EFFECT OF MODIFIED ATMOSPHERE PACKAGING AND EDIBLE WAX COATING ON SHELF LIFE OF MANGO

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled **''EFFECT OF MODIFIED ATMOSPHERE PACKAGING AND EDIBLE WAX COATING ON SHELF LIFE OF MANGO (*Mangifera indica*)"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another University or Society.

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SYMBOLS AND ABBREVIATIONS

APEDA	Agricultural and Processed Food Products Export Development Authority
ºBrix	Degree Brix
CO_2	Carbon di-oxide
ºC	ºCelcius
Cm	Centimeter
CA	Controlled Atmosphere
CAS	Controlled Atmospheric Storage
EMA	Equillibrium modified atmosphere
et al.,	and others
etc.	et cetra
Fig.	Figure
G	gram
Hrs	hour(s)

i.e.	that is
K.C.A.E.T	Kelappaji College of Agricultural Engineering and Technology
Kg	Kilogram
LDPE	Low Density Poly Ethylene
MA	Modified Atmosphere
MAP	Modified Atmosphere Packaging
M.C	Moisture Content
Mg	Milligram
Mm	Millimeter
Ml	Milliliter
MT	Million Tonnes
O_2	Oxygen
PAM	Passive Atmosphere Modification
PLW	Physiological Loss in Weight

PP	Poly Propylene
PVC	Poly Vinyl Chloride
TSS	Total Soluble Solids
UK	United Kingdom
USDA	United State Department of Agriculture
Viz	Namely
w/w	Weight by weight
Wb	Wet basis
%	Percent
/	Per
≈	Approximately

Introduction

Chapter 1

INTRODUCTION

Fruits and vegetables provide health benefits and are important for the prevention of illnesses. Fruits and vegetables contain a variety of nutrients including vitamins, minerals and antioxidants. Eating the recommended amount of fruits and vegetables each day can reduce the risk of chronic diseases. They have gained increasing importance among nutrition specialists, food scientists and consumers since frequent consumption of fruits reduces the risk of certain cardiovascular diseases and cancer (Liu, 2003). An estimated 6.7 million deaths worldwide were attributed to inadequate fruit and vegetable consumption in 2010 (Lim, 2010). In the recent years the demand for both fresh and processed fruits and vegetables have been substantial, and this trend is likely to continue in the future. This increase can be met by either increasing their production or by adopting suitable processing and packaging technologies for its preservation.

India's diverse climate ensures availability of all varieties of fresh fruits & vegetables. It ranks second in fruits and vegetables production in the world, after China. As per National Horticulture Database published by National Horticulture Board, during 2012-13 India produced 81.285 million metric tonnes of fruits and 162.19 million metric tonnes of vegetables. The area under cultivation of fruits stood at 6.98 million hectares while vegetables were cultivated at 9.21 million hectares. The major destinations for Indian fruits and vegetables are UAE, Bangladesh, Malaysia, UK, Netherland, Pakistan, Saudi Arabia, Sri Lanka and Nepal (APEDA, 2008).

Mangoes (*Mangifera indica*) are an important tropical fruit crop with good potential for expanded markets outside of the growing regions. The majority of this species are found in nature as wild mangoes. They all belong to the flowering plant family Anacardiaceae. The mango is native to south and southeast Asia, from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. Mango fruits are climacteric and ripen rapidly after harvest (in about 3 to 9 days).This short period seriously limits the long distance commercial transport of this fruit (Gomer and Lim, 1997). Fruit sensitivity to decay, low temperature and general fruit perishability due to the rapid ripening and softening limits the storage, handling and transport potential. Hence, treatments which would reduce the rate of mango ripening during distribution and allow the development of good quality in ripe fruit could help expand markets for mangoes. CA storage has been shown to extend the shelflife of mango (Bender *et al.*, 2000; Noomhorn and Tiasuwan, 1995) but it is cost prohibitive. So, there is a need to develop cheap and commonly available technology for extending the shelflife of these produce at least to manage the movement in the market change and control the losses.

Though India is the largest producer of fruits and vegetables, it processes only less than 2.5% of the huge production as compared to 70-83% in advanced countries (Akhila and Sharina, 2009). The postharvest losses in India is estimates to be around 5.8-18% which is valued over Rs. 27,500 crores annually (Nanda *et al*., 2012). If we reduce even 1% of these loss, that would save about Rs. 900 crores. Though postharvest management technology is available in certain sectors, the supply chain inefficiency and inadequate infrastructure are the main causes for such wastages. Fresh fruits and vegetables normally have an elaborate spoilage microflora, due to intensive contact with various types of microorganisms during growth and postharvest handling (Gorris, 1992). In addition to this highly perishable nature of fruits and vegetables due to their high water content makes them susceptible to desiccation, mechanical injury and pathological breakdown. This results in changes in texture, colour, flavor and nutritional value of food. These changes can render food unpalatable and potentially unsafe for human consumption.

Modified atmosphere packaging (MAP) is the enclosure of food in a package in which the atmosphere inside the package is modified or altered to provide an optimum atmosphere for increasing shelflife and maintaining quality of food (Robertson, 2006). Passive modification occurs as a consequence of the food's respiration or the metabolism of micro organisms associated with the food; the package structure normally incorporates a polymeric film and so the permeation of gases through the film (which varies depending on the nature of the film and the storage temperature) also influences the composition of atmosphere that develops (Robertson, 2006).

Edible coatings are used to create a MA and to reduce weight loss during transport and storage (Baldwin, 1994). MA storage using plastic bags or wrapping has shown some delay in ripening (Nakasone and Paull, 1998). Protective films modify the fruit's internal atmosphere and have great potential as shelflife extending treatment for many fruit species (Saftner, 1999; Arjona *et al*., 1994; Nisperos-Carriedo *et al*., 1990; Kader *et al*., 1989; Ben-Yehoshua, 1978). Film treatments function as barriers against water vapour, gases etc.

Due to heavy postharvest losses there is an urgent need to adopt practices such as improved packaging, handling, etc. Packaging is required to keep the mangoes in good condition until these are sold and consumed and it serves as an efficient handling unit to carry produce from field to consumer. The packaging should also protect the produce from rotting and from possible damages. Polythene films with higher gas permeabilities than those previously evaluated are now available and have shown some advantages for increasing postharvest shelflife of mangoes without negative effect on quality. In order to study the suitability of packaging materials and wax coating a study was undertaken in K. C. A. E. T., Tavanur with the following objectives:

- To study the suitability of various packaging methods for extending the Shelflife of mango
- To study the effect of edible wax coating on shelflife extension.
- To analyse the postharvest quality parameter of the stored mango.

Review of Literature

Chapter 2

REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various research workers related to the present study that gives general information on mango, its physicochemical characteristics and its storage studies.

2.1 MANGO

2.1.1 History and distribution

The mango is a juicy stone fruit belonging to the genus Mangifera, consisting of numerous tropical fruiting trees, cultivated mostly for edible fruit. The majority of these species are found in nature as wild mangoes. They all belong to the flowering plant family Anacardiaceae. The mango is native to South Asia, from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. The center of diversity of the Mangifera genus is in India (Morton J, 1987).

Mangoes have been cultivated in South Asia for thousands of years (Ensminger, 1995) and reached East Asia between the fifth and fourth centuries BC. By the 10th century AD, cultivation had begun in East Africa (Ensminger, 1995). The mango is now cultivated in most frost-free tropical and warmer subtropical climates; almost half of the world's mangoes are cultivated in India alone, with the second-largest source being China (Jedele *et al*., 2003).

2.1.2 Morphological characteristics

Mango trees grow up to 35–40 m tall, with a crown radius of 10 m. The trees are long lived, as some specimens still fruit after 300 years. The leaves are evergreen, alternate, simple, 15– 35 cm long, and 6–16 cm broad; when the leaves are young they are orange-pink, rapidly changing to a dark, glossy red, then dark green as they mature.

The flowers are produced in terminal panicles 10–40 cm long; each flower is small and white with five petals 5–10 mm long, with a mild, sweet odour suggestive of lily of the valley. Over 400 varieties of mangoes are known, many of which ripe in summer, while some give double crop.

The ripe fruit varies in size and color. Cultivars are variously yellow, orange, red, or green, and carry a single flat, oblong pit that can be fibrous or hairy on the surface, and which does not separate easily from the pulp. Ripe, unpeeled mangoes give off a distinctive resinous, sweet smell. Inside the pit 1–2 mm thick is a thin lining covering a single seed, 4–7 cm long. The seed contains the plant embryo. Mangoes have recalcitrant seeds; they do not survive freezing and drying (Julio *et al*., 2014).

Physical parameters are size, shape, surface color, pit around the pedicel, lenticels and specific gravity (Ketsa *et al*., 1991). As the mango fruit matures, bloom develops as wax and is deposited on the peel (Kosiyachinda *et al*., 1984). The chemical nature of mango wax deposits as well as changes during maturation, await characterization (Lizada, 1993).

2.1.3 Propagation

Mangoes can be propagated rather easily by several methods. Seeds are sometimes grown to produce new cultivars and are commonly used to produce rootstocks for improved cultivars. Polyembryonic cultivars of mango generally come true from seed, but monoembryonic types do not. Seedlings are fairly easy to grow, but they may require 6 to 10 years or more to bear and the fruit may not be of desired quality unless the seedling came from a cultivar which comes true from seed. Desired cultivars are propagated intact by budding, grafting, or other vegetative means. Budded or grafted mangoes will usually begin to bear within 3 to 5 years of propagation (Julian *et al*., 1994).

2.1.4 Fruit growth and development

Fruit growth shows a simple sigmoidal growth curve in terms of length, thickness, mass and volume against days from anthesis (Mendoza, 1981, Lam *et al*., 1982). Immature fruit skin is green or purplish and, upon ripening, becomes yellow, yellowish red, reddish or purplish red. The peel (exocarp) is thick and the flesh (mesocarp) of ripe fruit is yellow or orange-yellow and juicy. The pericarp can be separated into exocarp, mesocarp and endocarp at about 14 days after anthesis (Kader, 2003). There is a period of 9-14 weeks after fruit set when growth rate decreases, and this is associated with hardening of the endocarp and accumulation of starch and sugars. The endocarp is hard, with fibers that may extend into the flesh. The period from fruit set to maturity depends upon cultivars and climate which can range from 10 to 28 weeks. The 'Saigon' mango grown in hot climate is ready for harvest in 12-13 weeks. In cool areas where mean temperatures fall below 20˚C, maturation is delayed by up to 4 weeks (Nakasone and Paull, 1998).

2.1.5 Harvesting maturity

Mango fruit growth follows a simple sigmoid pattern (Mendoza, 1981, Lam *et al*., 1982, Tandon and Kalra, 1986). The period of rapid growth is characterized by an increase in alcohol insoluble solids, principally starch (Lizada, 1993). The accumulation of these is accompanied by increased amylase activity in 'Dashehari' (Tandon and Kalra, 1986) and 'Haden' varieties (Fuchs *et al*., 1980). The increase in dry matter has been recommended for use as an index of maturity in 'Kensington Pride' Baker, 1984) and specific gravity has been used as a maturity index in 'Alphonso' (Subramanyam *et al*., 1978), 'Dahehari' (Kapur *et al*., 1985) and 'Carabao' varieties (Cua and Lizada, 1990).

Maturity at harvest is the most important factor that determines storage life and final quality. The final quality of the mango depends not only on the physiological processes occurring during ripening, but also on processes during fruit development and maturation (Mitra and Baldwin, 1997).

Immature fruits are more subjected to shriveling and mechanical damage, and are of inferior quality when ripe. Overripe fruit are likely to become soft and mealy with insipid flavor soon after ripening. Any fruit picked either too early or too late in its season is more susceptible to physiological disorders and has a shorter storage life than fruit picked at the proper maturity (Kader, 2003). Mitra and Baldwin (1997) reported on the various maturity indices for harvesting mango fruits and have been suggested for several varieties. Harvest maturity is determined by using criteria, such as change in color, fullness of cheek and hardness of endocarp. The most reliable indicator of maturity is hardened endocarp; however, this test is a destructive test. Fruit set dates can be established as an index for harvesting. The fruit set date for each tree is determined when the panicles show a high percentage of initial fruit set. There is no particular parameter for judgment of fruit maturity, it depends on mango type, variety, production conditions and location. Physical, chemical and physiological parameters are used to define the maturity stage for harvesting of fruits. Useful chemical parameters are acidity, soluble solid content, phenolic constituents and carbohydrate content (Ketsa *et al*., 1991).

Fruits are usually picked after they develop some red, orange, or yellow color. Mangoes will ripen and may be picked when the flesh inside has turned yellow, regardless of exterior color. The harvest season is usually between June and September in Hawaii, depending on variety. Fruit matures three to five months after flowering. Mangoes should be picked before they are fully ripe, at which time they soften and fall. The fruit bruises easily and must be handled carefully to avoid damage. They are ripened at room temperature and then refrigerated. Mature mangoes keep fairly well under refrigeration for two to three weeks at 10 to 12.7°C (Chia *et al.*, 1988).

2.1.6 Harvesting

Harvesting is accomplished by experienced pickers who are hired by the collectors, contract buyers or by the farmers themselves. The quality of the harvested crop will be greatly influenced both by the ability of the picker to choose mature fruit and by the method of harvesting employed in the process. Ideally, repeated harvesting of the same tree should be carried out to ensure that only mature fruit is harvested. However, there is much resistance to this and the normal practice is for pickers to harvest all the fruit on a tree regardless of the stage of maturity. Hence, there is a range of maturity in harvested produce particularly when harvesting is earlier than ideal (Kosiyachinda and Mendoza, 1984).

Mango fruit are harvested by hand if the pickers can reach them (Mitra and Baldwin, 1997). Except for young trees where hand picking is convenient, some tool to assist in picking is needed to obtain fruit that is beyond reach. The picking tool may be used from the ground or after climbing the tree. Many of these tools are made of rattan, nylon or canvas formed into a half-elliptical basket which is attached to a bamboo pole or other lightweight material. On the upper end of most tools is a heavy gauge looped wire to facilitate separation of the fruit from the stalk (Kosiyachinda and Mendoza, 1984). About 1-2 cm of peduncle is usually left attached to the fruit in order to avoid rupture of the resin ducts, which results in later undesirable blemishes. In general, for the short time shipment, mango fruit will be harvested after color break. Fruits destine for long transportation distance or storage should be harvested when they are still firm, green and physiologically mature (Mitra and Baldwin, 1997).

2.1.7 Varieties

Worldwide, hundreds of mango cultivars exist. In mango orchards, multiple cultivars are often grown together to improve cross-pollination. Two of the most important cultivars are the Chaunsa, which is particularly common in Pakistan, and the

Tommy Atkins, which dominates the world export trade because it can be easily transported and has a good shelf-life.

2.1.8 Nutrient composition

Ripe mango is considered to be an excellent source of vitamin C, B1 and B2 and provitamin A. It is one of the most luscious of all tropical fruits with flavors varying from exceptionally sweet to turpentine (Lizada, 1993). Known for its unique flavor and attractive appearance, this fruit is a valued source of export income for the producing countries (Medlicott *et al*., 1986, Mitra and Baldwin, 1997).

People consume mango simply because of its pleasant taste and flavor without much thought about the content of minerals, vitamins, lipids and amino acid. However, the mango is a good to excellent source of provitamin A and is considered a fair source of vitamin C, although this varies greatly among cultivars, with a range between a low of 5 mg and as high as 142 mg/100 g of fresh material (Nakasone and Paull, 1998).

The energy value per 100 g serving of the common mango is 250 kJ, and that of the apple mango is slightly higher (330 kJ per 100g). Fresh mango contains a variety of nutrients, but only vitamin C and folate are in significant amounts of the Daily Value as 44% and 11%, respectively. The fruit contains 15% carbohydrates 13.7% sugars and 1.6% dietary fiber.

2.2 QUALITY CHARACTERISTICS

In the emerging trade scenario, cost and quality of a commodity determines the flow and dynamics of its trade in the world market (Kumar *et al*., 2008). Quality of the product is determined by its chemical and nutritional composition (Pritty, 2012).

2.2.1 Total soluble solids

Increase in total soluble solids (TSS) during storage may be due to acid hydrolysis of polysaccharides (Luh and Woodroof, 1975). The physiological maturity of the fruit at harvest is a major determinant of quality and TSS. Sugar import in vine-ripened fruit increases in the latter stages of ripening (Carrari *et al*., 2006). Jamal and Chieri (2006) observed that TSS was not affected either by room temperature or low temperature storage in tomatoes. The TSS is a refractometric index that indicates the proportion (%) of dissolved solids in a solution. It is the sum of sugars, acids and other minor components in the fruit pulp (Balibrea *et al.,* 2006; Kader, 2008). Fernando *et al.* (2012) had conducted a study for determining TSS of apples using nondestructive sensors. The greater weight loss in bulk cucumbers compared to packaged fruit was associated with accelerated chlorophyll degradation, lower acidity, and lower soluble solids content. (Nunes *et al*., 2011).

The increase in TSS might be due to the alteration in cell wall structure and breakdown storage. This increase and decrease in TSS are directly of complex carbohydrates into simple sugars during correlated with hydrolytic changes in starch and conversion of starch to sugar being an important index of ripening process in mango and other climacteric fruit and further hydrolysis decreased the TSS during storage (Kays, 1991; Kittur *et al*., 2001).

2.2.2 Colour

Colour characteristic of foods are an important quality attribute resulting from both pigmented and originally non pigmented compounds. The major causative factor of colour in most foods is due to the presence of a broad array of natural pigments. Visual perception of colour can be described by three variables namely, hue (a), value (L) and chroma (b) (Yeshajahu *et al*., 1996).

The loss of green color was the most obvious change in mango, which was probably due to the physico-chemical changes by degradation of the chlorophyll structure and increased in carotenoid pigments during storage. The principal agents responsible for this degradation might be the oxidative system, pH change and enzymes like chlorophyllases (Wills *et al*., 1998). Yahia *et al*. (1993) observed that fruit stored in open atmosphere (in air) lost their green color while those stored in control atmosphere remained green, and when transferred to air for normal ripening turned yellow but they were still more green than fruit stored continuously in air.

The delay in ripening, degradation of chlorophyll and retention of green color for a longer period also depends on types of coating (Manzano *et al*., 1997; Kittur *et al*., 2001). Doreyappa *et al.* (2001) reported that the green peel color of mature Alphonso and other varieties of mango was turned from light green or green or dark green to light yellow or yellow or orange yellow due to the breakdown of chlorophyll due to a series of physico-chemical changes during ripening, leading to disappearance of green colour. Whereas pulp color which was white to pale yellow, changed from white or pale yellow to yellow or orange yellow due to the development of carotenoids in fruit stored at 18-34˚C undergone a series of changes and one of the major changes were increased in carotenoids.

2.2.3 Titratable acidity

Acids are one of the energy reserves of the fruit; therefore these are used in the respiration process and converted to more simple molecules such as CO_2 and water (Wills *et al.,* 1998). As a result of respiration, acids decrease, but water loss in the fruit increases its concentration.

Titratable acid correlated very well with days after flower induction in the 'Carabao" mango (Del Mundo *et al.*, 1984), decreasing in the fully mature fruit to <44.8 meq/100 g. In 'Alphonso', titratable acid increased from the sixth to the tenth week after fruit set and steadily declined thereafter as the fruit matured (Lakshminarayana, 1970). Marupadi *et al*., (2011) studied the enhancement of storage life and quality maintenance of papaya fruits using Aloe Vera based antimicrobial coating. The results showed that the titratable acidity in the fruit samples decreased with storage time in both control and treated fruits. However, the difference was to a lesser extent in coated fruit compared to control.

It was observed that percent titratable acidity had decreasing trend during storage period that might be due to the degradation of citric acid which could be attributed to ripening or reduction in acidity may be due to their conversion into sugars and their further utilization in metabolic process in the fruit. These results coincided with those Doreyappa-Gowda (2001) who reported the similar pattern in different varieties of mango fruit stored at 18 -34ºC under gone a series of physic-chemical changes during ripening.

2.2.4 Physiological loss in weight

The effects of different wrappers and chemicals either alone or in combination of both on loss in weight of fruits due to physiological causes during storage have been at varying degrees in different fruits. Mango fruits kept in polyethylene bags showed considerably less physiological losses.

Carrillo *et al*. (2000) who observed that coated or uncoated Haden mango in Mexico had an increasing trend of weight loss with the passage of storage time. However, weight loss was lower in coated fruit (4.0 to 6.5%) as compared to control having higher percent weight loss (0.00 to 9.0%).

2.2.5 Respiration

The climacteric respiration occurs in mango fruits just before maturity. The immature fruits respire at higher rate than the mature ones. Similar results were found for strawberry (Ghaouth *et al.* 1991), tomato (Ghaouth *et al*. 1992), mango (Joseph and Aworth, 1992), and pear (Sumnu and Bayindirli, 1994).

2.2.6 Moisture content

Banks *et al*. (1997) stated that surface coatings can reduce moisture loss and retard ripening of avocados without adversely affecting the other aspects of fruit quality. The avocados can lose 1% of its moisture each day at 20^{0}C, 60% RH. Surface coatings like wax act as a good barriers to water vapour. This reduces the rate at which water evaporates from the fruit surface and thereby slows loss of saleable weight. Thus, he found that waxing reduced moisture loss by up to 50%.

George, (1972) had conducted a study on waxed and unwaxed cucumbers stored at 12.8ºC and 70-80% RH, and at 23.9ºC and 40-50% RH, for up to 21 days. And had reported that moisture loss was least at 12.8ºC in waxed cucumbers and varied between 9.7 and 15.2%, compared with up to 22.6% in the control.

2.3 TREATMENT STUDIES

2.3.1 Modified atmosphere packaging

MAP is the enclosure of food in a package in which the atmosphere inside the package is modified or altered to provide an optimum atmosphere for increasing shelflife and maintaining the quality of food (Robertson, 2006). It involves some initial modification of the atmospheric composition in an airtight storage room, which changes further with time as a result of respiratory activity of the fresh food and growth of microorganism.

Active packaging involves incorporation of certain additives into packaging film or within packaging containers to modify headspace atmosphere and to extend produt shelflife (Sudheer and Indira, 2007). In passinve MA, an atmosphere high in CO_2 and low in O_2 passively evolves within sealed package over time as a result of respiration of the product.

There is no current usage of CA storage, however long distance marine shipping in MA is commercially used on a very limited basis from Mexico (Yahia, 1993) and some other countries. The recent use of CA during shipping will most probably improve the quality of shipped fruit (Yahia, 1997). Besides the benefits of modifying the O_2 and CO_2 levels in lowering respiration rate, MAP has the additional benefits of water loss reduction, product protection, and brand identification (Kader *et al*., 1989).

2.3.2 Waxing

Edible coatings can provide an additional protective coating for fresh products and can also give the same effect as MAP in modifying internal gas composition. Wax was the first edible coating used on fruits.

The application of hydrophobic coating increased the postharvest storage life of mango fruit for at least 20 days more than uncoated fruit. (Diaz-Sovac *et al*., 1996). Carrillo *et al*. (2000) studied the effect of simper fresh edible coating film on shelflife quality of mango. The TSS, Weight loss and pH were lower in coated fruits but green colour, firmness and TA were highest compared to non-coated fruits. Fruit quality was maintained and shelflife was prolonged in fresh produce by irradiated crab chitosin (Abbasi *et al*., 2011).

Edible coating based on derivative of fatty acid and poly saccharides reduced the respiratory metabolism and maintained the postharvest quality of picota cherries (Alonso and Alique, 2004).

2.3.3 Shrink wrapping

Shrink film packaging involves use of thermoplastic films that have been stretched or oriented during manufacturing and have property of shrinking with application of heat. This technique provides all weather protection during transit or outside storage, simplifies load identification, and provides a barrier against dust and humidity (Sudheer and Indira, 2007). This helps in creating an internally modified atmosphere for the package.

Shrink-wrap packaging is a packaging method for postharvest handling of fruit and vegetables. The technology delays physiological deterioration of fruits and also prevents condensation of droplets within the package. Individual shrink-wrapping of the produce provides optimum gas and humidity for maintaining quality of the produce during the transit and storage. As a result, it doubles or sometimes triples storage life of the fruits under proper storage conditions. Such units packs also provide protection against abrasion and maintain attractive appearance of the product. Batagurki *et al.* (1995) have strongly recommended the use of shrink wrapping of fruits and vegetables in India.

The polyethylene wraps created the same condition as required in CA storage and on unwrapping the fruits resumed climacteric and normal softening for about three weeks (Aharoni *et al*., 1968). The pear fruits treated with shrink wrap remained in fair to good eating quality up to 105 days of refrigerated storage (Qurat-ul-ayn *et al*., 2014). Weight loss was significantly reduced in shrink wrapped and ethylene treated tomatoes compared to ethylene treated unwrapped ones (Lawrence *et al*., 1984). Shrink films have significantly influenced the Physiological loss of weight (PLW) and decay loss over unwrapped (control) apples stored in zero energy cool chamber (Sharma *et al*., 2010). Heat shrinkable films have been reported to have positive influence in the juice recovery of citrus fruits due to reduction in PLW over unwrapped fruits (Ladaniya, 2003).

McCollum *et al.* (1992) studied the effects of individual shrink film wrapping on mango fruit shelflife and quality. Mango fruit were wrapped with shrink film in Rd 106 film and other left none wrapped. The wrapped fruit had more decomposed and inferior fruit quality when compared with non wrapped fruit. They concluded from this study individual shrink film wrapping of mango fruit does not showed to be useful.

2.3.4 LDPE

In storability of Indian gooseberry the fruits treated with calcium nitrate 1.5% plus LDPE bag recorded the least physiological loss in weight and spoilage loss (Singh *et al*., 2004). Ordinary packaging films such as LDPE, PP and PVC can generate suitable impact gaseous environment for fresh produce with low and medium rate of respiration. However highly respiring produce such as mushroom, broccoli and asparagus developed anaerobic condition (Rai *et al*., 2007).

2.4 STORAGE STUDIES

Paull, (1999) reported that low temperature has been used to extend the shelflife of temperate fruits and vegetables while the negative effect of low temperature ($<10^{o}$C) on the shelflife of tropical plants and commodities. Low temperature storage has the additional benefit of protecting non appearance quality attributes: texture, nutrition, aroma and flavour. In addition, delays in cooling after harvest can reduce commodity shelflife and quality. Tano *et al*. (2007) found out that temperature fluctuations had a major impact on the composition of the package atmospheres and on product quality.

The quality of the product stored under the temperature fluctuating regime was severely affected as indicated by extensive browning, loss of firmness, weight loss increase, the level of ethanol in the plant tissue, and infection due to physiological damage and excessive condensation, compared to products stored at constant temperature. It was clear that temperature fluctuation, even if it should occur only once, can seriously compromise the benefits of MAP and safety of the packaged produce.

Materials and Methods

Chapter 3

MATERIALS AND METHODS

This chapter deals with the methodology adopted for satisfying the objectives of the study.

3.1 MANGO SAMPLE COLLECTION

Mangoes (*Mangifera indica*), which belong to the variety Moovandan were brought from Iritty, Kannur district. They were harvested four days before starting the treatments. The mangoes were washed with purified water. Eight samples at cold condition and four samples at ambient condition were kept for each treatment.

3.2 PHYSICO-CHEMICAL CHARACTERISTICS ESTIMATION

3.2.1 Respiration rate

Respiration plays a central role in the overall metabolism. Reduced oxygen and increased CO_2 levels will reduce the rate of respiration and result in slow ripening. Respiration is measured by O_2/CO_2 head space gas analyser PBI Dansensor (Checkmate2).

Plate 3.1 Experimental set up for respiration analysis (Check Mate 2)

Two mangoes from each treatment are taken in separate air tight container. Initial gas composition was measured. The containers are then kept for 3 hours and again gas composition was measured. A needle was penetrated into the gas stream (make sure the needle does not touch the contents in the container) through a silicon septum placed on the container. The measured O_2, CO_2 values and balance were displayed.

From the measured percentage value of O_2 and CO_2 respiration rate is calculated in mg/kg/h (Susana, 2002).

Respiration rate = $\frac{V \times m}{t \times w \times 100} \times \rho$

Where,

V = Volume of mangoes (ml)

m = Amount of CO_2 or O_2 (%)

t = Duration of respiration (h)

w = Weight of mangoes (kg)

ρ = Density of CO_2 or O_2 (g/cm^3)

3.2.2 Total Soluble Solids (TSS)

During the development of the flesh of a fruit, nutrients are deposited as starch, which during ripening transforms to sugars. The determination of Total Soluble Solids (TSS) in a fruit is measured using a hand refractometer.

A refractometer is a device with a prism, a numeric scale and an eyepiece. Two or three drops of mango juice are squeezed onto the prism and a demarcated line is viewed on the scale. It was expressed in degree Brix (Ranganna, 1995).

Plate 3.2 Hand Refractometer

3.2.3 Acidity

Titration method is used in ascertaining the amount citric acid in a sample, by using a standard counter-active reagent, e.g. an alkali (NaOH).The fruit is crushed and squeezed out the juice with an extractor. The skin and solids should not be included; the solids being filtered out through muslin cloth or fine filter extracting as much juice as possible.

Using a clean and dry pipette 10 ml of juice is pipette out and discharged into a 250 ml beaker. Using another dry pipette 50 ml of distilled water is pipette out and added to the juice in the beaker. Three drops of phenolphthalein is added to the juice/water solution in each beaker. Using a funnel, 0.1M solution of NaOH is poured into the burette until it reaches the zero mark. Then the NaOH is slowly titrated against juice/water solution in the beaker. The point of neutrality is reached when the indicator changes from colourless to pink. The indicator colour must remain stable (persisting for 30 seconds) and be light pink when viewed over a white background. Titration is repeated until concordant value is obtained. Then the titratable acidity was calculated and expressed as per cent citric acid (Ranganna, 1986). Amount of titratable acidity (Ns) present in 100 g of sample was calculated as follows:

$$\text{Percentage acid} = \frac{Titre\ value \times acid\ factor \times 100}{10(ml\ juice)}$$

Factor for citric acid**:** 0.0064 (Citrus fruit)

3.2.4 Moisture Content

The moisture content was determined by oven drying method. A piece of mango weighing exactly 10 g is taken from the sample and then it is sliced into thin slices (including peel) for uniform drying. The known weight of samples ($W_{initial}$) was kept inside a hot oven at a temperature of 90ºC. The samples were weighed in every two hours until the weight become constant and this weight is taken as final weight (W_{final}) of the samples. The moisture content was expressed as the percentage change in weight (Ranganna, 1995).

Moisture content (%) = $\frac{\mathbf{W}\,initial - \mathbf{W}\,final}{\mathbf{W}\,initial} \times 100$

3.2.5 Physiological loss in weight

The PLW in mango was calculated according to the method of Thakur *et al.* (2002). For determining the PLW of fruits were weighed immediately after imposing the treatment which served as the initial fruit weight. The loss in weight was recorded at regular interval until the product was spoiled, which served as the final weight. The PLW was determined with the following formula and expressed as percentage.

PLW (%) = $\frac{A-B}{A} \times 100$

Where A- initial/original fruit weight (g)

B- Final fruit weight in the day of observation (g)

3.2.6 Colour

The degree of greenness and yellowness were recorded by observing manually according to a colour score. According to the colour score the colour of the fruits were recorded using some digits as given below.

1- Green
2- More green less yellow
3- Half green half yellow
4- More yellow less green
5- Yellow
6- Yellow with black spot

3.3 MODIFIED ATMOSPHERIC PACKAGING OF MANGO

Mangoes coated with bee wax and non-coated fruits were stored under various MAP conditions.

3.3.1 LDPE

LDPE bags of 210 ± 2 gauges were used. Mangoes coated with bee wax and uncoated mangoes are packed with LDPE and kept at both cold (13 ± 1ºC, 95 ± 2% RH) and ambient (26 ± 4ºC, 75 ± 4% RH) conditions.

3.3.2 Intelligent Packaging

We had done EMA packaging using LDPE bags with a nano composite incorporated window (Techno Fresh) of 200 ± 1 gauge.

Techno fresh is a unique polymer based technology, which is capable of providing different packaging permeability, in order to create specific oxygen and carbon dioxide levels in a package and maintain this optimum atmosphere. This package maintains high quality, freshness and preserves nutrients of fresh produces by naturally regulating respiration

Mangoes coated with bee wax and non coated mangoes were packed using Techno Fresh and stored at both ambient (26 ± 4ºC, 75 ± 4% RH) and cold (13 ± 1ºC, 95 ± 2% RH) conditions.

3.3.3 Shrink wrapping machine, shrink film and tray

Shrink wrap, also shrink film, is a material made up of polymer plastic film. When heat is applied, it shrinks tightly over whatever it is covering. Heat can be applied with a handheld heat gun (electric or gas), or the product and film can pass through a heat tunnel on a conveyor. The most commonly used shrink wrap is polyolefin. Shrink film (Cryovac) of 9 micron thickness was used.

Two mangoes were placed in thermocol tray of 18×10 cm and then shrink wrapped with Sevana shrink wrapping machine. Mangoes coated with wax and noncoated mangoes were shrink wrapped and kept at both cold (13 ± 1ºC, 95 ± 2% RH) and ambient (26 ± 4ºC, 75 ± 4% RH) conditions.

3.3.4 Edible wax coating with natural bee wax and rice bran oil

Wax coating create an invisible, edible protective film around the fruit. They are effective in delaying ripening, and reducing spoilage of fresh produces.

Bees wax, a natural wax produced by honey bees were used. It has a melting point of 62 to 64ºC. It was never subjected beyond 64ºC to avoid chance of discolouration. Bee wax maintains the freshness and quality of the fruit. Also it prevents the evaporation of water, inhibits respiration rate and polishes the skin of fruit to increase attractiveness.

Since the bee wax cannot be used as such, a formulation of bee wax with rice bran oil was made. The wax coating with wax to oil ratio 1:100 (Alfiya *et.al*, 2010) was used. Mangoes coated with wax were kept at both cold (13 ± 1ºC, 95 ± 2% RH) and ambient (26 ± 4ºC, 75 ± 4% RH) conditions.

3.4 TREATMENTS

Eight treatments were performed on mangoes in cold (13 ± 1ºC, 95 ± 2% RH) as well as ambient (26 ± 4ºC, 75 ± 4%) conditions. For each treatment, eight samples for cold storage and four samples for ambient storage were kept.

T1 - LDPE Packaging (Low Density Poly Ethylene)

T2 - IP (Intelligent Packaging)

T3 - Shrink wrapping

T4 - LDPE packaging +Wax coating

T5 - IP + Wax coating

T6 - Shrink wrapping + Wax coating

T7 - Wax coating (Natural bee wax : Rice bran oil in proportion,1:100)

T8 - Control

Results and Discussions

Chapter 4

RESULTS AND DISCUSSIONS

This chapter articulate and discusses the outcomes of various experiments conducted to evaluate the change in different quality parameters on storage.

4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF MANGO

The estimated physico-chemical composition and quality parameters before various treatments and packaging of Moovandan variety of mangoes are presented in Table 4.1. The average moisture content of mango was found to be 85.14% (wb). The average values of the chemical components viz; TSS, and titratable acidity were estimated to be 8^{0}Brix, and 1.798% respectively for the average moisture content.

Table 4.1. Physico-chemical characteristics of fresh mango

Chemical characteristics	Value
1. Moisture (%)	85.14
2. TSS (ºBrix)	8
3. Titratable acidity (%)	1.798
4. Gas composition (ml/kg/hr)	101.28
Physical characteristics	
1. Colour (colour score)	1

4.2 POSTHARVEST BEHAVIOUR OF MANGOES DURING STORAGE PERIOD

The postharvest behaviour during storage of mango in cold storage (13 ± 2°C, 95 ± 2% RH) were evaluated by finding the quality parameters as described. Mangoes packed in various MAP and stored at cold storage conditions showed the signs of spoilage on the 20th day of analysis and hence they were discarded. However, the fruits kept as control cannot last for 10 days in cold storage condition.

At ambient condition (26 ± 4ºC, 75 ± 4% RH), mangoes under MAP and control were discarded on the 10th and 7th day of storage.

4.2.1 Respiration rate

The respiration rate of treated mangoes stored under ambient and cold storage conditions with respect to CO_2 and O_2 concentrations were shown in the figures and this variation is given by the polynomial equations .

Respiration (measured as CO_2 liberation) was suppressed in treated fruit compared to untreated ones. Mangoes of treatments T1, T4 and T6 exhibited less classical climacteric respiratory peak while mangoes under rest of the treatment showed climacteric peak on 13th day of cold storage. Among all the treatments, T4 (wax + LDPE) showed the best result. The suppression of respiration is due to the modification of the internal atmosphere of the package (depletion of O_2 and enrichment of CO_2) caused by the semi permeable characteristics of the coatings to these gases (Banks, 1984).The wax coating applied on fruit changes its internal atmosphere and in turn contributes to the reduction in respiration rate. Similar results were found for strawberry (Ghaouth *et al.* 1991), tomato (Ghaouth *et al*. 1992), mango (Joseph and Aworth, 1992), and pear (Sumnu and Bayindirli,1994).

At ambient condition also treatment 4 (wax + LDPE) showed the least respiration rate after seventh day of storage.

The percentage of O_2 is showed in Fig. 4.1and this variation is given by the polynomial equation

$$y = 1.038x^2 - 40.101x + 499.82 \quad (R^2 = 0.9529)$$

Where x is the storage period in days.

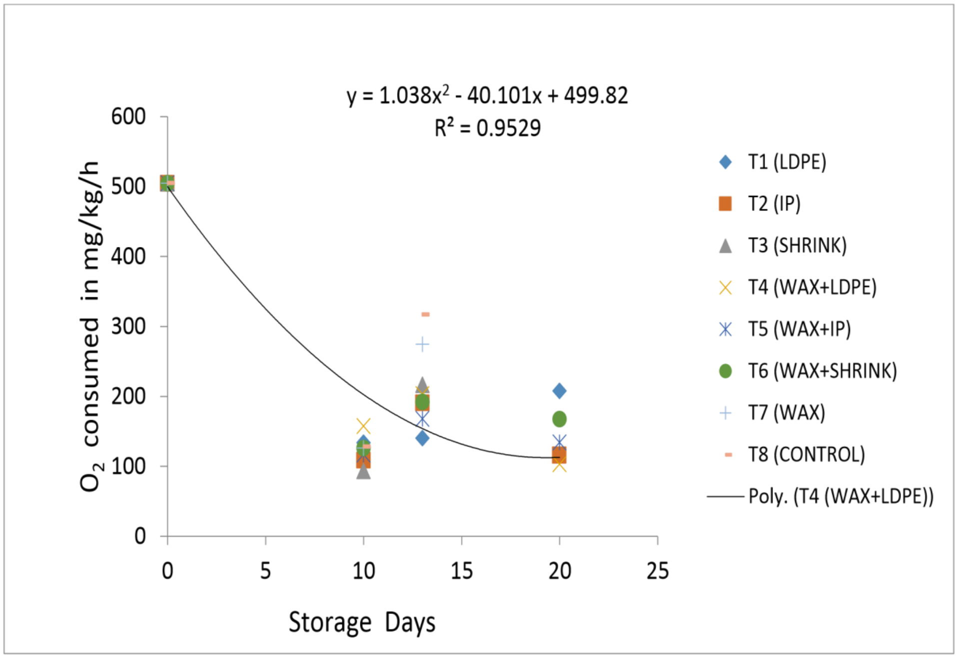


Fig. 4.1 Deplition of O_2 (%) in cold storage 13 ± 2ºC and 95 ± 2% RH

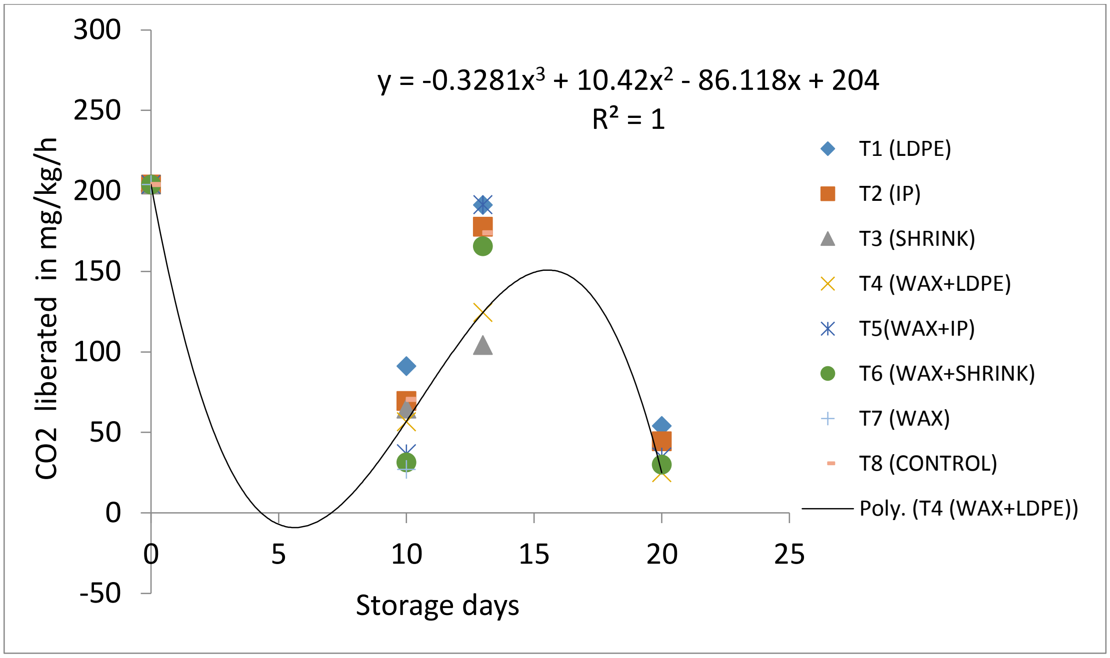


Fig. 4.2 Enrichment of CO_2 (%) in cold storage 13 ± 2ºC and 95 ± 2% RH

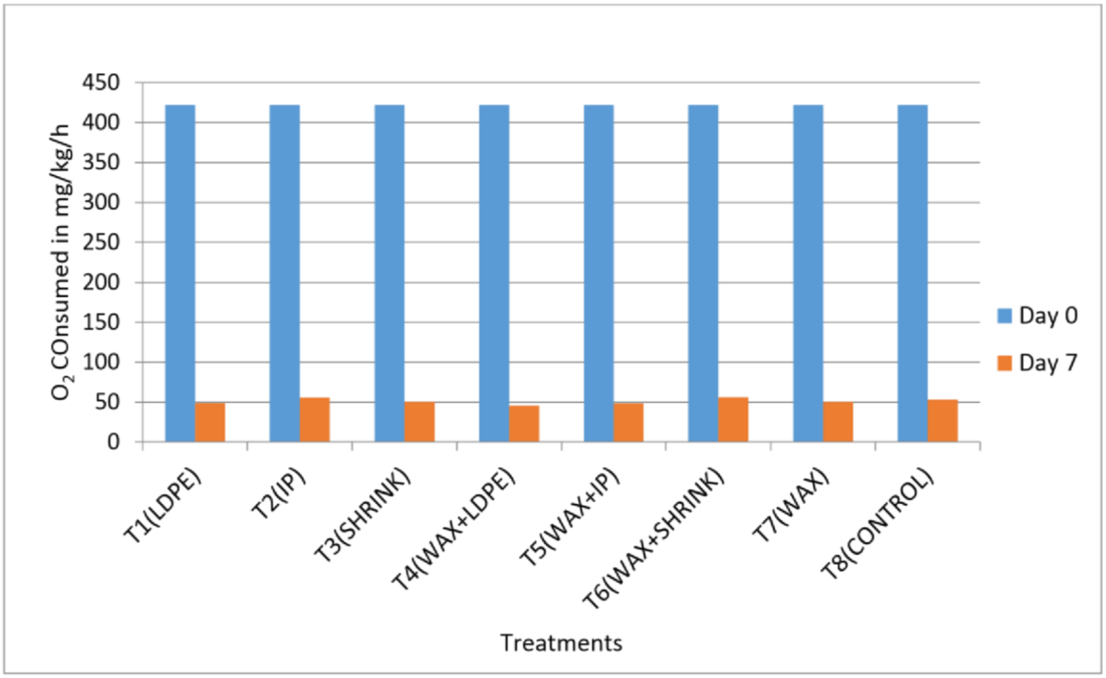


Fig. 4.3 Depletion of O_2 (%) in ambient storage 26 ± 4ºC and 75 ± 4% RH

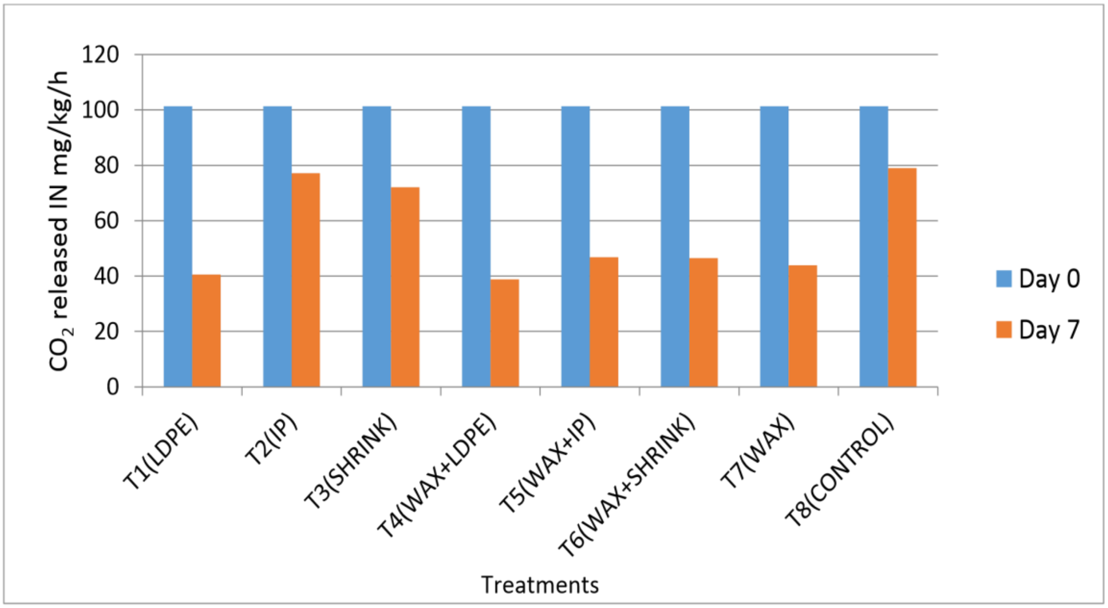


Fig. 4.4 Enrichment of CO_2 (%) in ambient storage 26 ± 4ºC and 75 ± 4% RH

4.2.2 Physiological Loss in Weight (PLW)

The PLW of mangoes occurs due to the reduction in moisture content. The PLW increased consistently as a function of storage. In general it was observed that the rate of increase of PLW was lesser in wax coated fruits when compared to uncoated fruits. The possible reason may be that bee wax served as a semi permeable membrane around fruit surface which resulted in reduction of water loss and rate of respiration, thereby reducing the moisture loss and hence the PLW. These results were similar to the findings of Souza *et al*. (2010).

Treatment T4 (wax + LDPE) was the most effective for retarding weight loss. After 20 days of cold storage, mangoes with treatment T4 (wax + LDPE) showed only a weight loss of 3.8 g. In contrast, fruits treated under treatments T2 and T7 exhibited high weight loss levels. The reason for the reduction in weight loss may be due to the blockage of lenticels and/or stomates (Dhalla and Hanson 1988) as evidenced by the reduction in respiration and gas exchange (Hagenmaier and Baker, 1993) . Edible bee wax is hydrophobic and thus presents a good barrier to water vapour. Similar result was obtained in passion fruit (Madhana *et al*, 2012).

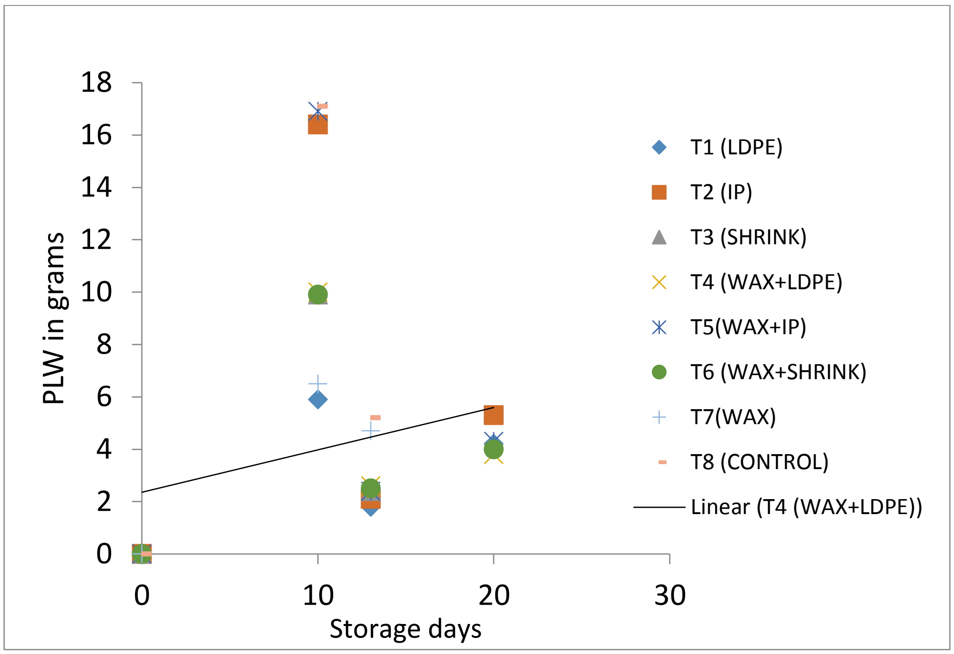


Fig. 4.5 Change in PLW of mango stored at 13 ± 1ºC, 95 ± 2% RH

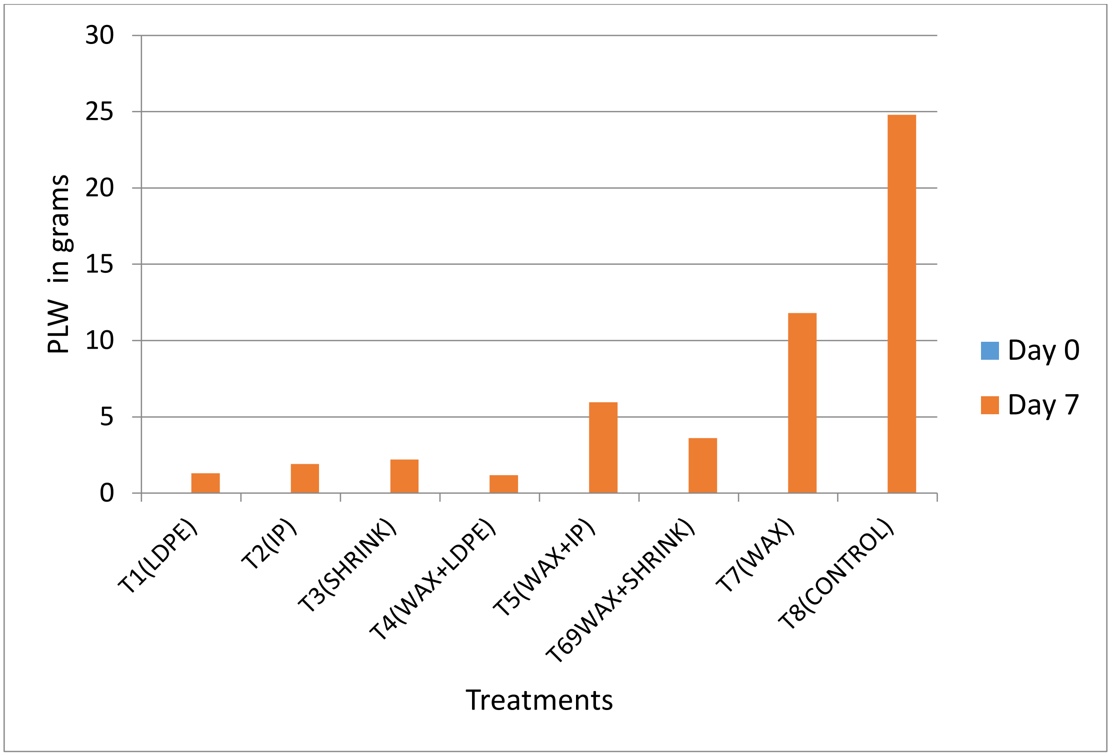


Fig. 4.6 Change in PLW of mango stored at 26 ± 4ºC, 75 ± 4% RH

4.2.3 Total Soluble Solids (TSS)

The TSS showed an increasing trend in all the mangoes irrespective of the treatments. The increase in TSS concentration during the storage period, may be due to the increased respiration rate and the transit of fruits towards ripening. However, TSS were significantly lower in treatment T4 with a value of 15ºBrix even after the 20th day of cold storage. The lowest TSS may be attributed to retarded respiration due to the combined effect of LDPE and wax coating.

In ambient condition, treatments T4 and T7 showed the least value of TSS reading 13.5 and 14.2ºBrix respectively at the seventh day of storage.

The change in TSS is given by the linear equation:

$y = 0.3694x + 8.4039 \quad (R^2 = 0.9194)$

Where, x is the storage days.

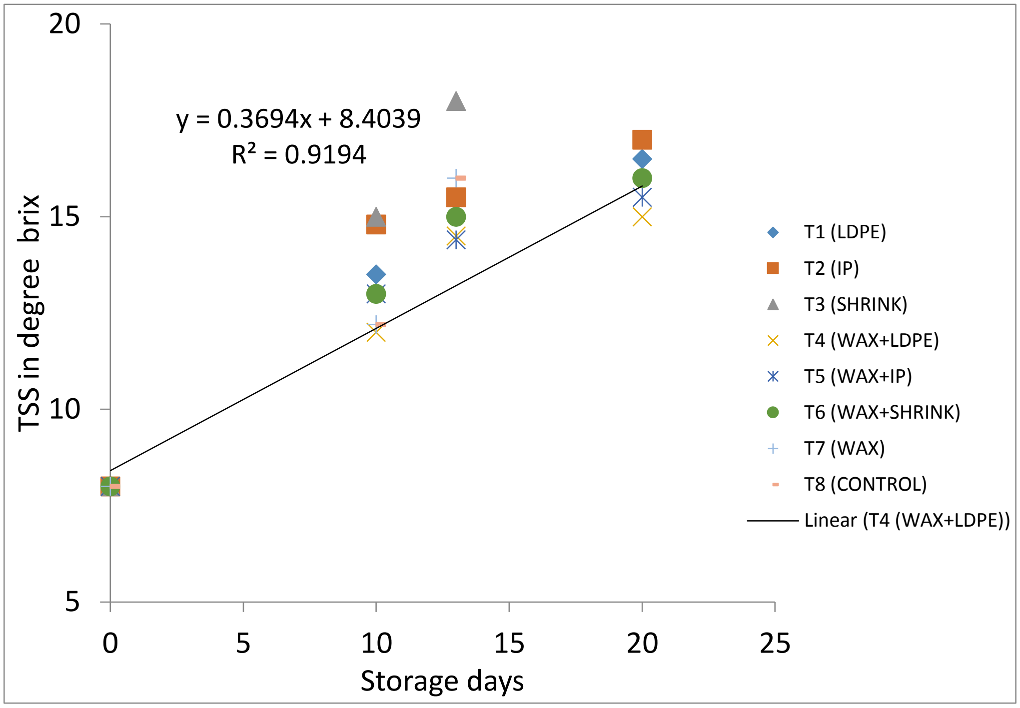


Fig. 4.7 Change in TSS of mango stored at 13 ± 1ºC, 95 ± 2% RH

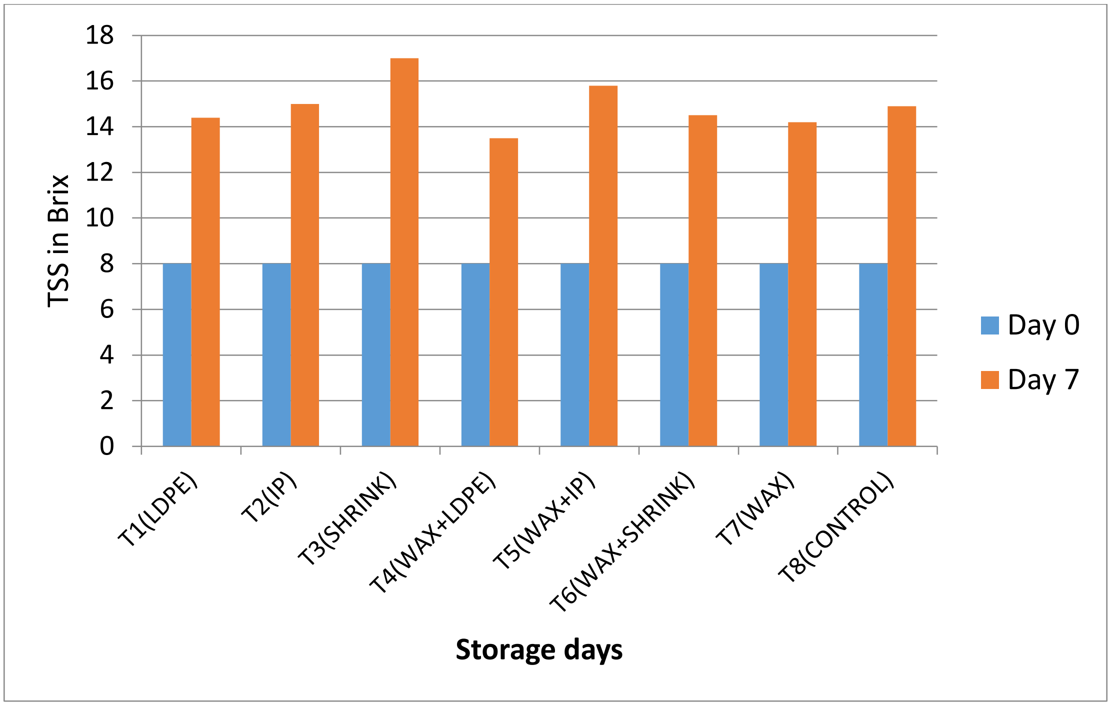


Fig. 4.8 Change in TSS of mango stored at 26 ± 4ºC, 75 ± 4% RH

4.2.4 Acidity

The titratable acidity of mango fruits decreased with storage, which could be expressed using the polynomial equation given below.

$$y = 0.6484e^{-0.143x} \quad (R^2 = 0.7965)$$

The TA values of all the treatments showed a significant decrease of about 90% compared to the initial values of the storage. Similar results were obtained in cucumber (Nunes *et al*, 2011; Hima *et al*, 2014). This decrease may be due to the increased respiration rate and starch hydrolysis. However on the 20th day of cold storage a slight hike (0.0576% citric acid) in the TA was observed in the treatment T4.

This is due to the delayed ripening in wax coated LDPE package.

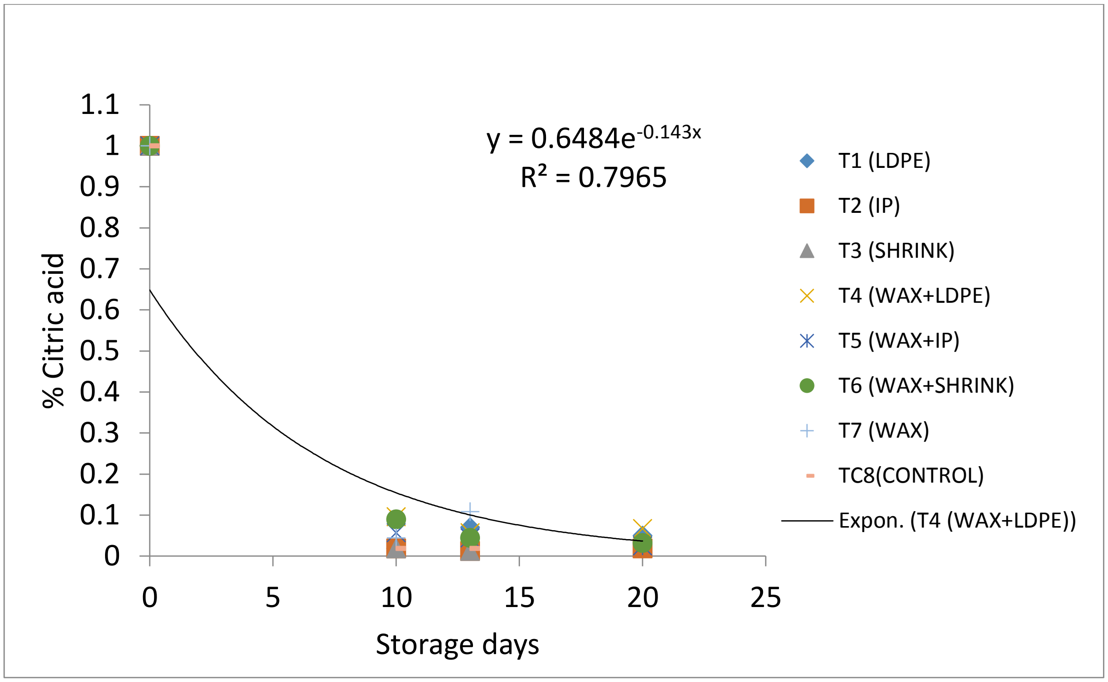


Fig. 4.9 Change in acidity of mango stored at 13 ± 1ºC, 95 ± 2% RH

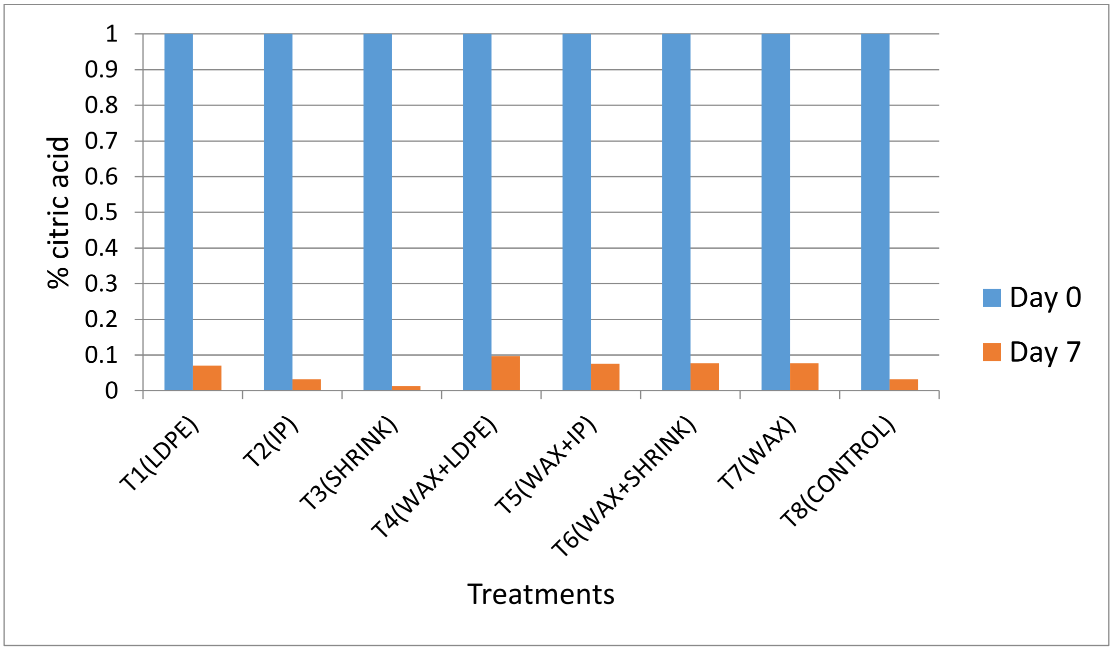


Fig. 4.10 Change in acidity of mango stored at 26 ± 4ºC, 75 ± 4% RH

4.2.5 Moisture Content

The variation in moisture content of mangoes of various treatments during the period of storage is shown in Fig. 4.11. In general the mangoes show a decreasing trend in moisture content with storage irrespective of the treatment. In contrast it was observed that the percentage of moisture content got increased in all wax coated treatments of which maximum moisture content was observed in treatments T4 and T5 with 89% on the 20th day of cold storage. This might be due to the restricted metabolic activity of wax coated mangoes at MAP created by non perforated LDPE and IP bags. In ambient condition again treatments T4 and T5 proved to be the best with a value of 89 and 91% respectively.

The variation in moisture content for the treatments can be predicted with the polynomial equations for waxed and unwaxed mangoes respectively as given below:

$$y = -0.0095x^2 + 0.3075x + 85.32$$

$$y = 0.0277x^2 - 0.3498x + 85.407$$

Where, x is the storage days.

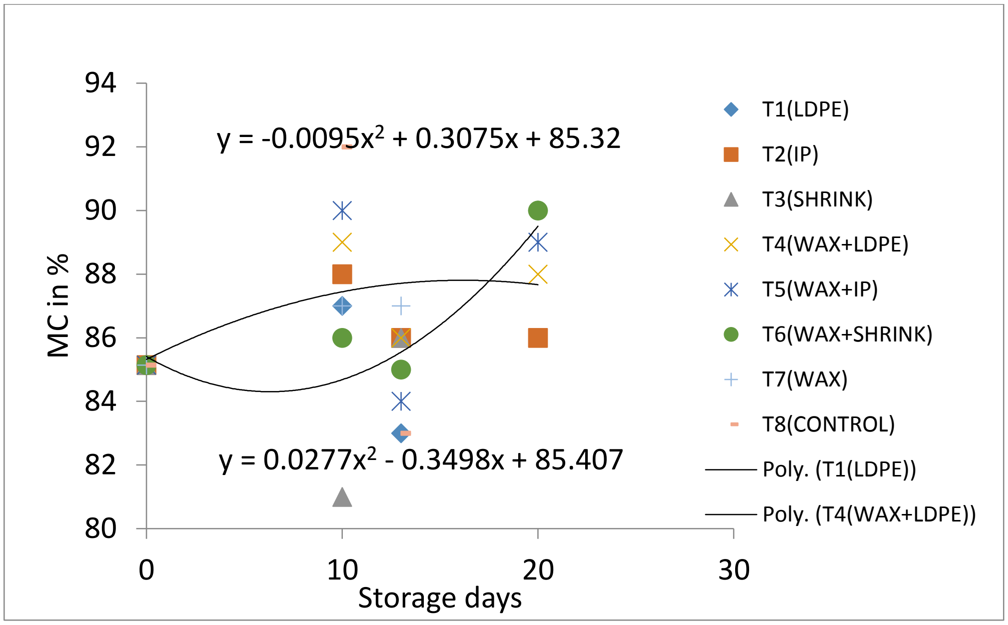


Fig. 4.11 Change in moisture content of mango stored at 13 ± 1ºC, 95 ± 2% RH

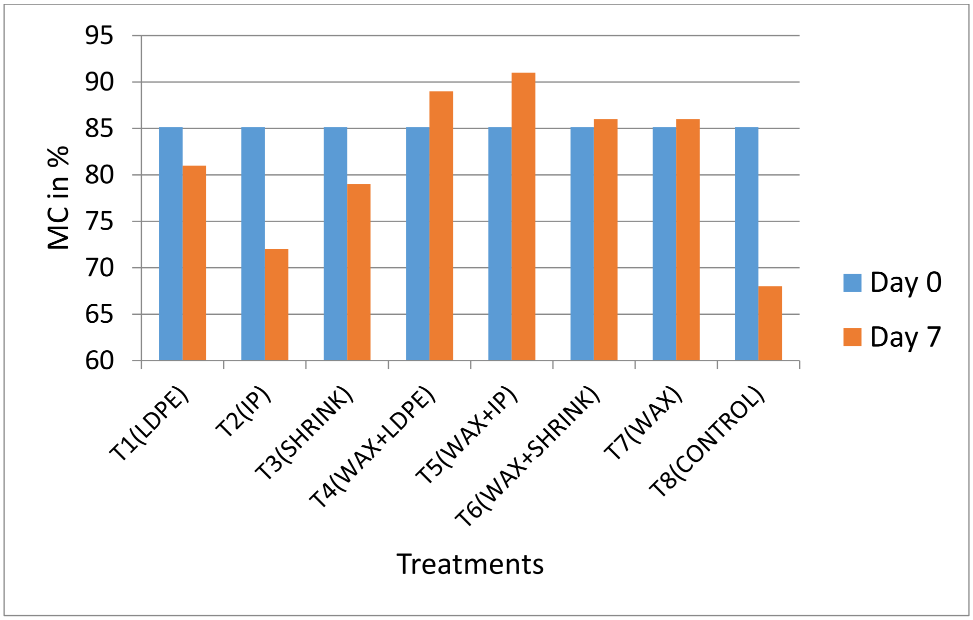


Fig. 4.12 Change in moisture content of mango stored at 26 ± 4ºC, 75 ± 4% RH

4.2.6 Colour

The development of fruit color is influenced by the internal gas environment (Buescher, 1979) including levels of CO_2 and ethylene. Elevated CO_2 concentration inhibits ethylene synthesis which in turn influences chlorophyll breakdown. Low levels of O_2 also inhibits ethylene production (Medlicott *et al*. 1987).

A significant change in colour was observed during the storage period of mangoes. Black spots were observed on treatments T2, T3, T6, T7 and T8 at the end of 20^{th} day of cold storage. The best result was obtained for the treatment T4 with a colour score of four, that is more yellow less green.

In ambient storage condition, a colour score of two was observed for treatment T1 which was the best among other treatments at the end of seventh day of storage.

The varying trend of colour is represented using the equation:

$$y = 0.0073x^2 + 0.0004x + 1.0277 \quad (R^2 = 0.9725)$$

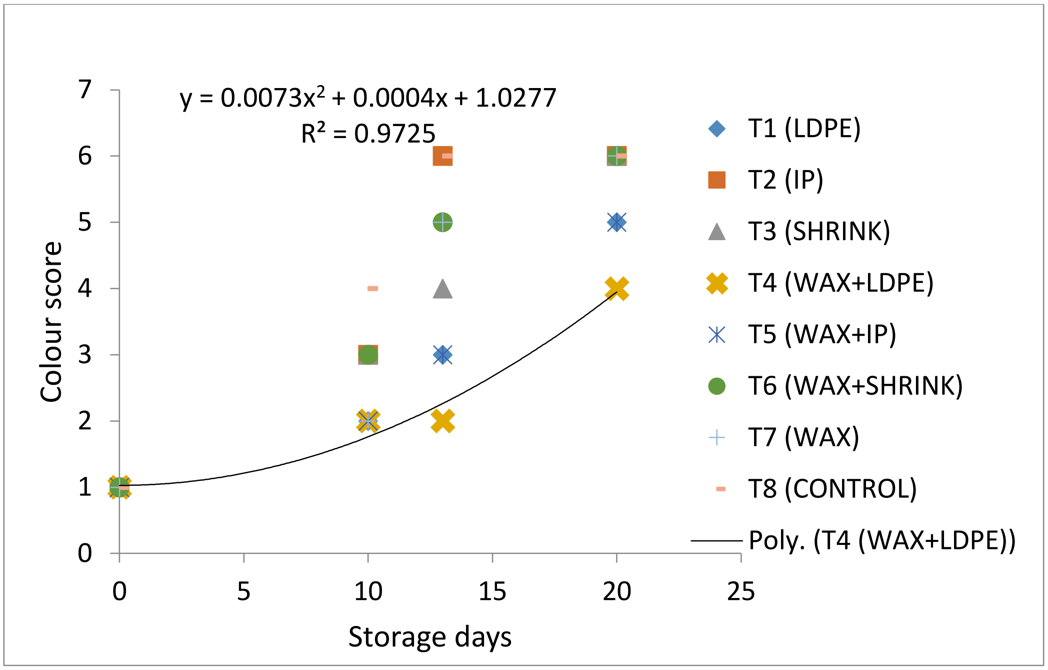


Fig. 4.13 Change in colour of mango stored at 13 ± 1ºC, 95 ± 2% RH

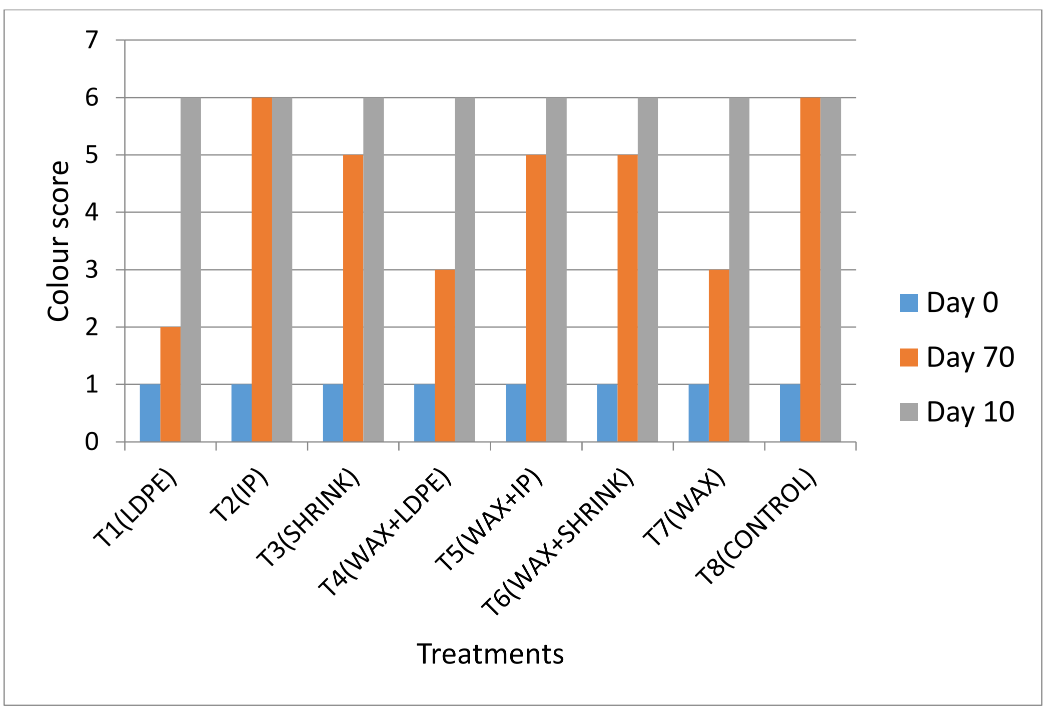


Fig. 4.14 Change in colour of mango stored at 26 ± 4ºC, 75 ± 4% RH

4.3 SHELFLIFE STUDIES

From the observations, it was found that the fruits coated with wax and packed in LDPE bags had acceptable qualities even after the 20^{th} day of cold storage, while the samples at ambient condition (wax + LDPE) became unacceptable on the 10^{th} day. The wax coated fruits and wax + MAP treated mangoes retained their qualities upto 14^{th} and 7^{th} day of storage in cold and ambient conditions respectively. The change in appearance of various treatments during storage is shown in plate.

Treatment 1: LDPE

Treatment 2: IP

Treatment 3: Shrink wrapping

Treatment 4: Wax + LDPE

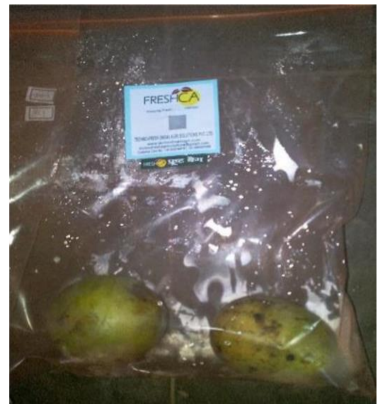
Treatment 5: Wax + IP

Treatment 6: Wax + Shrink film

Treatment 7: Wax

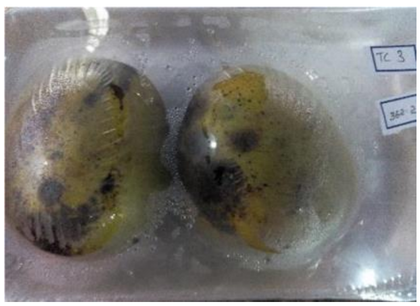
Treatment 8: Control

Plate 4.1 Mangoes at 10th day of storage under cold storage condition.



Treatment 1: LDPE

Treatment 2: IP



Treatment 3: Shrink film

Treatment 4: Wax + LDPE

Treatment 5: Wax + IP

Treatment 6: Wax + Shrink film

Treatment 7: Wax

Plate 4.2 Mangoes at 13th day of storage under cold storage condition

Treatment 1: LDPE

Treatment 2: IP

Treatment 4: Wax + LDPE

Treatment 5: Wax + IP

Treatment 6: Wax + Shrink film

Plate 4.3 Mangoes at 20th day of storage under cold storage condition

Summary and Conclusions

Chapter 5

SUMMARY AND CONCLUSION

Fruits and vegetables are the foundation of nutrition. They provide low- calorie, high nutrient options for the daily diet. They are packed with vitamins, minerals and protective plant compounds. They have gained increasing interest among nutrition specialists, food scientists and consumers, since frequent consumption of fruits reduces the risk of certain cardiovascular diseases and cancer (Liu, 2003). In the recent years, demand for both fresh and processed fruits and vegetables have been substantial, and this trend is likely to continue in future. The increase in demand can be regulated by either increasing their production or by adopting suitable processing and packaging techniques for its preservation.

The effects of MAP and edible wax (natural bee wax) coating on extending the shelf life of mangoes were studied under cold condition (13 ± 1^{0}C and 95 ± 2% RH) and ambient condition (26 ± 4ºC and 75 ± 4% RH). The bee wax was emulsified with rice bran oil and standardized in the ratio of 1:100. Eight treatments with eight replications in cold storage and four in ambient storage were arranged based on treatment of wax coating (bee wax), LDPE bags of 210 ± 2 gauge without perforation, self-breathing bags of 200 ± 1 gauge, shrink wrapping with shrink film of nine microns and their combination for use on fruits for the purpose of study. Their initial weight, TSS, acidity, moisture content, texture, colour and gas composition inside the packages were noted.

The postharvest behaviour of the fruits kept in all the treatments were evaluated for fruits kept in cold and ambient storage. The results obtained for different parameters are summarised below.

Among the treatments, wax coating in combination with the use of LDPE 210 ± 2 gauge bags were found to be effective. The mangoes coated with wax and packed in LDPE bags without perforation showed minimum PLW of 1.1% when compared to that of uncoated fruits after the 20^{th} day of cold storage. The fruits kept at ambient condition exhibited higher PLW of 15% after 10^{th} day of storage. Since the coated wax is hydrophobic in nature it restricted the movement of water hence reducing PLW.

The results revealed that in general the TSS concentration has an increasing trend with storage, irrespective of the treatments. The mango coated with bee wax and packed in LDPE bags without perforation showed the lowest TSS concentration of 15^0Brix whereas the maximum TSS concentration (18 ^{0}Brix) was observed in uncoated fruits in shrink wrapping in cold storage on 20^{th} day. In ambient condition, mangoes under treatment T4 (wax + LDPE) showed the least value of TSS (13.5ºBrix) and treatment T3 (shrink wrapping) exhibited the maximum (17º Brix) on 7^{th} day of storage.

Generally there was a decreasing trend in the titratable acidity irrespective of the treatments given, since the mangoes were respiring and in a transit of ripening. Initially the value of TA was 1%. In cold and ambient storage, treatment T4 displayed high value of acidity by restricting the ripening.

Mangoes under wax coated treatments showed a general increase in moisture content where as the untreated ones displayed a decrease in moisture content from the initial value. The applied wax was hydrophobic in nature and restricted the moisture loss. There was significant change in colour irrespective of the treatments among which treatment T4 (wax + LDPE) had a better visual appearance with no black spots in both storage conditions.

It was found that the O_2 concentration decreased and CO_2 concentration increased with storage period. It was also noticed that the rate of respiration was less for treatment T4 in both cold and ambient condition due to the combined effect of wax and MAP condition created by LDPE bags without perforation.

In conclusion, all seven treatments limited the respiratory rate of mangoes during storage, and delayed ripening compared to control at both ambient and cold storage conditions. From the studies it was able to conclude that bee wax coated mango fruits in combination with MAP condition created by LDPE bags of 210 ± 2 gauge thickness without perforation could store the Cv ‘Moovandan’ for 20 days in cold storage under set condition with acceptable quality. While the fruits stored under ambient condition of same treatment lasted only for seven days. The results showed that the edible wax coating (bee wax emulsified with rice bran oil and standardized in the ratio of 1:100) in combination with MAP created by LDPE bags under low temperature storage is a beneficial treatment for extending the shelflife of mango.

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Appendices

APPENDIX

a. Variation of respiration rate in terms of oxygen consumption under cold storage condition

TREATMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	505	133.8	140.39	207.9
T2	505	108.75	190.54	115.85
T3	505	93.57	216.84	-
T4	505	157.69	203.27	103.35
T5	505	117.05	168.21	134.2
T6	505	126.33	192.1	167.78
T7	505	126.04	274.58	-
T8	505	127.88	316.43	-

b. Variation of respiration rate in terms of CO_2 enrichment under cold storage condition

TREATMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	204	91.242	191.28	54.07
T2	204	69.498	177.84	44.51
T3	204	64.78	104.23	-
T4	204	56.72	124.63	25
T5	204	36.74	191.51	34.83
T6	204	31.48	165.71	29.93
T7	204	27.02	194.47	-
T8	204	70.56	174.01	-

c.Respiration rate in terms of O_2 consumption under ambient storage condition

TREATMENTS	Day 0	Day 7
T1	421.85	48.63
T2	421.85	55.87
T3	421.85	50.2
T4	421.85	45.26
T5	421.85	48.5
T6	421.85	56.206
T7	421.85	50.187
T8	421.85	53.26

d. Variation in respiration rate in terms of CO_2 enrichment under ambient storage condition

TREATMENTS	Day 0	Day 7
T1	101.28	40.56
T2	101.28	77.14
T3	101.28	72.02
T4	101.28	38.81
T5	101.28	46.86
T6	101.28	46.53
T7	101.28	43.87
T8	101.28	78.96

e. Variation in PLW (%) in mangos during storage under cold storage condition

TREATMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	0	1.8	3.4	4.2
T2	0	2.1	4.1	5.3
T3	0	2.4	6.2	-
T4	0	2.1	2.8	3.8
T5	0	2.4	3.3	4.3
T6	0	2.5	3.6	4
T7	0	4.7	6.54	-
T8	0	5.2	-	-

f. Variation in PLW (%) in mangos during storage under ambient storage condition

TREATMENTS	Day 0	Day 7
T1	0	1.3
T2	0	1.9
T3	0	2.2
T4	0	1.17
T5	0	5.96
T6	0	3.6
T7	0	11.8
T8	0	24.8

g. Variation in TSS (^{o}Brix) in mango under cold storage condition

TREATMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	8	13.5	15	16.5
T2	8	14.8	15.5	17
T3	8	15	18	-
T4	8	12	14.5	15
T5	8	13	14.4	15.5
T6	8	13	15	16
T7	8	12.2	16	-
T8	8	16	-	-

h. Variation in TSS (^{o}Brix) in mango under ambient storage condition

TREATMENTS	Day 0	Day 7
T1	8	14.4
T2	8	15
T3	8	17
T4	8	13.5
T5	8	15.8
T6	8	14.5
T7	8	14.2
T8	8	14.9

i. Variation in titrable acidity (%) in mango under cold storage condition

TRAETMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	1	0.0192	0.0704	0.0501
T2	1	0.0192	0.0128	0.011
T3	1	0.0192	0.0128	-
T4	1	0.096	0.0672	0.0576
T5	1	0.0576	0.0448	0.0256
T6	1	0.0896	0.0448	0.032
T7	1	0.1088	0.0488	-
T8	1	0.0192	-	-

j. Variation in titrable acidity (%) in mango under ambient storage condition

TREATMENTS	Day 0	Day 7
T1	1	0.0704
T2	1	0.032
T3	1	0.0128
T4	1	0.0961
T5	1	0.076
T6	1	0.0768
T7	1	0.0765
T8	1	0.032

k. Variation in moisture content (%) in mango under cold storage condition

TREATMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	85.14	83	79	75
T2	85.14	82	80	72
T3	85.14	81	78	-
T4	85.14	86	87	89
T5	85.14	86	88	89
T6	85.14	86	87	88
T7	85.14	87	89	-
T8	85.14	80	-	-

l. Variation in moisture content (%) in mango under ambient storage condition

TREATMENTS	Day 0	Day 7
T1	85.14	81
T2	85.14	72
T3	85.14	79
T4	85.14	89
T5	85.14	91
T6	85.14	86
T7	85.14	86
T8	85.14	68

m. Variation in colour of mangos stored under cold storage

TREATMENTS	DAY 0	DAY 10	DAY 13	DAY 20
T1	1	2	3	5
T2	1	3	6	6
T3	1	3	4	6
T4	1	2	2	4
T5	1	2	3	5
T6	1	3	5	6
T7	1	2	5	6
T8	1	4	6	6

n.Variation in colour of mangos stored under ambient storage

TREATMENTS	Day 0	Day 7	Day 10
T1	1	2	6
T2	1	6	6
T3	1	5	6
T4	1	3	6
T5	1	5	6
T6	1	5	6
T7	1	3	6
T8	1	6	6

Abstract

EFFECT OF MODIFIED ATMOSPHERE PACKAGING AND EDIBLE WAX COATING ON SHELF LIFE OF MANGO

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PROJECT REPORT

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In

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ABSTRACT

Mangoes (*Mangifera indica*) are an important tropical fruit crop with good potential for expanded markets outside of the growing regions. Mango fruits are climacteric and ripen rapidly in about three to nine days after harvest. This short period seriously limits the long distance commercial transport of this fruit. Fruit sensitivity to decay, low temperature and general fruit perishability due to the rapid ripening and softening limits the storage, handling and transport potential. Hence a study has been undertaken to analyse the effect of MAP and edible wax coating on shelflife of mango.

The effect of edible coating (1% bee wax in rice bran oil) and MAP on shelflife extension of mango fruit was investigated. The physical and biochemical quality parameters such as titratable acidity, TSS, physiological loss in weight, respiration and skin colour were monitored. The analysis was carried out under ambient (26 ± 4ºC, 75 ± 4% RH) and cold (13 ± 1ºC, 95 ± 2% RH) storage conditions. This study showed that use of edible coating along with MAP condition could reduce the respiration rate and there by extend the shelflife by one to three weeks. From the studies it was able to conclude that bee wax coated mango fruits in combination with MAP condition created by LDPE bags of 210 ± 2 gauge thickness without perforation could store mangoes for 20 days in cold storage under set condition with acceptable quality, while the fruits under ambient condition of same treatment lasted only for seven days.