of Kinnow fruits at major wholesale market of India, which lead to glut and huge post-harvest losses due to inadequate post-harvest facilities. Hence, to enhance the storage-life, introduction of an ideal storage method is required to achieve the goals for better transportation. Modified atmospheric packaging (MAP) is an ideal tool to enhance the post-harvest life of horticultural commodities (Mangaraj and Goswami 2009). In spite of maintaining a desirable high humidity atmosphere around fruits, MAP films delayed the ripening of banana fruits cv. Mas and Sucrier (Tan *et al* 1990 and Romphophak*et al* 2004). However, commercial exploitation of MAP films is yet to be done (Thompson 1998). Information on effectiveness of MAP (PP and LDPE) to extend the post-harvest life of Kinnow mandarin is limited. In the present investigation, effectiveness of perforated and non perforated PP and LDPE films on Kinnow fruit was evaluated under cold storage conditions (5-7^{0}C and 90-95% RH).

2 | MATERIALS AND METHODS

The present investigations was conducted in the Department of Fruit Science and Punjab Horticultural Postharvest Technology Centre, Ludhiana during the consecutive seasons of 2016-17 and 2017-18. In the experiment, uniform sized, quality kinnow fruits were harvested with the help of clipper by retaining a small button of the stalk from uniform and healthy plants selected and maintained under recommended cultural practices at Regional Fruit Research Station, Abohar. The fruits were packed in cushioned crated and transported to the Postharvest laboratory of Department of Fruit Science, PAU, Ludhiana. The fruits were sorted, graded and washed with chlorine solution (100 ppm). Thereafter fruits were packed in commercially available packaging films in the market *i.e* Low density polyethylene 100 and 150 gauge film (Model LD, Sol Pack system) with 5% perforation and without perforation and Polypropylene 100 gauge and 150 gauge (Model PP, Sol Pack Syestem) with 5% perforation and without perforation. Each packaging material was labelled before sealing it with sealing machine and kept inside cold rooms maintained at 5-7^{0}C and 90-95% RH.

2.1 | Evaluation of physical attributes

Spoilage loss was calculated from the number of fruits infected at each storage interval of observation to the number of fruits initially taken. Then per cent of spoilage loss was worked out by the following formula,

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

The overall organoleptic sensory rating of the fruits was done by a panel of ten judges on the basis of external appearance of fruits, texture, taste and flavor and calculated making use of nine-point

Hedonic scale (Amerine *et al* 1965). The fruit Juice was extracted with the help of screw type extractor and was strained through mesh (32 mm) and weighed. The percentage of juice was calculated on fresh weight basis.

$$\text{Juice percentage} = \frac{\text{Juice weight}}{\text{Weight of fruit}} \times 100$$

2.2 | Evaluation of physico-chemical attributes

The total soluble solids (TSS) of the fruit juice were determined using a hand refractometer and expressed as percent TSS after making the temperature correction at 20^0C. The titratable acidity, vitamin C, reducing sugars and total sugars content were determined as per standard procedure (AOAC 2005). Protein content and total free amino acid content was determined with slight modifications as per according to the method given by Lowry *et al* (1951) and Yemm and Cocking (1954), respectively.

3 | Experimental design and statistical analysis

The experiment consisted of 9 treatments and 4 storage intervals i.e. 30, 45, 60 and 75 days. Experiment was laid out in completely randomized block design with three replication for each treatment (n=15) and each storage interval. Data were analyzed for variance by using the SAS (V 9.3, SAS Institute Inc., and Cary, NC, USA) package.

4 | Results and Discussion

4.1 | Spoilage (%)

Fruit decay incidence occurred due to a rise in rotting with an advancement in storage period irrespective of treatments (Table 1). In general, an abrupt loss in spoilage was noticed after 60 days of storage which further increased till end of the storage i.e. 75 days. Among all the packaging films, fruits packed in perforated PP 100 gauge film registered the lowest spoilage (12.49%) after 75 days of storage whereas, the non perforated PP 100 gauge packed fruits resulted the highest incidence of spoilage (91.66%) even higher than that of unpacked fruits; this might be due to accumulation of excessive moisture inside non perforated packaging film because of non permeability of Co_2, O_2 and water through the film (Tijskens and Vollebregt 2003; Soliva and Martin 2003 and Mahajan *et al* 2015). The interaction between packaging films and storage interval was found to be significant. These results are in conformity to the findings of Nath *et al* (2012) who observed a lowest cumulative decay loss in pear fruits packed in perforated PP film in contrast to non perforated film and unpacked. Similar findings were also reported in pear (Kaur *et al* 2013; Geason *et al* 1991 and Sandhu *et al* 2000).

Table 1 Effect of packaging materials and storage intervals on the spoilage per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	0.00 (0.00)	8.33 (2.04)	12.50 (2.50)	33.33 (5.77)	83.33 (9.11)	$3.88^c \pm 0.65$
LDPE 150 gauge	0.00 (0.00)	8.33 (2.04)	12.50 (2.50)	49.99 (6.97)	79.16 (8.87)	$4.07^b \pm 0.68$
LDPE 100 gauge with 5% perforation	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.83 (4.54)	$0.91^g \pm 0.34$
LDPE 150 gauge with 5% perforation	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.33 (1.47)	50.00 (7.07)	$1.71^f \pm 0.52$
PP 100 gauge	0.00 (0.00)	16.66 (4.08)	20.83 (4.54)	33.33 (5.77)	91.66 (9.57)	$4.79^a \pm 0.57$
PP 150 gauge	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	12.50 (2.50)	91.66 (9.57)	$2.41^d \pm 0.72$
PP 100 gauge with 5% perforation	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	12.49 (3.48)	$0.70^h \pm 0.26$
PP 150 gauge with 5% perforation	0.00 (0.00	0.00 (0.00)	0.00 (0.00)	12.49 (3.48)	75.00 (8.66)	$2.43^d \pm 0.63$
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.83 (4.54)	33.33 (5.77)	$2.06^e \pm 0.48$
Mean ±SE	$0.00^d \pm 0.00$	$0.91^d \pm 0.23$	$1.06^c \pm 0.27$	$3.39^b \pm 0.36$	$7.40^a \pm 0.30$	
LSD (P≤0.05)	Treatment (MAP) = 0.059 Days (SI) = 0.043 SI x MAP = 0.13					
F value ((P≤0.05)	Treatment (MAP) = 1136.05 Days (SI) = 10123.28 SI x MAP = 348.12					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Figures in parenthesis are square root transformation values. Each value represents pooled mean of 2 years (2017 and 2018)

4.2 | Organoleptic sensory attributes (Hedonic scale 1-9)

The data on sensory rating of Kinnow fruit influenced by different packaging films followed an identical trend during storage (Table 2). In general, the sensory attributes increased till 30 days of storage thereafter a gradual decline was noticed till end of the storage. Among all the packaging films, fruits packed in perforated PP 100 and LDPE 100 gauge remained fit for consumption by retaining acceptable sensory rating (8.35 and 7.95, respectively) after 60 days of storage. On the other hand, fruits packed in non perforated LDPE 150 gauge film registered the highest sensory score (8.32) after 30 days of storage; thereafter followed by a rapid decline thereby declared unfit to eat and rated as extremely undesirable after 75 days of storage. Highest sensory rating by the fruits packed in perforated PP 100 gauge and perforated LDPE 100 gauge films might be due to better retention of the quality parameter *viz* TSS and sugars during storage may be to delayed ripening and senescence processes; which simultaneously delayed the conversion of starch into sugars. However, fruits packed in non perforated LDPE 150 gauge and non perforated PP 100 gauge film showed an unpleasant appearance due to creation of an anaerobic environment inside packaging film led to development of off flavors and volatile compounds. The interaction between packaging film and storage interval was found to be significant. These results are however, interestingly are contrary to the findings of Ramaya *et al* (2012) who reported that mango fruits packed in non perforated OPP film maintained higher sensory rating in contrast to perforated OPP film. Similarly, Mahajan and Singh (2014) also reported that Kinnow fruits wrapped in shrink films maintained higher sensory score in contrast to control (unpacked). Similar findings were also reported in peach (Mahajan *et al* 2015) and apple cv. 'Red delicious' (Sharma *et al* 2013).

Table 2 Effect of packaging films and storage periods on the organoleptic sensory attributes (Hedonic scale 1-9) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	7.50 (2.74)	8.34 (2.89)	7.75 (2.78)	6.94 (2.63)	4.97 (2.22)	2.65^e±0.046
LDPE 150 gauge	7.50 (2.74)	8.32 (2.88)	7.70 (2.77)	6.83 (2.61)	0.00 (0.00)	2.20^g±0.20
LDPE 100 gauge with 5% perforation	7.50 (2.74)	8.57 (2.93)	8.25 (2.87)	7.95 (2.82)	6.68 (2.58)	2.79^b±0.024
LDPE 150 gauge with 5% perforation	7.50 (2.74)	8.72 (2.95)	8.07 (2.84)	7.74 (2.78)	6.04 (2.45)	2.75^c±0.034
PP 100 gauge	7.50 (2.74)	8.45 (2.91)	7.55 (2.75)	7.13 (2.67)	0.00 (0.00)	2.20^g±0.21
PP 150 gauge	7.50 (2.74)	8.40 (2.90)	7.61 (2.76)	7.04 (2.65)	0.00 (0.00)	2.21^g±0.20
PP 100 gauge with 5% perforation	7.50 (2.74)	8.72 (2.95)	8.50 (2.92)	8.35 (2.89)	6.63 (2.57)	2.81^a±0.028
PP 150 gauge with 5% perforation	7.50 (2.74)	8.65 (2.94)	7.87 (2.80)	7.17 (2.68)	5.85 (2.42)	2.71^d±0.035
Control	7.50 (2.74)	7.20 (2.68)	6.63 (2.57)	6.12 (2.47)	5.80 (2.41)	2.57^f±0.03
Mean ±SE	2.74^c±0.013	2.89^a±0.014	2.78^b±0.015	2.69^d±0.018	1.63^e±0.16	
LSD ($P \leq 0.05$)	Treatment (MAP) = 0.025 Days (SI) = 0.018 SI x MAP = 0.057					
F value (($P \leq 0.05$)	Treatment (MAP) = 229.56 Days (SI) = 2120.58 SI x MAP = 145.58					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Figures in parenthesis are square root transformation values. Each value represents pooled mean of 2 years (2017 and 2018)

4.3 | Juice (%)

Juice content decreased with prolongation in storage period irrespective of the treatments (Table 3). The highest juice (49.00 ± 0.17 per cent) content was registered at the time of harvest (0 day) which decline gradually till the end of the storage. Fruits packed in perforated PP 100 gauge film maintained the highest juice content (45.40%) after 75 days of storage. By contrast, control (unpacked) fruits followed an abrupt decline in juice content with an advancement in storage period thereby retained the lowest juice **(**34.48 %) content after 75 days of storage. Fruits packed in perforated PP 100 and perforated LDPE 100 gauge film maintained the highest juice content; might be due to influence of polymeric packaging films on differential rate of water loss from the fruit surface. The interaction between packaging films and storage interval was found to be significant. These results are in conformity to the findings of Sharma *et al* (2013) who reported that fruits of apple cv. 'Royal delicious' wrapped in cryovac films maintained higher juice recovery.Heat shrinkable films are known to influence juice recovery in Mosambi and Kinnow, primarily due to curve on PLW over unwrapped fruits (Ladaniya and Singh 2001; Ladaniya 2003).

Table 3 Effect of packaging conditions and storage periods on the juice percentage (%) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	49.00 (6.99)	45.19 (6.72)	44.71 (6.68)	42.96 (6.55)	41.52 (6.44)	6.68^{cd}±0.039
LDPE 150 gauge	49.00 (6.99)	44.72 (6.69)	43.83 (6.62)	42.94 (6.55)	40.89 (6.39)	6.65^{d}±0.040
LDPE 100 gauge with 5% perforation	49.00 (6.99)	48.59 (6.97)	47.79 (6.91)	45.32 (6.73)	42.71 (6.53)	6.83^{ab}±0.036
LDPE 150 gauge with 5% perforation	49.00 (6.99)	46.79 (6.84)	46.46 (6.82)	45.10 (6.71)	42.77 (6.54)	6.78^{b}±0.032
PP 100 gauge	49.00 (6.99)	44.75 (6.69)	41.93 (6.47)	41.46 (6.44)	38.05 (6.17)	6.55^{e}±0.054
PP 150 gauge	49.00 (6.99)	45.44 (6.74)	44.67 (6.68)	43.31 (6.58)	41.74 (6.46)	6.69^{cd}±0.038
PP 100 gauge with 5% perforation	49.00 (6.99)	48.41 (6.96)	47.19 (6.87)	45.51 (6.75)	45.40 (6.74)	6.86^{a}±0.025
PP 150 gauge with 5% perforation	49.00 (6.99)	46.71 (6.83)	44.99 (6.71)	43.43 (6.59)	40.51 (6.36)	6.70^{c}±0.043
Control	49.00 (6.99)	46.37 (6.81)	45.02 (6.71)	38.26 (6.18)	34.48 (5.87)	6.51^{e}±0.080
Mean ±SE	6.99^{a}±0.012	6.80^{b}±0.018	6.72^{c}±0.021	6.56^{d}±0.025	6.39^{e}±0.034	
LSD (P≤0.05)	Treatment (MAP) = 0.048 Days (SI) =0.036 SI x MAP = 0.11					
F value ((P≤0.05)	Treatment (MAP) = 42.43 Days (SI) = 316.26 SI x MAP = 7.99					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Figures in parenthesis are square root transformation values. Each value represents pooled mean of 2 years (2017 and 2018)

4.4 | Titratable acidity (%)

Irrespective of treatments, the level of acid content of Kinnow fruits followed a decline with progress in storage period (Table 4). Among all the packaging films, lowest mean acid content was noticed in the unpacked fruits (0.74 ± 0.048 %). However, fruits packed in perforated PP 100 gauge film maintained highest mean acidity (0.91 ± 0.05) content followed by perforated LDPE 100 gauge film (0.85 ± 0.053%). The decline in acid content during storage might be due to the metabolic changes occurs in fruit resulting from the use of organic acids as substrate for respiratory metabolism in detached fruits in respiratory process (Diaz-Mula*et al* 2012 and Valero and Serrano 2010). Fruits packed in perforated PP 100 and perforated LDPE 100 gauge retained higher acid content; might be due to lack of oxidation of organic acids participates during respiratory process. The interaction between packaging films and storage interval are found to be significant. The results are in corroboration with the findings of Azene*et al* (2014) who reported that fruits of papaya wrapped in HDPE and LDPE maintained higher acid content (0.37 and 0.36%, respectively) over unwrapped fruits (0.30%) after 18 days of storage. Similar results were also reported in mango cv. 'Alphonso and 'Banganapalli' by Rao and shivashankara (2015). Mahajan and Singh (2014) registered that Kinnow fruits wrapped in shrink films maintained the higher acid content (0.54%)in contrast to unpacked (0.48%) fruits during storage.

Table 4 Effect of packaging films and storage periods on the titratable acidity per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	1.24	0.86	0.77	0.63	0.44	$0.79^{f} \pm 0.051$
LDPE 150 gauge	1.24	0.84	0.68	0.62	0.50	$0.78^{f} \pm 0.049$
LDPE 100 gauge with 5% perforation	1.24	0.96	0.89	0.76	0.39	$0.85^{b} \pm 0.053$
LDPE 150 gauge with 5% perforation	1.24	0.98	0.78	0.63	0.46	$0.82^{c} \pm 0.052$
PP 100 gauge	1.24	0.76	0.64	0.63	0.51	$0.76^{g} \pm 0.048$
PP 150 gauge	1.24	1.01	0.80	0.55	0.37	$0.80^{de} \pm 0.060$
PP 100 gauge with 5% perforation	1.24	1.18	0.85	0.79	0.48	$0.91^{a} \pm 0.05$
PP 150 gauge with 5% perforation	1.24	0.94	0.78	0.63	0.44	$0.81^{cd} \pm 0.05$
Control	1.24	0.71	0.62	0.60	0.53	$0.74^{h} \pm 0.048$
Mean ±SE	$1.24^{a}\pm0.014$	$0.92^{b}\pm0.022$	$0.76^{c}\pm0.014$	$0.65^{d}\pm0.012$	$0.46^{e}\pm0.00079$	
LSD (P≤0.05)	Treatment (MAP) =0.017 Days (SI) =0.013 SI x MAP = 0.038					
F value ((P≤0.05)	Treatment (MAP) = 72.32 Days (SI) = 4277.33 SI x MAP = 34.11					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

4.5 | Vitamin C (mg/100g)

The data on vitamin C content influenced by various packaging films followed a decline with prolongation in storage period (Table 5). In general, the highest ascorbic acid content was registered at the time of harvest (0 day data) i.e. 33.92 ± 0.13mg/100g pulp, thereafter a gradual decline was noticed till the end of the storage i.e. 75 days of the storage (18.47 ±0.24 mg/100g pulp). Fruits packed in perforated PP 100 gauge film maintained the highest mean ascorbic acid content (24.90 ± 0.89mg/100g pulp) followed by perforated LDPE 100 gauge film (24.59 ± 0.96 mg/100g pulp). However, control fruits followed an abrupt decline in ascorbic acid content at faster pace thereby registered the lowest mean ascorbic acid (22.90 ± 1.06 mg/100g pulp) content. The decline in ascorbic acid content might be due to conversion of ascorbic acid to dehydroascorbic acid by the action of ascorbic acid oxidase (Mapson 1970 and Singh *et al* 2005). The interaction between packaging films and storage interval was found to be significant. The results are in agreement with the findings of Nath *et al* (2012) who observed that pear fruits packed in perforated PP film maintained the higher ascorbic acid content in contrast to non perforated and unpacked fruits. Fruits of 'papaya' wrapped in LDPE retained the maximum ascorbic acid content (45.6 mg/100g) in contrast to control (40.60 mg/100 g) after 18 days of storage (Azene*et al* 2014). Similarly, Mahajan and Singh (2014) reported that fruits of Kinnow wrapped in shrink film retained the maximum ascorbic acid content over unwrapped fruits during storage.

Table 5 Effect of packaging films and storage periods on the vitamin C (mg/100g) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	33.92	22.83	22.32	20.30	18.60	23.60^d±1.03
LDPE 150 gauge	33.92	22.55	21.81	20.13	18.39	23.36^{de}±1.05
LDPE 100 gauge with 5% perforation	33.92	24.71	24.09	20.47	19.76	24.59^{ab}±0.96
LDPE 150 gauge with 5% perforation	33.92	25.77	23.06	21.39	18.22	24.47^{abc}±1.01
PP 100 gauge	33.92	22.42	20.75	20.32	17.72	23.03^{ef}±1.07
PP 150 gauge	33.92	28.10	23.45	19.05	16.22	24.15^c±1.20
PP 100 gauge with 5% perforation	33.92	23.38	23.22	22.96	20.99	24.90^a±0.89
PP 150 gauge with 5% perforation	33.92	25.71	23.00	21.28	17.93	24.37^{bc}±1.03
Control	33.92	21.73	20.66	19.76	18.39	22.90^f±1.06
Mean ±SE	33.92^a±0.13	24.14^b±0.33	22.49^c±0.23	20.63^d±0.23	18.47^e±0.24	
LSD (P≤0.05)	Treatment (MAP) = 0.43 Days (SI) =0.32 SI x MAP =0.97					
F value ((P≤0.05)	Treatment (MAP) = 21.89 Days (SI) = 2659.17 SI x MAP = 12.74					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

4.6 | Total Soluble Solids (%)

TSS content followed an identical trend with an advancement in storage period (Table 6). In general, a gradual rise in TSS content was observed after 60 days of storage i.e. 11.44 ± 0.11 per cent, thereafter a decline was noticed at the end of the storage i.e. 10.86 ± 0.07 per cent. Among the various packaging films, fruits packed in perforated PP 100 gauge film registered the highest mean TSS (10.73 ± 0.22%) content followed by perforated LDPE 100 gauge film 10.63 ± 0.26 per cent**)**. However, the lowest TSS (9.67 ± 0.18%) content was recorded in unwrapped fruits. An increase and decrease in TSS content during storage; might be due to conversion of starch into sugars further no increase and on the completion of starch hydrolysis, no further increase occurred thereafter; and subsequently the TSS content declined as the sugars act as substrate during respiration (Wills *et al* 1980). The interaction between packaging films and storage interval was found to be significant. The results are in conformity to the findings of Azene *et al* (2014) who reported that fruits of papaya wrapped in LDPE maintained higher TSS content during storage. Similar findings were also reported in mango (Rao and shivashankara 2015). Mahajan and Singh (2014) observed that shrink film resulted the maximum TSS content in Kinnow. Similar findings were also reported in peach fruit (Mahajan *et al* 2015).

Table 6 Effect of packaging films and storage periods on the total soluble solids (TSS) per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	8.60	9.90	10.27	11.72	10.62	10.22^{h}±0.21
LDPE 150 gauge	8.60	9.20	10.40	10.77	10.67	9.93^{c}±0.17
LDPE 100 gauge with 5% perforation	8.60	10.27	10.67	12.80	10.82	10.63^{a}±0.26
LDPE 150 gauge with 5% perforation	8.60	10.55	10.75	11.10	10.85	10.37^{b}±0.18
PP 100 gauge	8.60	9.27	9.87	10.90	10.45	9.82^{cd}±0.16
PP 150 gauge	8.60	10.00	10.55	11.10	11.00	10.25^{b}±0.18
PP 100 gauge with 5% perforation	8.60	10.57	11.10	12.00	11.37	10.73^{a}±0.22
PP 150 gauge with 5% perforation	8.60	9.55	10.80	11.62	11.48	10.41^{b}±0.23
Control	8.60	8.70	9.67	10.95	10.45	9.67^{d}±0.18
Mean ±SE	8.60^{e}±0.04	9.78^{d}±0.096	10.46^{c}±0.080	11.44^{a}±0.11	10.86^{b}±0.07	
LSD (P≤0.05)	Treatment (MAP) =0.19 Days (SI) =0.14 SI x MAP = 0.43					
F value ((P≤0.05)	Treatment (MAP) = 27.65 Days (SI) = 459.94SI x MAP = 5.92					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Each value represents pooled mean of 2 years (2017 and 2018).

4.7 | Reducing sugars (%)

The reducing sugars followed an increase till 60 days of storage and thereafter a decline was noticed till end of the storage (Table 7). Among different packaging films, fruits packed in perforated PP 100 gauge film maintained the highest mean reducing sugars (3.17 ± 0.23%) content followed by perforated LDPE 100 gauge film (3.09 ± 0.24%). On the other hand, unpacked fruits recorded the lowest mean reducing sugars (2.35%) content. The progressive increase in sugars during storage period up to 60 days followed by a gradual decrease decline; might be due to breakdown of starch into sugars, as on complete hydrolysis of starch no further increase in sugars occurs and subsequently a decline in these parameter is predictable as they along with other organic acids are primary substrate for respiration (Wills *et al* 1980).The interaction between packaging films and storage interval was found to be significant.

Table 7 Effect of packaging films and storage periods on the reducing sugars per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	1.68	2.20	2.36	4.06	2.82	2.63^e±0.15
LDPE 150 gauge	1.68	1.90	2.38	4.29	3.05	2.66^{de}±0.18
LDPE 100 gauge with 5% perforation	1.68	2.37	2.59	5.35	3.47	3.09^b±0.24
LDPE 150 gauge with 5% perforation	1.68	2.34	2.83	5.22	3.09	3.04^c±0.23
PP 100 gauge	1.68	1.81	2.82	3.25	3.18	2.55^f±0.12
PP 150 gauge	1.68	2.05	2.40	4.12	3.21	2.70^d±0.17
PP 100 gauge with 5% perforation	1.68	2.54	2.85	5.44	3.32	3.17^a±0.23
PP 150 gauge with 5% perforation	1.68	2.39	2.75	4.88	3.51	3.04^{bc}±0.21
Control	1.68	2.29	2.32	3.04	2.43	2.35^g±0.081
Mean ±SE	1.68^e±0.00070	2.21^d±0.038	2.59^c±0.034	4.41^a±0.12	3.12^b±0.056	
LSD ($P \leq 0.05$)	Treatment (MAP) = 0.053 Days (SI) = 0.039 SI x MAP = 0.12					
F value (($P \leq 0.05$)	Treatment (MAP) = 231.58 Days (SI) = 5473.61 SI x MAP = 83.96					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

4.8 | Total sugars (%)

A progressive rise in total sugars content was noticed till 60 days of storage; thereafter a decline was noticed at the end of the storage (Table 8). In general, the maximum total sugars (7.60 ±0.13%**)** content was noticed after 60 days of storage. Among different packaging films, fruits packed in perforated PP 100 gauge film registered the maximum total sugars (7.06 ± 0.22%) content followed by perforated LDPE 100 gauge film (6.80 ± 0.31%). However, unpacked fruits recorded the lowest total sugars (5.45 ± 0.083%) content. The initial increase in total sugars content of fruits under different packaging conditions might be due to loss of moisture from the fruit surface and conversion of polysaccharides and pectic substances into sugars. The increase in total sugars with the storage interval up to 60 days might be due to the hydrolysis of starch into mono and disaccharides. Thereafter, decline can be attributed to metabolic breakdown and senescence of fruits as a result of moisture and firmness loss during storage (Ryall and Pentzer 1982). The higher total sugars content in perforated PP 100 and perforated LDPE 100 gauge film might be due to delayed hydrolysis of starch and other polysaccharides to soluble form of sugars at slower rate. The interaction between packaging films and storage interval was found to be significant. These results are in conformity to the findings of Nath *et al* (2012) recorded higher sugar content in the pear fruits packed in PP films in contrast to unpacked fruits Similarly, Azene *et al* (2014) reported that papaya fruits wrapped in LDPE registered higher reducing sugar and total sugars content in contrast to unpacked fruits. Mahajan *et al* (2015) also noticed that peach fruits wrapped in shrink film maintained the maximum sugars content during storage.

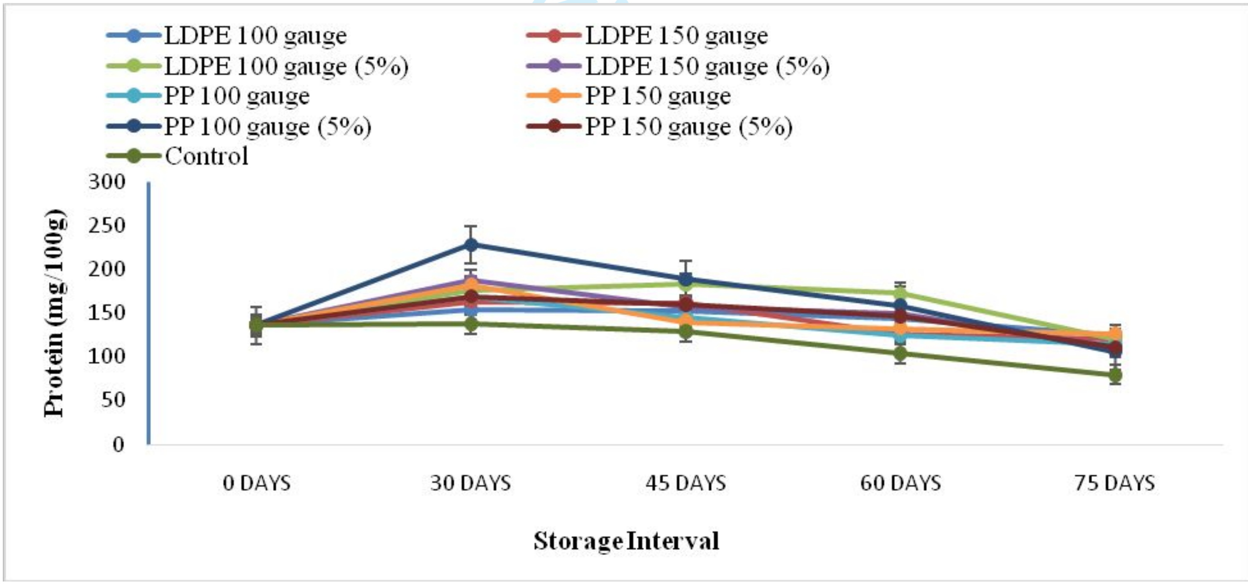
Table 8 Effect of packaging films and storage periods on the total sugars per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean±SE**
LDPE 100 gauge	4.89	5.59	6.03	7.95	6.57	$6.21^{e}\pm0.21$
LDPE 150 gauge	4.89	5.64	6.09	7.91	6.58	$6.22^{de}\pm0.21$
LDPE 100 gauge with 5% perforation	4.89	5.41	6.23	8.78	8.65	$6.80^{b}\pm0.31$
LDPE 150 gauge with 5% perforation	4.89	5.62	6.84	8.30	7.85	$6.70^{b}\pm0.24$
PP 100 gauge	4.89	5.41	5.93	6.44	6.28	$5.79^{f}\pm0.11$
PP 150 gauge	4.89	5.76	6.56	7.51	7.02	$6.35^{cd}\pm0.18$
PP 100 gauge with 5% perforation	4.89	6.97	7.54	8.20	7.70	$7.06^{a}\pm0.22$
PP 150 gauge with 5% perforation	4.89	6.29	6.80	7.33	6.82	$6.43^{c}\pm0.16$
Control	4.89	5.12	5.77	5.94	5.53	$5.45^{g}\pm0.083$
Mean±SE	$4.89^{e}\pm0.036$	$5.76^{d}\pm0.077$	$6.42^{c}\pm0.092$	$7.60^{a}\pm0.13$	$7.00^{b}\pm0.13$	
LSD ($P\leq0.05$)	Treatment (MAP) = 0.14 Days (SI) = 0.10 SI x MAP = 0.31					
F value (($P\leq0.05$)	Treatment (MAP) = 100.06 Days (SI) = 807.75 SI x MAP = 21.98					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

4.9 | Protein (mg/100g)

The protein content decreased with prolongation in storage period (Fig 1). In general, the maximum protein content was noticed after 30 days of storage i.e.173.89 ± 3.37mg/100g pulp, which thereafter declined to 112.59± 1.91 mg/100g pulp after 75 days of storage. Fruits packed in perforated PP 100 gauge film maintained highest mean protein (163.58± 7.91 mg/100g pulp) content followed by perforated LDPE 100 gauge film (157.26± 4.77 mg/100g pulp). On the other hand, unpacked fruits followed a decline in protein content at faster pace thereby registered the lowest mean protein (117.25± 4.41 mg/100g) content. The higher protein content of fruits packed in perforated PP 100 and perforated LDPE 100 gauge film might be due to changes in metabolic pathways of maturation that involve synthesis of protein; hydrolytic enzymes—e.g. α-amylase, β-amylase, starch phosphorylase accumulate inverted sugars and polygalacturonase involved in fruit softening, and promote and accelerate the changes during ripening. The interaction between packaging films and storage interval was found to be significant during both the season of investigation. The results are in conformity to the findings of Tejacal *et al* (2005) who reported 82 mg kg^{-1} protein content at physiological maturity and 950 mg kg-1 during ripening and 299.1 mg kg-1 during senescence for zapotemamey (*Pouteriasapota*Jacq.). Similar findings were also reported b Duenas-Gonmez*et al* (2008) and Baxter and Waters (1991).

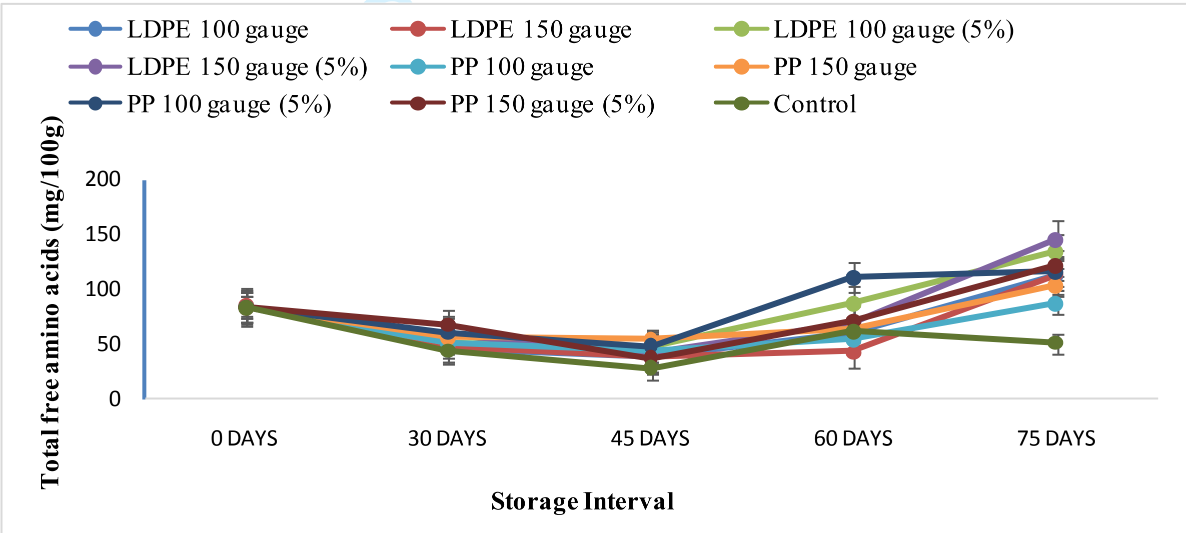


The vertical bar represents standard error (SE) mean of three replicates

FIGURE 1 Effect of packaging fims and storage periods on the protein content (mg/100g) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH. Data are from pooled results of two seasons and represented as the Mean ± Standard Error (S.E.) of the Mean of three replicates.

4.10 | Total free amino acids (mg/100g)

The total free amino acids content followed an identical trendwith prolongation in storage period (Fig 2). In general, total free amino acids content was decreased till 45 days of storage; thereafter followed a gradual rise till the end of the storage i.e. 75 days of the storage. Among all the packaging films, fruits packed in perforated PP 100 gauge film registered the highest mean total free amino acids (83.76± 5.04 mg/100g pulp) content followed by perforated LDPE 100 gauge film (81.11± 5.81mg/100g pulp). However, unpacked fruits retained the lowest mean total free amino acids (53.22± 3.54mg/100g) content. The higher total free amino acids content of fruits packed in perforated PP 100 and perforated LDPE 100 gauge film might be due to with progress in storage period;changes occurs in metabolic pathways of maturation that involve synthesis of amino acids due to protein degradation advances with the beginning of senescence process (Backer 1987 and Tulio*et al* 2002). At senescence, the rate of protein degradation is higher than the rate of protein synthesis. The results are in conformity to the findings of Simoes*et al* (2009) who reported that minimally processed leaves of collard stored at 5^{0}C showed the highest contents of soluble amino acids after twelve days of storage. The interaction between treatments and storage interval was found to be significant.



The vertical bar represents standard error (SE) mean of three replicates

FIGURE 2 Effect of packaging films and storage periods on the total free amino acids (mg/100g) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH. Data are from pooled results of two seasons and represented as the Mean ± Standard Error (S.E.) of the Mean of three replicates.

5 | Conclusion

Kinnow fruits harvested in 3rd week of January can be successfully stored for 60 days at 5-7^{0}C and 90-95% RH packed in perforated (5%) PP 100 gauge and LDPE 100 gauge films.

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Table 1 Effect of packaging materials and storage intervals on the spoilage per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	0.00 (0.00)	8.33 (2.04)	12.50 (2.50)	33.33 (5.77)	83.33 (9.11)	$3.88^c \pm 0.65$
LDPE 150 gauge	0.00 (0.00)	8.33 (2.04)	12.50 (2.50)	49.99 (6.97)	79.16 (8.87)	$4.07^b \pm 0.68$
LDPE 100 gauge with 5% perforation	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.83 (4.54)	$0.91^g \pm 0.34$
LDPE 150 gauge with 5% perforation	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.33 (1.47)	50.00 (7.07)	$1.71^f \pm 0.52$
PP 100 gauge	0.00 (0.00)	16.66 (4.08)	20.83 (4.54)	33.33 (5.77)	91.66 (9.57)	$4.79^a \pm 0.57$
PP 150 gauge	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	12.50 (2.50)	91.66 (9.57)	$2.41^d \pm 0.72$
PP 100 gauge with 5% perforation	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	12.49 (3.48)	$0.70^h \pm 0.26$
PP 150 gauge with 5% perforation	0.00 (0.00	0.00 (0.00)	0.00 (0.00)	12.49 (3.48)	75.00 (8.66)	$2.43^d \pm 0.63$
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.83 (4.54)	33.33 (5.77)	$2.06^e \pm 0.48$
Mean ±SE	$0.00^d \pm 0.00$	$0.91^d \pm 0.23$	$1.06^c \pm 0.27$	$3.39^b \pm 0.36$	$7.40^a \pm 0.30$	
LSD ($P \leq 0.05$)	Treatment (MAP) = 0.059 Days (SI) = 0.043 SI x MAP = 0.13					
F value (($P \leq 0.05$)	Treatment (MAP) = 1136.05 Days (SI) = 10123.28 SI x MAP = 348.12					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Figures in parenthesis are square root transformation values. Each value represents pooled mean of 2 years (2017 and 2018)

Table 2 Effect of packaging films and storage periods on the organoleptic sensory attributes (Hedonic scale 1-9) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	7.50 (2.74)	8.34 (2.89)	7.75 (2.78)	6.94 (2.63)	4.97 (2.22)	$2.65^e \pm 0.046$
LDPE 150 gauge	7.50 (2.74)	8.32 (2.88)	7.70 (2.77)	6.83 (2.61)	0.00 (0.00)	$2.20^g \pm 0.20$
LDPE 100 gauge	7.50 (2.74)	8.57 (2.93)	8.25 (2.87)	7.95 (2.82)	6.68 (2.58)	$2.79^b \pm 0.024$

with 5% perforation						
LDPE 150 gauge with 5% perforation	7.50 (2.74)	8.72 (2.95)	8.07 (2.84)	7.74 (2.78)	6.04 (2.45)	2.75[c] ± 0.034
PP 100 gauge	7.50 (2.74)	8.45 (2.91)	7.55 (2.75)	7.13 (2.67)	0.00 (0.00)	2.20[g] ± 0.21
PP 150 gauge	7.50 (2.74)	8.40 (2.90)	7.61 (2.76)	7.04 (2.65)	0.00 (0.00)	2.21[g] ± 0.20
PP 100 gauge with 5% perforation	7.50 (2.74)	8.72 (2.95)	8.50 (2.92)	8.35 (2.89)	6.63 (2.57)	2.81[a] ± 0.028
PP 150 gauge with 5% perforation	7.50 (2.74)	8.65 (2.94)	7.87 (2.80)	7.17 (2.68)	5.85 (2.42)	2.71[d] ± 0.035
Control	7.50 (2.74)	7.20 (2.68)	6.63 (2.57)	6.12 (2.47)	5.80 (2.41)	2.57[f] ± 0.03
Mean ±SE	2.74[c] ± 0.013	2.89[a] ± 0.014	2.78[b] ± 0.015	2.69[d] ±0.018	1.63[e] ±0.16	
LSD ($P \leq 0.05$)	Treatment (MAP) = 0.025 Days (SI) = 0.018 SI x MAP = 0.057					
F value (($P \leq 0.05$)	Treatment (MAP) = 229.56 Days (SI) = 2120.58 SI x MAP = 145.58					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Figures in parenthesis are square root transformation values. Each value represents pooled mean of 2 years (2017 and 2018)

Table 3 Effect of packaging conditions and storage periods on the juice percentage (%) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	49.00 (6.99)	45.19 (6.72)	44.71 (6.68)	42.96 (6.55)	41.52 (6.44)	6.68[cd] ±0.039
LDPE 150 gauge	49.00 (6.99)	44.72 (6.69)	43.83 (6.62)	42.94 (6.55)	40.89 (6.39)	6.65[d] ± 0.040
LDPE 100 gauge with 5% perforation	49.00 (6.99)	48.59 (6.97)	47.79 (6.91)	45.32 (6.73)	42.71 (6.53)	6.83[ab] ± 0.036
LDPE 150 gauge with 5% perforation	49.00 (6.99)	46.79 (6.84)	46.46 (6.82)	45.10 (6.71)	42.77 (6.54)	6.78[b] ± 0.032
PP 100 gauge	49.00 (6.99)	44.75 (6.69)	41.93 (6.47)	41.46 (6.44)	38.05 (6.17)	6.55[e] ± 0.054
PP 150 gauge	49.00 (6.99)	45.44 (6.74)	44.67 (6.68)	43.31 (6.58)	41.74 (6.46)	6.69[cd] ± 0.038
PP 100 gauge with 5% perforation	49.00 (6.99)	48.41 (6.96)	47.19 (6.87)	45.51 (6.75)	45.40 (6.74)	6.86[a] ± 0.025
PP 150 gauge with 5% perforation	49.00 (6.99)	46.71 (6.83)	44.99 (6.71)	43.43 (6.59)	40.51 (6.36)	6.70[c] ± 0.043

Control	49.00 (6.99)	46.37 (6.81)	45.02 (6.71)	38.26 (6.18)	34.48 (5.87)	6.51[e] ± 0.080
Mean ±SE	6.99[a] ± 0.012	6.80[b] ± 0.018	6.72[c] ± 0.021	6.56[d] ± 0.025	6.39[e] ± 0.034	
LSD (P≤0.05)	Treatment (MAP) = 0.048 Days (SI) =0.036 SI x MAP = 0.11					
F value ((P≤0.05)	Treatment (MAP) = 42.43 Days (SI) = 316.26 SI x MAP = 7.99					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Figures in parenthesis are square root transformation values. Each value represents pooled mean of 2 years (2017 and 2018)

Table 4 Effect of packaging films and storage periods on the titratable acidity per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	1.24	0.86	0.77	0.63	0.44	0.79[f] ± 0.051
LDPE 150 gauge	1.24	0.84	0.68	0.62	0.50	0.78[f] ± 0.049
LDPE 100 gauge with 5% perforation	1.24	0.96	0.89	0.76	0.39	0.85[b] ± 0.053
LDPE 150 gauge with 5% perforation	1.24	0.98	0.78	0.63	0.46	0.82[c] ± 0.052
PP 100 gauge	1.24	0.76	0.64	0.63	0.51	0.76[g] ± 0.048
PP 150 gauge	1.24	1.01	0.80	0.55	0.37	0.80[de] ± 0.060
PP 100 gauge with 5% perforation	1.24	1.18	0.85	0.79	0.48	0.91[a] ± 0.05
PP 150 gauge with 5% perforation	1.24	0.94	0.78	0.63	0.44	0.81[cd] ± 0.05
Control	1.24	0.71	0.62	0.60	0.53	0.74[h] ± 0.048
Mean ±SE	1.24[a] ± 0.014	0.92[b] ±0.022	0.76[c] ± 0.014	0.65[d] ±0.012	0.46[e] ±0.00079	
LSD (P≤0.05)	Treatment (MAP) =0.017 Days (SI) =0.013 SI x MAP = 0.038					
F value ((P≤0.05)	Treatment (MAP) = 72.32 Days (SI) = 4277.33 SI x MAP = 34.11					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 5 Effect of packaging films and storage periods on the vitamin C (mg/100g) of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	33.92	22.83	22.32	20.30	18.60	23.60^{d} ±1.03
LDPE 150 gauge	33.92	22.55	21.81	20.13	18.39	23.36^{de} ± 1.05
LDPE 100 gauge with 5% perforation	33.92	24.71	24.09	20.47	19.76	24.59^{ab} ± 0.96
LDPE 150 gauge with 5% perforation	33.92	25.77	23.06	21.39	18.22	24.47^{abc} ± 1.01
PP 100 gauge	33.92	22.42	20.75	20.32	17.72	23.03^{ef} ± 1.07
PP 150 gauge	33.92	28.10	23.45	19.05	16.22	24.15^{c} ± 1.20
PP 100 gauge with 5% perforation	33.92	23.38	23.22	22.96	20.99	24.90^{a} ± 0.89
PP 150 gauge with 5% perforation	33.92	25.71	23.00	21.28	17.93	24.37^{bc} ±1.03
Control	33.92	21.73	20.66	19.76	18.39	22.90^{f} ±1.06
Mean ±SE	33.92^{a} ± 0.13	24.14^{b} ± 0.33	22.49^{c} ± 0.23	20.63^{d} ±0.23	18.47^{e} ±0.24	
LSD (P≤0.05)	Treatment (MAP) = 0.43 Days (SI) =0.32 SI x MAP =0.97					
F value ((P≤0.05)	Treatment (MAP) = 21.89 Days (SI) = 2659.17 SI x MAP = 12.74					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 6 Effect of packaging films and storage periods on the total soluble solids (TSS) per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	8.60	9.90	10.27	11.72	10.62	10.22^{h} ±0.21
LDPE 150 gauge	8.60	9.20	10.40	10.77	10.67	9.93^{c} ± 0.17
LDPE 100 gauge with 5% perforation	8.60	10.27	10.67	12.80	10.82	10.63^{a} ± 0.26
LDPE 150 gauge with 5% perforation	8.60	10.55	10.75	11.10	10.85	10.37^{b} ± 0.18
PP 100 gauge	8.60	9.27	9.87	10.90	10.45	9.82^{cd} ± 0.16

PP 150 gauge	8.60	10.00	10.55	11.10	11.00	10.25^{b} ± 0.18
PP 100 gauge with 5% perforation	8.60	10.57	11.10	12.00	11.37	10.73^{a} ± 0.22
PP 150 gauge with 5% perforation	8.60	9.55	10.80	11.62	11.48	10.41^{b} ± 0.23
Control	8.60	8.70	9.67	10.95	10.45	9.67^{d} ± 0.18
Mean ±SE	8.60^{e} ± 0.04	9.78^{d} ± 0.096	10.46^{c} ± 0.080	11.44^{a} ± 0.11	10.86^{b} ±0.07	
LSD (P≤0.05)	Treatment (MAP) =0.19 Days (SI) =0.14 SI x MAP = 0.43					
F value ((P≤0.05)	Treatment (MAP) = 27.65 Days (SI) = 459.94SI x MAP = 5.92					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018).

Table 7 Effect of packaging films and storage periods on the reducing sugars per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

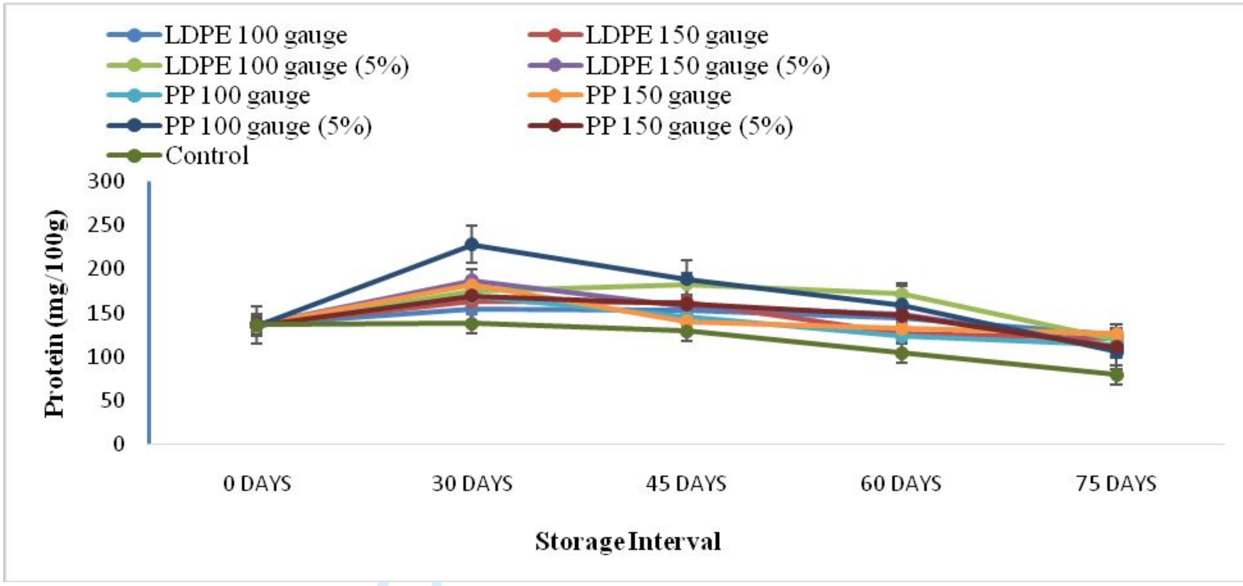
	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	1.68	2.20	2.36	4.06	2.82	2.63^{e} ±0.15
LDPE 150 gauge	1.68	1.90	2.38	4.29	3.05	2.66^{de} ± 0.18
LDPE 100 gauge with 5% perforation	1.68	2.37	2.59	5.35	3.47	3.09^{b} ± 0.24
LDPE 150 gauge with 5% perforation	1.68	2.34	2.83	5.22	3.09	3.04^{c} ± 0.23
PP 100 gauge	1.68	1.81	2.82	3.25	3.18	2.55^{f} ± 0.12
PP 150 gauge	1.68	2.05	2.40	4.12	3.21	2.70^{d} ± 0.17
PP 100 gauge with 5% perforation	1.68	2.54	2.85	5.44	3.32	3.17^{a} ± 0.23
PP 150 gauge with 5% perforation	1.68	2.39	2.75	4.88	3.51	3.04^{bc} ± 0.21
Control	1.68	2.29	2.32	3.04	2.43	2.35^{g} ± 0.081
Mean ±SE	1.68^{e} ± 0.00070	2.21^{d} ± 0.038	2.59^{c} ± 0.034	4.41^{a} ± 0.12	3.12^{b} ± 0.056	
LSD (P≤0.05)	Treatment (MAP) = 0.053 Days (SI) = 0.039 SI x MAP = 0.12					
F value ((P≤0.05)	Treatment (MAP) = 231.58 Days (SI) = 5473.61 SI x MAP = 83.96					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 8 Effect of packaging films and storage periods on the total sugars per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

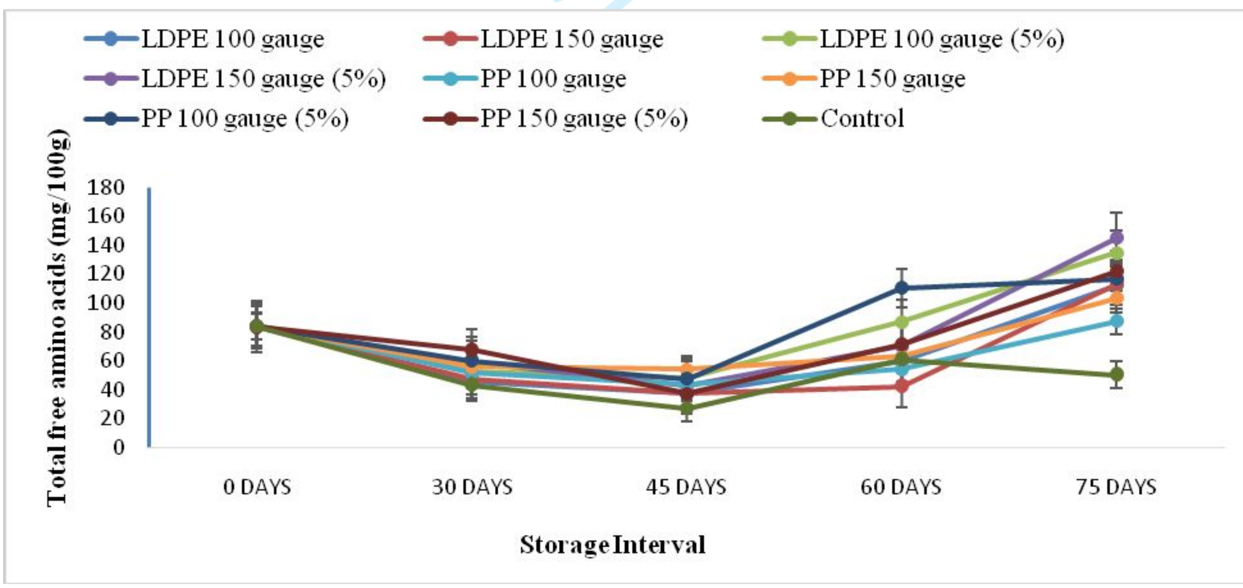
	Storage interval (Days)					
MAP films	**0**	**30**	**45**	**60**	**75**	**Mean ±SE**
LDPE 100 gauge	4.89	5.59	6.03	7.95	6.57	6.21^e ±0.21
LDPE 150 gauge	4.89	5.64	6.09	7.91	6.58	6.22^{de} ± 0.21
LDPE 100 gauge with 5% perforation	4.89	5.41	6.23	8.78	8.65	6.80^b ± 0.31
LDPE 150 gauge with 5% perforation	4.89	5.62	6.84	8.30	7.85	6.70^b ± 0.24
PP 100 gauge	4.89	5.41	5.93	6.44	6.28	5.79^f ± 0.11
PP 150 gauge	4.89	5.76	6.56	7.51	7.02	6.35^{cd} ± 0.18
PP 100 gauge with 5% perforation	4.89	6.97	7.54	8.20	7.70	7.06^a ± 0.22
PP 150 gauge with 5% perforation	4.89	6.29	6.80	7.33	6.82	6.43^c ± 0.16
Control	4.89	5.12	5.77	5.94	5.53	5.45^g ± 0.083
Mean ±SE	4.89^e ± 0.036	5.76^d ± 0.077	6.42^c ± 0.092	7.60^a ± 0.13	7.00^b ± 0.13	
LSD ($P \leq 0.05$)	Treatment (MAP) = 0.14 Days (SI) = 0.10 SI x MAP = 0.31					
F value (($P \leq 0.05$)	Treatment (MAP) = 100.06 Days (SI) = 807.75 SI x MAP = 21.98					

Mean values with same alphabets are statistically similar at $p \leq 0.05$ (n =15). Each value represents pooled mean of 2 years (2017 and 2018)



The vertical bar represents standard error (SE) mean of three replicates

FIGURE 1 Effect of packaging fims and storage periods on the protein content (mg/100g) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH. Data are from pooled results of two seasons and represented as the Mean ± Standard Error (S.E.) of the Mean of three replicates.



The vertical bar represents standard error (SE) mean of three replicates

FIGURE 2 Effect of packaging films and storage periods on the total free amino acids (mg/100g) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH. Data are from pooled results of two seasons and represented as the Mean ± Standard Error (S.E.) of the Mean of three replicates.

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Comparative efficacy of packaging films for retaining the bioactive compounds and antioxidants in Kinnow fruits under cold storage

--Manuscript Draft--

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Abstract:	The comparative efficacy of packaging films i.e. polypropylene (PP) and low density polyethylene (LDPE) was evaluated for retaining the bioactive compounds and antioxidants in Kinnow fruits during storage. Uniform and physiologically mature kinnow fruits were packed in PP and LDPE films of 100 and 150gauge thickness, with or without 5 per cent perforation. The control fruits were kept unpacked. The fruits were stored under cold storage conditions at 5-70C and 90-95% RH for 75 days. The stored fruits were periodically assessed for attributes like firmness, pectin, total phenolics, total flavonoids, total carotenoids and total antioxidant activity from the edible portion of Kinnow fruit. Results revealed that fruits packed in PP 100 and LDPE100 gauge films (both perforated) maintained higher firmness, pectin,total phenolics, total flavonoids, total antioxidant activity and total carotenoids content during storage.
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_Arvind Kumar Baswal_____________
(Signature of corresponding author on behalf of all authors)

Comparative efficacy of packaging films for retaining the bioactive compounds and antioxidants in Kinnow fruits under cold storage

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Comparative efficacy of packaging films for retaining the bioactive compounds and antioxidants in Kinnow fruits under cold storage

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Abstract The comparative efficacy of packaging films *i.e*. polypropylene (PP) and low density polyethylene (LDPE) was evaluated for retaining the bioactive compounds and antioxidants in Kinnow fruits during storage. Uniform and physiologically mature kinnow fruits were packed in PP and LDPE films of 100 and 150gauge thickness, with or without 5 per cent perforation. The control fruits were kept unpacked. The fruits were stored under cold storage conditions at 5-7^{0}C and 90-95% RH for 75 days. The stored fruits were periodically assessed for attributes like firmness, pectin, total phenolics, total flavonoids, total carotenoids and total antioxidant activity from the edible portion of Kinnow fruit. Results revealed that fruits packed in PP 100 and LDPE100 gauge films (both perforated) maintained higher firmness, pectin,total phenolics, total flavonoids, total antioxidant activity and total carotenoids content during storage.

Keywords Kinnow. Firmness. Total phenolics. Total antioxidant activity. Total carotenoids. MAP films

Introduction

Kinnow mandarin(*Citrus nobilis*L.x*Citrus deliciosa*L. is known for its health friendly bioactive compounds *viz.*hesperidins, vitamin C, carotenoids, antioxidants,naringin,ferulic acid, hydrocinnamic acid and cyaniding glucoside.When consumed kinnow fruit help in boosting the human immune system against coronary heart diseases, cancer, infections and alsoaidthe absorption of iron and zinc. Being so nutritionally rich,Kinnowis highly sought after fruit inIndian as well as international markets.Kinnow gets matured and harvested during a short span of time ranging from December to February and these months often witnessglut and contribute to huge post-harvest losses of about 35-40 per cent of the produce (Rajput and Haribabu 1995). The viable option to reduce the post-harvest losses under Indian scenario is by extending the marketable period through noble approaches of shelf-life enhancement. Modified atmospheric Packaging (MAP) is an important intervention in post-harvest handling of produce, which not only enhances the shelf life but also maintains the quality and add value to the produce during marketing (Hardenberg 1971; Mangaraj and Goswami 2011)

In previous studies, MAP has shown the positive effects on extending shelf-life and maintaining quality of certain horticultural produce. For instance, table grape (Martinez-Romero *et al* 2003), broccoli (Serrano *et al* 2006) and sweet cherry (Serrano *et al* 2005. MAP consists of sealing a certain amount of fruit or vegetable by using a polymeric plastic films with selective permeability to CO_2, O_2 and water vapour diffusion. Inside packaging materialalteration in CO_2 and O_2 levels occurs due to respiration by commodity placed inside packaging film. These modifications minimize the loss in physiological weight of weight, respiration rate and ethylene production and thereby delay in the senescence process (Artes*et al* 2006). Information on the effect of MAP on the changing behavior of bioactive compounds and nutritive valueof Kinnowfruit during storage is scanty. In the present study an attempt was made to assess the changes in bioactive compounds of Kinnowmandarin using various MAP conditions under cold storage conditions (5-7^{0}C and 90-95% RH).

Materials and Methods

Plant materials

The present study was conducted in the Department of Fruit Science, Punjab Agricultural University, Ludhiana during the consecutive years of 2016-17 and 2017-18. Uniform sized, disease and bruise free kinnow fruits were harvested at optimum maturity in third week of January. The experimental fruits were obtained from uniform and healthy plants selected and maintained under recommended cultural practices at Regional Fruit Research Station, Abohar (Anonymous 2018). The fruits were transported in cushioned crates to the Postharvest laboratory of Department of Fruit Science, Punjab Agricultural University, Ludhiana. The fruits were sorted, graded and washed with chlorine solution (100 ppm). Thereafter fruits were divided into requisite lots (50kg per treatment) for further handling.

Packaging

The experimental fruits was packed in LDPE (Model LD, Sol Pack system) and PP (Model PP, Sol Pack System) of 100 and 150 gauge thickness with or without perforation (5%). Both LDPE and PP bags (41.60cm x 30.8cm and 46.30cm x 30.50cm, respectively) of holding capacity of 12 fruits (250g) were used. For 5 % perforation holes were made in the bags after calculating the exact volume of the bag. The experimental packages were duly labelled before sealing and kept inside cold rooms maintained at 5-7^{0}C and 90-95% RH.

Observations recorded

Disease and bruise free Kinnow fruits of uniform sized were subjected to physico-chemical analysis immediately after harvest (for 0-day data). A representative sample of fruits were taken out periodically to assess the changes in stored fruits from the cold storage at 30, 45, 60 and 75 days.

2.4 Physical and Bioactive compounds determination

Firmness

Firmness of randomly selected fruits (15 from each replication) was measured with the help of a 'Penetrometer' (Tr di turonil Co. Snc. Italy). Fruits were firmly held in the left hand; by holding the fruit tester between thumb and forefinger of right hand, place the plunger (with diameter 7.9 mm) against the fruit press with increasing strength until the plunger tip is penetrated into the Kinnow fruit up to the notch to obtain uniform application of force was recorded in terms Kg force (Kg f).

Pectin, total phenolics, toral flavonoids, total carotenoids and total antioxidant activity

Pectin content determined with slight modifications by gravimetric method described by Ruck (1961). Precipitated pectin was obtained from an acidic solution by adding calcium chloride. The precipitate was thoroughly washed with boiling water to make it chlorine free. Results were expressed as per cent calcium pectate.

Total phenolics were estimated with slight modifications byFolin-Ciocalteu (FC) reagent as described by Bray and Thorpe (1954) and expressed as mg/100g of edible portion.

For the estimation of total flavanoids, 1 ml of methanolic extract of Kinnow pulp was taken in 4 ml of distilled water, 0.5 ml of 5% sodium nitrite ($NaNO_2$) and 0.5 ml of 10% aluminium chloride ($AlCl_3 \cdot 6H2O$). The mixture was allowed to stand for 6 min at room temperature. After adding 2 ml of 1 N NaOH; solution was diluted to 10 ml by using distilled water. Finally, the absorbance of the solution was recorded at 510 nm using spectrophotometer against a reagent blank. The results were expressed as mg catechin equivalent per $100g^{-1}$FW (Zhishen*et al* 1999).

Total carotenoids was determined as described by Gao and Wu (2005). Fruit juice was pulverized in glass mortar, 2 ml of fruit juice was taken in a 25 ml test tube then 7ml solution (petroleum ether : acetone, 1:1) was added , with shaking (100rpm) test tube was soaked in dark for 6 hours. Then absorbance was measured at 445 nmby discarding the lower layer of extract. Total carotenoid content was estimated by using following formula and expressed as mg/100 of edible portion.

$$\text{Total carotenoids (mg/100g)} = \frac{A.y(ml) \times 10^6}{A^{\%}_{1cm} \times 1000 \times g}$$

A- The highest absorbency value of 445nm

y - Quantity of extracting solution

$A^{\%}_{1\,cm}$- Average absorption coefficient 2500 of carotenoid molecule

g- Weight of sample

The total antioxidant activity (TAA) towards the DPPH (2,2-diphenyl-1-picrylhydrazyl) was estimated following method by adding 0.1 ml of Kinnow pulp extract in 3.9 ml aliquot of DPPH solution (0.0780 mM) made in 100 ml of 95% methanol. The mixture was incubated for 30 mins in a dark room. The change in absorbance of the sample was recorded at 517 nm for 30 min against 95%

methanol as reagent blank. Total antioxidant activity was expressed as the percentage inhibition of DPPH radical (Brand-Williams *et al* 1995).

Statistical analysis

Experimetal data were subjected to analysis of variance. The treatment means were compared using the least significant difference (LSD) values at a significance level of $P < 0.05$. The data are analyzed statistically according to completely randomized block design using procedures of the Statistical Analysis System 9.3 (S.A.S. Institute Inc., Cary, NC, USA). Linear regression were performed between total antioxidants and the other bioactive compounds taking into account all sampling data.

Results and Discussion

Firmness

The data on firmness influenced by various packaging films followed a decline with an advancement in storage period (Table 1). The maximum firmness was recorded immediate after harvest (0 day data) i.e. 6.19 ± 0.027kg force which declined with further prolongation in storage period thereby retained the lowest firmness after 75 days of storage (3.06 ±0.056 kg f). The highest mean firmness was maintained in the fruits packed in perforated PP 100 gauge film (5.44 ± 0.27 kg force) followed by perforated LDPE 100 gauge film (5.43 ± 0.20kg force) while, control fruits retained the lowest mean firmness (4.21 ± 0.21kg force). The interaction between packaging films and storage interval was found to be significant. The softening of fruits during storage attributed to degradation of soluble pectin due to high activity of endo-polygalacturonase enzyme in fruits (Martin-Cabrejas*et al* 1994). Higher firmness maintained by the fruits packed in perforated PP 100 and perforated LDPE 100 gauge films might be due to maintenance of high humidity inside the packaging films, helps in reducing the transpiration loss and respiratory activity thus maintained turgidity of the cells. These results are in corroboration with the findings of Nath *et al* (2012) who recorded the highest firmness in pear fruits packed in perforated PP followed by non-perforated LDPE film after 12 days of storage. Similar findings were reported in mango cv. ‘Alphonso and Banganapalli’ (Rao and Shivashankara 2015). Likewise, Mahajan and Singh (2014) reported that fruits of Kinnow wrapped in shrink film maintained the higher firmness than that of unpacked ones during storage. Similar results were obtained in apple (Sharma *et al* 2013).

Table 1 Effect of packaging conditions and storage intervals on the firmness (kg f) per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	6.19	5.19	4.84	4.19	3.25	4.73±0.18^e
LDPE 150 gauge	6.19	5.95	4.94	3.59	2.70	4.68±0.25^e
LDPE 100 gauge with 5% perforation	6.19	6.50	6.10	4.58	3.78	5.43±0.20^a
LDPE 150 gauge with 5% perforation	6.19	6.50	6.30	4.17	3.37	5.31±0.24^b
PP 100 gauge	6.19	4.83	4.57	4.49	2.80	4.58±0.20^f

PP 150 gauge	6.19	6.01	5.06	4.44	2.72	4.88±0.23[d]
PP 100 gauge with 5% perforation	6.19	7.29	6.21	4.19	3.33	5.44±0.27[a]
PP 150 gauge with 5% perforation	6.19	7.07	5.67	4.25	2.57	5.15±0.29[c]
Control	6.19	4.54	3.93	3.39	3.01	4.21±0.21[g]
Mean±SE	6.19±0.027[a]	5.99±1.13[b]	5.29±0.11[c]	4.14±0.055[d]	3.06±0.056[e]	
LSD (P≤0.05)	Treatment (MAP) = 0.096 Days (SI) = 0.072 SI x MAP = 0.21					
F value ((P≤0.05)	Treatment (MAP) = 152.78 Days (SI) = 2640.58 SI x MAP = 43.33					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Pectin (Ca pectate %)

Irrespective of all the treatments, pectin content followed a decline with prolongation in storage period (Table 2). In general, the highest pectin content was noticed immediate after harvest (0 days data) i.e.0.65 ±0.021 per cent thereafter; a gradual decline in pectin was noticed till the end of the storage i.e. 0.16± 0.00043 per cent after 75 days of storage. However, the highest mean pectin (0.41±0.037 per cent) content was maintained in the fruits packed in perforated PP 100 gauge film followed by perforated LDPE 100 gauge film (0.40 ± 0.039 per cent). On the other hand, control fruits followed an abrupt decline in pectin content thereby retained the lowest mean pectin (0.34 ±0.040%) content. All the packaging films significantly maintained the higher pectin content in contrast to unpacked fruits. The interaction between packaging films and storage interval was found to be significant. The decline in pectin content may be attributed to degree of fruit ripening particularly affected the pectin contents, which supports the hypothesis that softening is closely related to pectin solubilisation and depolymerization (Kurz*et al* 2008 and Rosli*et al* 2004).These results are in conformity to the findings of Mohammed *et al* (1996) who reported that fruits of ‘sapota’ wrapped in LDPE films maintained higher insoluble pectin content over wrapped in shrink film and unwrapped fruits. Similar findings were also reported in apple (Tavakoli and Wiley 1968). Likewise, Schreiner *et al* (2003) also noticed higher soluble pectin content in radish wrapped in OPP-Coex-film packaging film (Antifog film).

Table 2 Effect of packaging conditions and storage intervals on the pectin (Ca pectate %) content of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	0.65	0.49	0.35	0.21	0.16	0.37±0.038[d]
LDPE 150 gauge	0.65	0.48	0.26	0.22	0.18	0.36±0.040[e]
LDPE 100 gauge with 5% perforation	0.65	0.57	0.34	0.27	0.16	0.40±0.039[a]
LDPE 150 gauge with 5% perforation	0.65	0.54	0.34	0.28	0.15	0.39±0.039[b]
PP 100 gauge	0.65	0.46	0.30	0.23	0.12	0.35±0.039[e]
PP 150 gauge	0.65	0.54	0.34	0.23	0.15	0.38±0.041[c]
PP 100 gauge	0.65	0.53	0.36	0.32	0.19	0.41±0.037[a]

with 5% perforation						
PP 150 gauge with 5% perforation	0.65	0.52	0.34	0.28	0.16	0.39±0.038^{bc}
Control	0.65	0.44	0.25	0.21	0.13	0.34±0.040^{f}
Mean±SE	0.65±0.021^{a}	0.51±0.024^{b}	0.32±0.011^{c}	0.25±0.00071^{d}	0.16±0.00043^{e}	
LSD (P≤0.05)	Treatment (MAP) = 0.00091 Days (SI) = 0.00068 SI x MAP =0.020					
F value ((P≤0.05)	Treatment (MAP) = 53.53 Days (SI) = 6658.41 SI x MAP = 11.89					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Total phenolics (mg/100g)

Total phenolics content decreased with an advancement in storage period (Table 3). In general, total phenolics content ranged from 129.98 ± 0.63to30.77 ± 1.30 mg/100g pulp from the day of harvest to till 75 days of storage. Fruits packed in perforated PP 100 gauge film maintained the highest mean total phenolics (126.39 ± 10.40mg/100g pulp) content followed by perforated LDPE 100 gauge film (121.91 ±11.15mg/100g pulp).The lowest mean total phenolics content was retained in the unpacked fruits (89.65 ±7.15mg/100g pulp). The interaction between different packaging films and storage conditions was found to be significant. MAP films coupled with low temperature storage conditions delayed a decrease in total phenolics content; might be due to MAP conditions (low O_2 and high CO_2) retards the postharvest ripening by low ethylene production, fruit softening, colour change and acidity loss (Diaz-Mula *et al* 2011). The results are in agreement with the findings of Mohebbi*et al* (2015) who reported that cherry fruits cv. Comalian packed in perforated LDPE and PP polymeric films delayed an increase in total phenolics content than that of unpacked. Likewise,Rana*et al* (2015) found that guava fruits wrapped in cling and shrink films delayed a decline in total phenolics content. an advancement in storage period. Similar results were also noticed in stonefruit such sweet cherry, peach and nacterine (Di Vaio*et al* 2008; Diaz-Mula*et al* 2009 and Serrano *et al* 2009).

Table 3 Effect of packaging conditions and storage intervals on the total phenolics (mg/100g) content of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean ±SE
LDPE 100 gauge	129.98	212.96	110.48	80.89	42.90	115.45 ±10.79^{d}
LDPE 150 gauge	129.98	165.32	153.80	90.77	20.56	112.09 ±9.76^{e}
LDPE 100 gauge with 5% perforation	129.98	185.05	180.41	89.04	25.08	121.91 ±11.15^{b}
LDPE 150 gauge with 5% perforation	129.98	196.03	146.56	89.75	38.25	120.12±10.04^{bc}
PP 100 gauge	129.98	158.77	94.72	71.56	18.68	94.74 ±9.00^{f}
PP 150 gauge	129.98	211.18	115.21	82.52	40.63	115.91±10.74^{d}
PP 100 gauge with 5% perforation	129.98	191.15	163.90	120.19	26.74	126.39 ±10.40^{a}
PP 150 gauge	129.98	193.33	148.57	87.23	36.92	119.21±10.06^{c}

with 5% perforation						
Control	129.98	126.93	93.94	70.27	27.11	89.65 ±7.15^{g}
Mean ±SE	129.98±0.63^{c}	182.30±3.96^{a}	134.18±4.22^{b}	86.91±2.03^{d}	30.77±1.30^{e}	
LSD (P≤0.05)	Treatment (MAP) =2.53 Days (SI) = 1.88 SI x MAP = 5.66					
F value ((P≤0.05)	Treatment (MAP) = 188.77 Days (SI) = 7106.22 SI x MAP = 76.69					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Total flavonoids (mg/100g)

During storage total flavonoids content increased till 30 days of storage; thereafter a gradual decline was noticed till the end of the storage i.e. 75 days of storage (Table 4). The highest mean flavonoids (74.05 ± 4.33mg/100g pulp) content was maintained in the fruits packed in perforated PP 100 gauge film followed by perforated LDPE 100 gauge film (68.64 ± 4.02mg/100g pulp). However, unpacked (control) fruits retained the lowest mean flavonoids (54.24 ± 3.99mg/100g pulp) content). It was noticed that all the MAP delayed a decline in flavonoids content. The interaction between packaging films and storage interval was found to be significant. The results are in conformity with the findings of Rao and Shivshankara (2015) who found that mango fruits cv Alphonso and Banganapalli maintained the higher content of flavonoids in contrast to unwrapped fruits.

Table 4 Effect of packaging conditions and storage intervals on the total flavonoids (mg/100g) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	57.95	83.90	71.51	63.90	38.06	63.07±2.89^{de}
LDPE 150 gauge	57.95	75.62	72.02	70.92	37.96	62.90 ±2.62^{e}
LDPE 100 gauge with 5% perforation	57.95	108.13	71.49	60.28	45.37	68.64±4.02^{b}
LDPE 150 gauge with 5% perforation	57.95	99.00	69.34	54.96	51.78	66.61 ±3.27^{c}
PP 100 gauge	57.95	74.23	70.81	49.60	41.83	58.89 ±2.33^{f}
PP 150 gauge	57.95	96.60	66.79	65.27	35.18	64.36±3.71^{d}
PP 100 gauge with 5% perforation	57.95	102.94	93.48	75.73	40.15	74.05 ±4.33^{a}
PP 150 gauge with 5% perforation	57.95	85.61	67.37	64.05	47.27	64.45 ±2.42^{d}
Control	57.95	85.42	64.93	38.84	24.05	54.24 ±3.99^{g}
Mean±SE	57.95 ±0.44^{d}	90.16 ±1.70^{a}	71.97±1.17^{b}	60.40±1.51^{c}	40.19±1.07^{e}	
LSD (P≤0.05)	Treatment (MAP) = 1.39 Days (SI) = 1.03 SI x MAP = 3.10					
F value ((P≤0.05)	Treatment (MAP) = 128.03 Days (SI) = 2485.44 SI x MAP = 49.88					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Total carotenoids (mg/100g)

Total carotenoids increased initially thereafter; followed a gradual decline with further prolongation in storage period (Table 5). Among all the storage intervals, the highest carotenoid (0.61± 0.011mg/100g pulp) content was recorded after 30 days of storage whereas, the lowest accumulation of carotenoids (0.24 ± 0.00098mg/100g) content was registered after 75 days of storage. However, fruits packed in perforated PP 100 gauge film maintained the highest mean carotenoids (0.53 ± 0.024mg/100g pulp) content followed by perforated LDPE 100 gauge film (0.45 ± 0.031mg/100g pulp). On the other hand, unpacked fruits maintained the lowest carotenoids (0.35 ± 0.029 mg/100g) content. All the MAP films delayed a decline in total carotenoids content. The interaction between packaging films and storage interval was found to be significant. The results are in conformity to the findings of Mahajan and Singh (2014) who reported that shrink wrapped Kinnow fruits registered an increase in carotenoid content up to 15 days of storage. Similar findings were also noticed in mango cv. ‘Alphonso and ‘Banganapalli’ (Rao and Shivshankara 2015). Muftuoglu *et al* (2012) who, however, registered no significant effects of packaging atmosphere and packaging material on total carotenoid content in apricot.

Table 5 Effect of packaging conditions and storage intervals on the total carotenoids (mg/100g) content of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	0.42	0.52	0.48	0.30	0.19	0.38 ±0.023^{f}
LDPE 150 gauge	0.42	0.57	0.36	0.26	0.24	0.37±0.024^{ef}
LDPE 100 gauge with 5% perforation	0.42	0.64	0.61	0.31	0.23	0.45 ±0.031^{b}
LDPE 150 gauge with 5% perforation	0.42	0.60	0.52	0.35	0.25	0.43±0.023^{c}
PP 100 gauge	0.42	0.53	0.35	0.27	0.26	0.37 ±0.021^{g}
PP 150 gauge	0.42	0.56	0.45	0.35	0.18	0.40 ±0.024^{e}
PP 100 gauge with 5% perforation	0.42	0.76	0.53	0.49	0.41	0.53 ±0.024^{a}
PP 150 gauge with 5% perforation	0.42	0.71	0.47	0.23	0.22	0.41±0.034^{d}
Control	0.42	0.59	0.35	0.23	0.15	0.35±0.029^{h}
Mean ±SE	0.42±0.00078^{c}	0.61±0.011^{a}	0.46±0.012^{b}	0.31±0.011^{d}	0.24 ±0.00098^{e}	
LSD (P≤0.05)	Treatment (MAP) =0.00091 Days (SI) = 0.00068 SI x MAP = 0.020					
F value (P≤0.05)	Treatment (MAP) = 266.23 Days (SI) = 3493.20 SI x MAP = 60.84					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Total Antioxidant activity (%)

TAA followed a gradual decline with an advancement in storage period (Table 6). At harvest (0 day data) highest TAA (26.60 ±0.27 per cent) was recorded which declined thereafter with an advancement in storage period thereby registered lowest carotenoid content at the end of the storage i.e. 75 days of storage (9.86 ±0.25 per cent). Among different MAP films, fruits packed in perforated PP 100 gauge maintained the highest mean TAA (19.62 ± 1.10%) followed by perforated LDPE 100 gauge (19.20 ± 1.14 per cent). On the other hand, unwrapped fruits retained the lowest mean TAA (15.28 ± 1.36%). During storage unpacked fruits followed an abrupt decline in TAA at faster pace in contrast to fruits packed into MAP films. Thus all the MAP films delayed the decline in TAA during storage. The interaction between packaging films and storage was found to be significant. These results are in conformity to the findings of Rao and Shivshankara (2015) who reported that mango fruits cv Alphonso and Banganapalli wrapped in D-955 and LD-935 films maintained higher FRAP and DPPH values, respectively than that of LDPE film.

Table 6 Effect of packaging conditions and storage intervals on the total antioxidants (%) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean ±SE
LDPE 100 gauge	26.60	22.76	18.41	13.66	8.51	17.99 ±1.23^d
LDPE 150 gauge	26.60	23.52	18.58	12.13	8.22	17.81 ±1.30^{de}
LDPE 100 gauge with 5% perforation	26.60	25.03	18.51	14.80	11.03	19.20 ±1.14^b
LDPE 150 gauge with 5% perforation	26.60	24.04	17.16	13.92	11.53	18.65 ±1.11^c
PP 100 gauge	26.60	23.37	17.51	12.07	8.63	17.64±1.28^e
PP 150 gauge	26.60	25.46	17.28	11.51	11.28	18.43 ±1.25^c
PP 100 gauge with 5% perforation	26.60	25.18	19.31	15.35	11.63	19.62 ±1.10^a
PP 150 gauge with 5% perforation	26.60	23.85	15.90	14.93	11.43	18.54 ±1.13^c
Control	26.60	19.59	13.81	9.90	6.50	15.28±1.36^f
Mean ±SE	26.60±0.27^a	23.65±0.42^b	17.39 ±0.29^c	13.14±0.26^d	9.86±0.25^e	
LSD (P≤0.05)	Treatment (MAP) =0.33 Days (SI) = 0.24 SI x MAP = 0.73					
F value ((P≤0.05)	Treatment (MAP) = 112.22 Days (SI) = 6411.86 SI x MAP = 19.05					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Linear Regression

Taking into account data for all packaging films and storage intervals, a positive correlation was observed between total antioxidants and pectin content (5.12 + 34.527*Pectin; R^2 = 0.95) (Fig 1.), between total antioxidants and firmness (5.12 + 34.527* Firmness, R^2 = 0.80) (Fig 2.) and between Total antioxidants and total phenols (5.12 + 34.527* Total phenols, R^2 = 0.64) (Fig 3). Similar findings on correlation between total phenolics and total antioxidants were also reported in peach, plum, nacterine and sweet cherry (Gill *et al* 2002; Cevallos-Casals *et al* 2006; Rupasinghe *et al* 2006; Vizzotto *et al* 2007 and Diaz-Mula *et al* 2008).

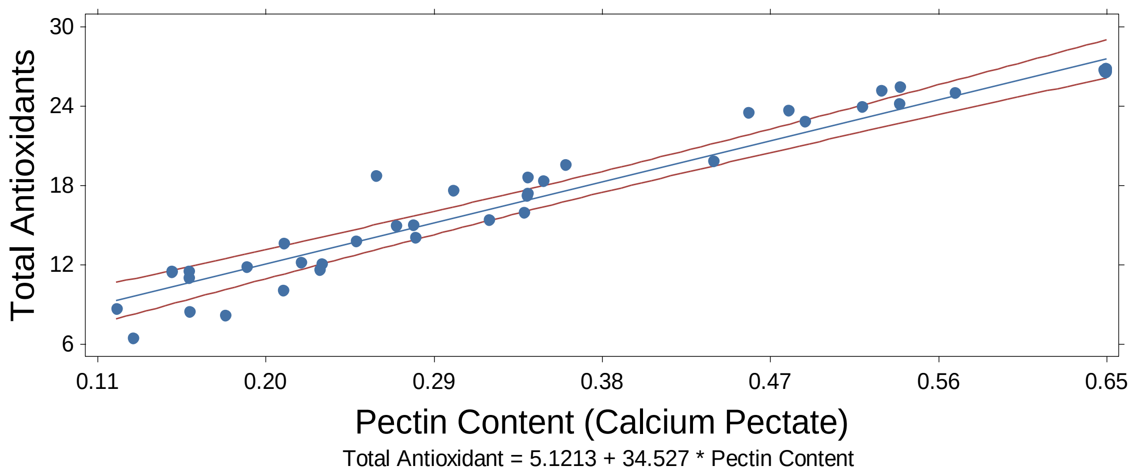

Fig. 1 Linear regression between Total antioxidants and pectin (Ca pectate) content

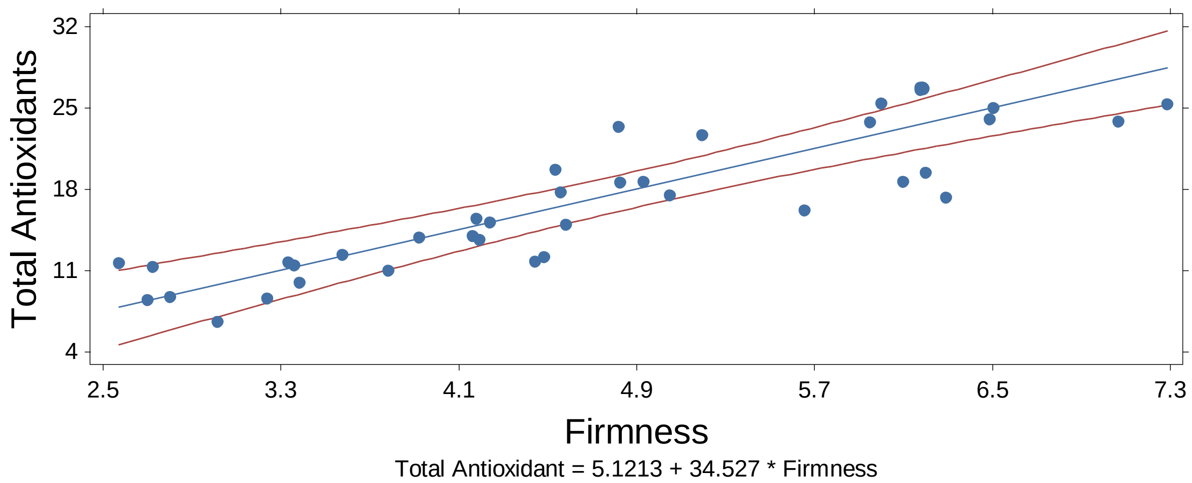

Fig. 2 Linear regression between Total antioxidants and firmness

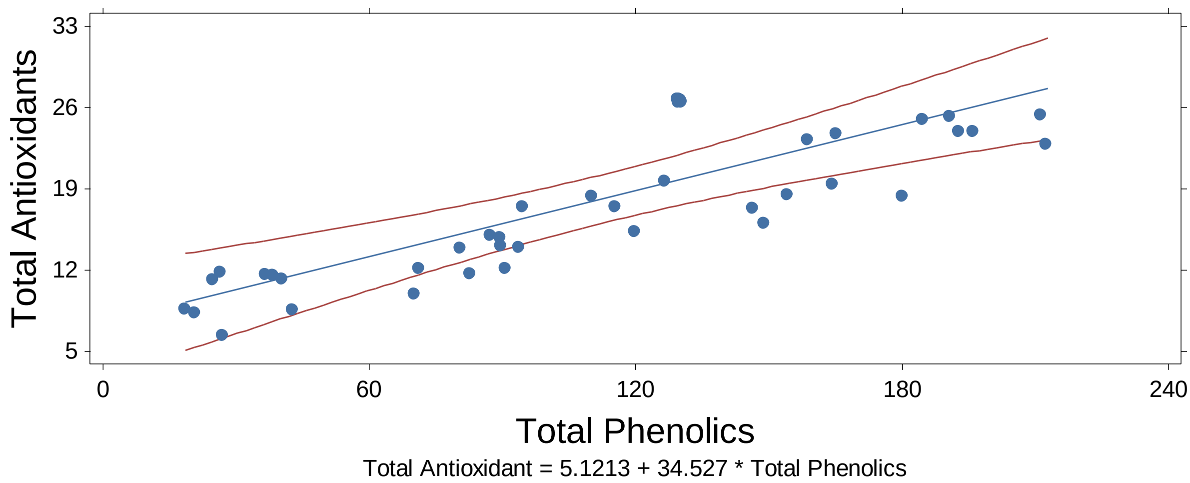

Fig. 3 Linear regression between Total antioxidants and total phenolics content

Conclusion

Results suggest that MAP films delayed the fruit senescence process despite maintaining physical and bioactive attributes. Packaging of Kinnow fruits in different MAP films helped in retaining and maintaining higher content of phenolics, total antioxidants and carotenoids content in contrast to unpacked fruit

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Table

Table 1 Effect of packaging conditions and storage intervals on the firmness (kg f) per cent of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	6.19	5.19	4.84	4.19	3.25	4.73±0.18^e
LDPE 150 gauge	6.19	5.95	4.94	3.59	2.70	4.68±0.25^e
LDPE 100 gauge with 5% perforation	6.19	6.50	6.10	4.58	3.78	5.43±0.20^a
LDPE 150 gauge with 5% perforation	6.19	6.50	6.30	4.17	3.37	5.31±0.24^b
PP 100 gauge	6.19	4.83	4.57	4.49	2.80	4.58±0.20^f
PP 150 gauge	6.19	6.01	5.06	4.44	2.72	4.88±0.23^d
PP 100 gauge with 5% perforation	6.19	7.29	6.21	4.19	3.33	5.44±0.27^a
PP 150 gauge with 5% perforation	6.19	7.07	5.67	4.25	2.57	5.15±0.29^c
Control	6.19	4.54	3.93	3.39	3.01	4.21±0.21^g
Mean±SE	6.19±0.027^a	5.99±1.13^b	5.29±0.11^c	4.14±0.055^d	3.06±0.056^e	
LSD (P≤0.05)	Treatment (MAP) = 0.096 Days (SI) = 0.072 SI x MAP = 0.21					
F value ((P≤0.05)	Treatment (MAP) = 152.78 Days (SI) = 2640.58 SI x MAP = 43.33					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 2 Effect of packaging conditions and storage intervals on the pectin (Ca pectate %) content of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	0.65	0.49	0.35	0.21	0.16	0.37±0.038^d
LDPE 150 gauge	0.65	0.48	0.26	0.22	0.18	0.36±0.040^e
LDPE 100 gauge with 5% perforation	0.65	0.57	0.34	0.27	0.16	0.40±0.039^a
LDPE 150 gauge with 5% perforation	0.65	0.54	0.34	0.28	0.15	0.39±0.039^b
PP 100 gauge	0.65	0.46	0.30	0.23	0.12	0.35±0.039^e
PP 150 gauge	0.65	0.54	0.34	0.23	0.15	0.38±0.041^c
PP 100 gauge with 5% perforation	0.65	0.53	0.36	0.32	0.19	0.41±0.037^a
PP 150 gauge with 5% perforation	0.65	0.52	0.34	0.28	0.16	0.39±0.038^{bc}
Control	0.65	0.44	0.25	0.21	0.13	0.34±0.040^f
Mean±SE	0.65±0.021^a	0.51±0.024^b	0.32±0.011^c	0.25±0.00071^d	0.16±0.00043^e	
LSD (P≤0.05)	Treatment (MAP) = 0.00091 Days (SI) = 0.00068 SI x MAP =0.020					
F value ((P≤0.05)	Treatment (MAP) = 53.53 Days (SI) = 6658.41 SI x MAP = 11.89					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 3 Effect of packaging conditions and storage intervals on the total phenolics (mg/100g) content of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean ±SE
LDPE 100 gauge	129.98	212.96	110.48	80.89	42.90	115.45 ±10.79^d
LDPE 150 gauge	129.98	165.32	153.80	90.77	20.56	112.09 ±9.76^e

LDPE 100 gauge with 5% perforation	129.98	185.05	180.41	89.04	25.08	121.91 ±11.15^{b}
LDPE 150 gauge with 5% perforation	129.98	196.03	146.56	89.75	38.25	120.12±10.04^{bc}
PP 100 gauge	129.98	158.77	94.72	71.56	18.68	94.74 ±9.00^{f}
PP 150 gauge	129.98	211.18	115.21	82.52	40.63	115.91±10.74^{d}
PP 100 gauge with 5% perforation	129.98	191.15	163.90	120.19	26.74	126.39 ±10.40^{a}
PP 150 gauge with 5% perforation	129.98	193.33	148.57	87.23	36.92	119.21±10.06^{c}
Control	129.98	126.93	93.94	70.27	27.11	89.65 ±7.15^{g}
Mean ±SE	129.98±0.63^{c}	182.30±3.96^{a}	134.18±4.22^{b}	86.91±2.03^{d}	30.77±1.30^{e}	
LSD (P≤0.05)	Treatment (MAP) =2.53 Days (SI) = 1.88 SI x MAP = 5.66					
F value ((P≤0.05)	Treatment (MAP) = 188.77 Days (SI) = 7106.22 SI x MAP = 76.69					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 4 Effect of packaging conditions and storage intervals on the total flavonoids (mg/100g) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	57.95	83.90	71.51	63.90	38.06	63.07±2.89^{de}
LDPE 150 gauge	57.95	75.62	72.02	70.92	37.96	62.90 ±2.62^{e}
LDPE 100 gauge with 5% perforation	57.95	108.13	71.49	60.28	45.37	68.64±4.02^{b}
LDPE 150 gauge with 5% perforation	57.95	99.00	69.34	54.96	51.78	66.61 ±3.27^{c}
PP 100 gauge	57.95	74.23	70.81	49.60	41.83	58.89 ±2.33^{f}
PP 150 gauge	57.95	96.60	66.79	65.27	35.18	64.36±3.71^{d}
PP 100 gauge with 5% perforation	57.95	102.94	93.48	75.73	40.15	74.05 ±4.33^{a}
PP 150 gauge with 5% perforation	57.95	85.61	67.37	64.05	47.27	64.45 ±2.42^{d}
Control	57.95	85.42	64.93	38.84	24.05	54.24 ±3.99^{g}
Mean±SE	57.95 ±0.44^{d}	90.16 ±1.70^{a}	71.97±1.17^{b}	60.40±1.51^{c}	40.19±1.07^{e}	
LSD (P≤0.05)	Treatment (MAP) = 1.39 Days (SI) = 1.03 SI x MAP = 3.10					
F value ((P≤0.05)	Treatment (MAP) = 128.03 Days (SI) = 2485.44 SI x MAP = 49.88					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 5 Effect of packaging conditions and storage intervals on the total carotenoids (mg/100g) content of Kinnow fruit stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean±SE
LDPE 100 gauge	0.42	0.52	0.48	0.30	0.19	0.38 ±0.023^{f}
LDPE 150 gauge	0.42	0.57	0.36	0.26	0.24	0.37±0.024^{ef}
LDPE 100 gauge with 5% perforation	0.42	0.64	0.61	0.31	0.23	0.45 ±0.031^{b}
LDPE 150 gauge with 5% perforation	0.42	0.60	0.52	0.35	0.25	0.43±0.023^{c}
PP 100 gauge	0.42	0.53	0.35	0.27	0.26	0.37 ±0.021^{g}

PP 150 gauge	0.42	0.56	0.45	0.35	0.18	0.40 ±0.024[e]
PP 100 gauge with 5% perforation	0.42	0.76	0.53	0.49	0.41	0.53 ±0.024[a]
PP 150 gauge with 5% perforation	0.42	0.71	0.47	0.23	0.22	0.41±0.034[d]
Control	0.42	0.59	0.35	0.23	0.15	0.35±0.029[h]
Mean ±SE	0.42±0.00078[c]	0.61±0.011[a]	0.46±0.012[b]	0.31±0.011[d]	0.24 ±0.00098[e]	
LSD (P≤0.05)	Treatment (MAP) =0.00091 Days (SI) = 0.00068 SI x MAP = 0.020					
F value (P≤0.05)	Treatment (MAP) = 266.23 Days (SI) = 3493.20 SI x MAP = 60.84					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Table 6 Effect of packaging conditions and storage intervals on the total antioxidants (%) of Kinnow fruits stored at 5-7^{0}C and 90-95% RH

	Storage interval (Days)					
MAP films	0	30	45	60	75	Mean ±SE
LDPE 100 gauge	26.60	22.76	18.41	13.66	8.51	17.99 ±1.23[d]
LDPE 150 gauge	26.60	23.52	18.58	12.13	8.22	17.81 ±1.30[de]
LDPE 100 gauge with 5% perforation	26.60	25.03	18.51	14.80	11.03	19.20 ±1.14[b]
LDPE 150 gauge with 5% perforation	26.60	24.04	17.16	13.92	11.53	18.65 ±1.11[c]
PP 100 gauge	26.60	23.37	17.51	12.07	8.63	17.64±1.28[e]
PP 150 gauge	26.60	25.46	17.28	11.51	11.28	18.43 ±1.25[c]
PP 100 gauge with 5% perforation	26.60	25.18	19.31	15.35	11.63	19.62 ±1.10[a]
PP 150 gauge with 5% perforation	26.60	23.85	15.90	14.93	11.43	18.54 ±1.13[c]
Control	26.60	19.59	13.81	9.90	6.50	15.28±1.36[f]
Mean ±SE	26.60±0.27[a]	23.65±0.42[b]	17.39 ±0.29[c]	13.14±0.26[d]	9.86±0.25[e]	
LSD (P≤0.05)	Treatment (MAP) =0.33 Days (SI) = 0.24 SI x MAP = 0.73					
F value ((P≤0.05)	Treatment (MAP) = 112.22 Days (SI) = 6411.86 SI x MAP = 19.05					

Mean values with same alphabets are statistically similar at p ≤ 0.05 (n =15). Each value represents pooled mean of 2 years (2017 and 2018)

Figure

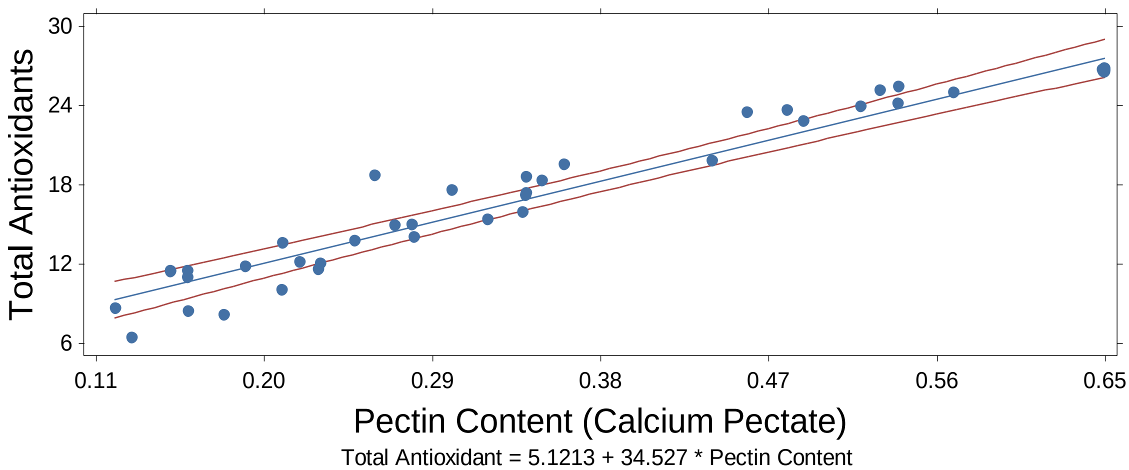

Fig. 1 Linear regression between Total antioxidants and pectin (Ca pectate) content

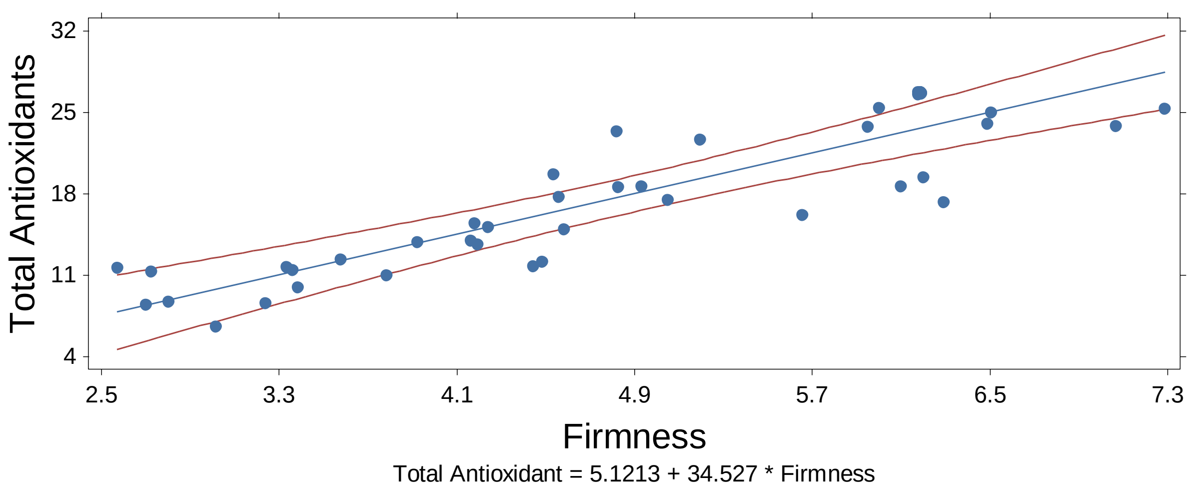

Fig. 2 Linear regression between Total antioxidants and firmness

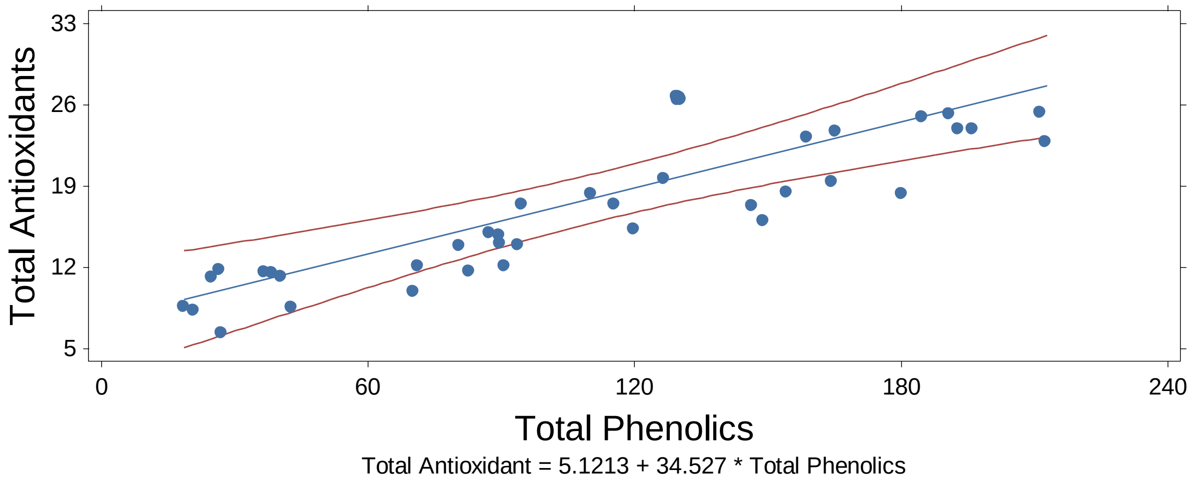

Fig. 3 Linear regression between Total antioxidants and total phenolics content

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Title of the article

Comparative efficacy of packaging film for retaining the bioactive compounds and antioxidants in Kinnow fruits under cold storage

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Date

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VITA

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