ALOE VERA BASED EDIBLE FILM COATING FOR SHELF LIFE EXTENSION IN TOMATO (*Solanum lycopersicum*)

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DECLARATION

I, hereby declare that this thesis entitled **"*Aloe vera* based edible film coating for shelf life extension in tomato (Solanum lycopersicum)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABREVIATIONS

%	per cent
μl	micro litre
χ^2	chi square
^0B	degree brix
CD	Critical difference
cfu	colony forming units
cm	Centimetre
Cm^2	square centimeter
CRD	Completely Randomized Design
et al	And others
Fig.	Figure
g	gram
i.e.	That is
kg	Kilogram
Kw	Kruskall Wallis
lit	litre
mg	milligram
min	minutes
ml	millilitre
mm	millimetre
nm	nanometre
NS	Non significant
^0C	Degree Celcius
PE	polyethylene
PLEAG	plant leaf extract incorporated aloe gel
CFB	Corrugated fibre box
ppm	parts per million
TSS	total soluble solids
viz.,	namely

INTRODUCTION

1. INTRODUCTION

Importance of postharvest technology increases in the field of horticulture, as horticultural produces are highly perishable in nature. It is a paradox that people of the country producing huge quantities of horticultural produce are still suffering from many nutritional deficiencies in their diet. The credit of this would predominantly go to our poor postharvest infrastructure as well as knowhow and accessibility to the facilities. All this make us one among those countries having largest postharvest losses, accounting to 25-40 percent.

Other major issues of postharvest loss include seasonality, non-planning and inefficient production creating gluts and shortages in the market. Prices of perishables come down drastically during glut to consumer's relief, while farmers are hit by low prices. This is considered as a regular and serious problem with regard to tomatoes, where the favourable climatic conditions lead to bumper yield from hybrid varieties of tomato and farmers are forced to sell their produce at a cheap rate. This tomato glut has created anxiety among growers as well as researchers and unless there are systematic solutions to manage the surplus, time and money spent on cultivation will be a mere waste. Hence a study is needed to develop a postharvest management practice for extending the shelf life of tomato in order to preserve them during glut period.

Tomato (*Solanum lycopersicum*) is one of the most important supplementary sources of minerals and vitamins in human diet. It is a rich source of lycopene along with fairly large amounts of β-carotene, vitamin C, phenolics, smaller amounts of vitamin E, flavonoids and tracer amounts of copper, manganese, and zinc (Kaur 2004). The cultivated tomato, Solanum lycopersicum, is the second most important non-cereal crop worldwide and an important model species for fruit physiology and development (Lippman *et al.*, 2007). It is the most preferred vegetable in culinary purposes as well as it ranks first among processed vegetables in world.

The highly perishable nature of tomatoes require careful attention in the harvesting and subsequently post harvest processing operations in order to reduce the losses and meet the market demand and to fetch high market process during the lean season. The post harvest losses are due to moisture loss, rough handling, packaging, bruises, diseases and transportation. Owing to lack of information on appropriate postharvest treatments, packaging, temperature, etc the fruits not only lose their quality but also encounter a substantial postharvest loss.

For fresh tomatoes, the two quality attributes that are most important to buyers and consumers are texture and skin colour. Texture is influenced by flesh firmness and skin strength. Softening during storage, distribution and ripening of tomatoes can be a major problem because it may increase their susceptibility to damage.

Today's consumers are very much concern about the eating quality of tomatoes. Bio preservation is a novel food preservation method defined for extension of shelf life and enhanced food safety by the use of natural or controlled micro biota and/or anti-microbial compounds. Recently it has been discovered that plants products can be used as a natural preservatives for minimizing the post harvest loss by forming an edible coating on fruits.

Edible coatings are thin layers of edible material applied to the product surface in addition to or as a replacement for natural protective waxy coatings and provide a barrier to moisture, oxygen and solute movement for the food. They are applied directly on the food surface by dipping, spraying or brushing. These coating acts as a barrier and helps reduce water vapor loss hence increasing the shelf life, slowing down the ripening and decay.

Aloe vera gel is one of the most commonly used edible coating for fruits. It is efficient as well as cheap, easily available, prevents the spoilage due to microbial attack, controls respiration rate and prevents the loss of firmness and moisture. It also has antimicrobial and anti fungal properties against gram positive and gram negative bacterial pathogens. This natural product is a safe and environmentally friendly alternative.

Absence of cold storage facility, inadequate transportation facilities and improper handling during transportation are the other possible causes of post harvest losses. Hence if the treated tomato fruits could withstand storage and transportation loss, postharvest losses during those stages could be minimized. The present study is aimed to prevent moisture loss and decay and thereby increasing the shelf life of tomato during glut periods with the application of Aloe vera based gel, which is an economic and biodegradable natural preservative.

Hence a study on "*Aloe vera* based edible film coating for shelf life extension in tomato (Solanum lycopersicum)" was undertaken at the Department of Post Harvest Technology, College of Agriculture, Vellayani with the following objectives.

1. To standardise an Aloe vera gel based edible film coating for tomato fruits to withstand storage and transportation losses.
2. To formulate a viable and efficient postharvest management practice for extending shelf life of tomato.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Fresh tomatoes are popular and versatile vegetable throughout the world, making significant contributions to human nutrition for its sugars, acids, vitamins, minerals, lycopene and other carotenoid contents, among other constituents.

Tomatoes contain 80–90% water by weight and thereby making it more perishable resulting in poor product shelf life. Major losses in quality and quantity of fresh tomatoes occur between harvest and consumption. Edible film coatings on fresh tomatoes can provide a modified internal atmosphere for the product and thereby acts as an alternative for reducing the quality and quantity losses, and thus the major post harvest loss of tomatoes can be reduced.

Research findings already reported by various workers on edible film coatings are reviewed here under.

2.1. Importance of tomato

Tomato fruit is believed to have been originated from wild in Peru, Ecuador and other parts of tropical America. The nutritional and economic importance of the crop has led to its global production (Rick and Butler, 1956).

Tomato (*Solanum lycopersicum L.*) is one of the most widely cultivated warm season crop and extensively consumed horticultural crop globally (Grandillo *et al.,* 1999). The cultivated tomato, *Solanum lycopersicum*, is the second most important non-cereal crop worldwide and an important model species for fruit physiology and development, quantitative genetics and plant breeding (Lippman *et al.*, 2007).

Tomato contains higher amounts of lycopene, a type of carotenoid with antioxidant properties (Arab and Steck, 2000) which is beneficial in reducing the incidence of some chronic diseases like cancer (Basu and Imrhan, 2007) and many other cardio vascular disorders (Burton and Reimers, 2011). Tomato and tomato-based foods provide a wide variety of nutrients and many health related benefits to the body (Wilcox *et al.*, 2003).

2.2. Quality characteristics of tomato

The quality components of tomato include appearance (color, size, shape, freedom from defects and decay), firmness, flavor and nutritional value.

Kader *et al*., (1978) stated that the fruit composition at the time of harvest and compositional changes during post harvest handling influenced the color, firmness, flavor, nutritive value and safety of tomatoes.

Consumers prefer tomatoes based on appearance and firmness. According to Battu, (2004) texture of tomato is influenced by flesh firmness and skin strength. High quality fruit have a firm, turgid appearance, uniform shiny color and no signs of mechanical injury, shriveling, or decay. The principal causes for postharvest losses in tomato are decay, external damage incurred during harvest and handling, and harvest at an improper maturity stage (AMS, 2007)

2.3. Importance of harvest maturity

The physico-chemical characteristics of fruits change significantly with maturity (Chandra and Kar, 2003). (Giusti *et al*., 2008; Sonkar *et al*., 2008) revealed that the changes in harvest maturity lead to certain post harvest constraints like short shelf life, susceptibility to many diseases and pests and faster fruit ripening at warmer temperatures which limit its long duration storage and transportation.

Martins *et al*., (2008), assessed the fruit maturity subjectively by the fruit colour and days after fruit set, physical and chemical properties are determined objectively in the laboratory prior to harvesting, storage, transportation and marketing.

2.3.1. Harvest maturity in tomato

The average time from transplanting to harvest of large-fruited tomato cultivars ranges from 60 to 70 days for early cultivars, 70 to 80 days for mid-season cultivars, and more than 80 days for late cultivars. There are several reliable external and internal indices of tomato fruit maturity.

The external fruit maturity index is based on skin color, while the internal indices are based on seed development and locular gel formation. Depending on the market and production area, tomatoes are harvested at different stages of maturity ranging from physiological maturity (mature-green stage through full-ripe).

According to Shankara *et al*., (2005) ripe fruits are to be picked profitably for nearby market and mature green fruits are harvested for distant transport which will develop normal colour in 3-7 days and fruits for canning or for juice extraction are harvested when they reach the ripe stage, and processed soon after.

Athmaselvi *et al.,* (2013) described mature green fruits as those which have not begun to turn pink, while those classed as turning show some pink at the blossom end, half-ripe fruits show pink colour over most or all of the surface; ripe or red-ripe fruits are those that have developed full red colour peculiar to the type but are at the same time firm.

2.4. Post harvest loss of tomato during peak season

According to Grierson and Kader (1986), the major postharvest losses of tomatoes are due to fungal infection, physiological disorders, and physical injuries.

Ameyapoh *et al*., (2008) reported that high production of tomato and inefficient post-harvest processing and preservation techniques resulted in early spoilage of fruits.

Tomato is a climacteric fruit and continues to ripen even after harvest and during ripening; carotenoids are synthesized by the degradation of green pigment chlorophyll (Liu *et al*., 2009).

Kader (2005) and Pila *et al.,* (2010) reported 50% loss in tomatoes between the harvesting and consumption stages of the distribution chain in tropical countries.

Muhammad *et al.,* (2011) stated tomato as a perishable crop due to its high moisture content and reported a short shelf life of about 48 hours under tropical conditions. Specialized postharvest handling practices and treatment methods are needed to extend the shelf life of the tomato fruit after harvest and failure to adhere to these specialized handling practices and treatment methods results in high post harvest loss.

During harvesting, a change in the gaseous balance occurs between the consumption of oxygen and production of carbon dioxide and in this condition, the cells are not renewed and the gas transfer rates increase, causing a metabolic loss and taking the fruit to a gradual maturation and eventual senescence (Dhall, 2013).

Postharvest loss is a major challenge hampering tomato production in most developing countries (Arah *et al.,* 2015).

2.5. Importance of post harvest management for reducing post harvest loss

According to Erbil and Gil (1986) optimum extension of post harvest life of any food product is critically dependent upon three factors *viz*., reduction in desiccation, reduction in the physiological process of maturation and senescence, and reduction in the onset and rate of microbial growth.

Dhall (2013) reported the importance of several techniques like controlled atmosphere storage and modified atmosphere storage for preserving fruits to reduce their quality and quantity losses during storage. Hence it is important to know the appropriate handling practices and treatment methods needed for harvested tomatoes in order to reduce postharvest losses thereby increasing profitability for handlers.

Isac *et al.,* (2016) stated that postharvest quality and shelf life of fruits depend on postharvest handling practices and treatments carried out after harvest, and the quality of any fruit after harvest cannot be improved by the use of any postharvest handling practices or treatment methods, however it can be maintained.

2.6. Bio preservative approach for post harvest management

Bio preservation is a novel food preservation method defined for extension of shelf life and enhanced food safety by using natural or controlled micro biota and/or anti-microbial compounds and plant-based products in fresh fruits and vegetables as bio preservatives in the form of edible coatings (Baldwin *et al*., 1996).

According to Lin and Zhao (2007) an increased effort has been made to develop new natural preservatives and antimicrobials, as consumers around the world demand food of high-quality, without chemical preservatives, with an extended shelf life.

Antunesa *et al.*, (2012) reported the exploitation of natural products to control decay and extend storage life of perishables getting more attention.

Jawadul *et al.*, (2014) reported that edible films and coatings have received considerable attention in recent years because of their advantages including use as edible packaging materials over synthetic films.

2.6.1. Post harvest management using surface coatings

The fruits and vegetables remain as living tissues until the time they are consumed fresh, cooked for consumption, or processed for preservation.

Banks *et al.*, (1993) reported that surface coatings can increase a fruit's skin resistance to gas diffusion, modify its internal atmosphere composition, depress its respiration and transpiration rate.

Baldwin (1994) reported that the use of coatings for fresh fruits and vegetables is not a new concept, and the fruits and vegetables are coated in nature by a natural waxy coating called cuticle, consisting of a layer of fatty acid – related substances, such as waxes and resins, with low permeability to water.

Yaman and Bayindirh (2002) reported the use of Semperfresh as skin coating reduced weight loss and softening, and thereby extended the shelf life of sweet cherry.

Thompson (2003) reported that fruits or vegetables are usually coated by dipping in or spraying with a range of edible materials, so that a semi permeable membrane is formed on the surface for reducing respiration, controlling moisture loss, and providing other functions.

According to Alonso and Alique (2004), derivatives of fatty acids and polysaccharides decreased sweet cherry fruit respiration rate and weight loss.

Cha and Chinnan (2004) observed different compounds which can be used as skin coatings to prevent commodity weight loss, including wax, milk proteins, celluloses, lipids, starch, zein and alginates.

2.7. Bio preservation using edible coatings

2.7.1. Edible coatings – definition

Guilbert *et al.,* (1995) defined edible coatings as a thin layer of material that covers the surface of the food and can be eaten as part of the whole product.

According to Mc Hugh and Senesi (2000) edible coatings are thin layers of edible material applied to the product surface in addition to or as a replacement for natural protective waxy coatings and to provide a barrier to moisture, oxygen and solute movement for the food and they are applied directly on the food surface by dipping, spraying or brushing.

Souza *et al.,* (2010) defined an edible coating as a suspension or an emulsion, which is applied directly to the food surface and later forms a film.

According to Dhall (2013) an ideal edible coating is defined as one that can extend storage life of fresh fruit without causing anaerobiosis, and that reduces decay without affecting the quality of the fruit.

2.7.2. Importance of edible films

According to Park *et al.*, (1994) edible coatings can provide an additional protective coating for fresh products and can also give the same effect as modified atmosphere storage in modifying internal gas composition.

Guilbert *et al.,* (1996) revealed the major benefit of edible coatings as that they can be consumed along with food, provide additional nutrients, enhance sensory characteristics and include quality enhancing antimicrobials.

Edible coatings are traditionally used to improve food appearance and conservation due to their environment friendly nature, because they are obtained from both animal and vegetable agricultural products (Petersen *et al.,* 1999).

Park (1999) revealed that edible coatings extend the shelf life of fresh fruits and vegetables by reducing moisture and solute migration, gas exchange, respiration, and oxidative reaction rates as well as by reducing or even suppressing physiological disorders.

Edible coatings are also used on processed fruits and vegetables for improving structural integrity of frozen fruits and vegetables and preventing moisture absorption and oxidation of freeze-dried fruits or vegetables (Baldwin and Baker 2002; Olivas and Barbosa 2005; Park 2005).

The use of edible films and coatings in food protection and preservation has recently increased since they offer several advantages over synthetic materials, such as being biodegradable and environmentally friendly (Tharanathan, 2003).

According to Min and Krochta (2005), edible coatings carry functional ingredients such as antioxidants, antimicrobials, nutrients and flavors to further enhance food stability, quality, functionality and safety.

Castillo and Serrano (2005) reported that edible coatings improves food quality and prolongs the shelf life of fresh produce by regulating the transfer of moisture, oxygen, carbon dioxide, aroma and taste compounds in a food system.

According to Lin and Zhao (2007) edible films and coatings act as carriers of active compounds, which on application to the surface of fruits and vegetables, lead to the extension of shelf-life, reduction of the risk of food borne pathogenic microorganisms growth and also improvement of quality, stability and safety of coated foods.

Vargas *et al.,* (2008) reported that in addition to the traditional role of edible coatings as a barrier to water loss and delaying fruit senescence, the new generation coatings are being designed for incorporation and/or for controlled release of antioxidants, nutraceuticals, chemical additives and natural antimicrobial agents.

Antunesa *et al*., (2012) reported that the permeability of the edible coating is of significant importance to prevent an anaerobic environment or excessive water loss which depends on the respiration rate of the produce and storage environment.

Edible coatings on fresh fruits and vegetables can provide an alternative to modified atmosphere storage by reducing quality and quantity losses through modification and control of the internal atmosphere of the individual fruit or vegetable (Dhall, 2013).

2.8. Aloe vera as an edible film for fresh fruits and vegetables

2.8.1. Importance of *Aloe vera*

Aloe vera is a well-known plant for its marvelous medicinal properties, but today aloe vera industry is flourishing and the gel is used in many products such as fresh gel, juice and other formulations for health, medicinal and cosmetic purposes (Eshun and He, 2004).

Tripathi and Dubey (2004) reported that researchers from Spain developed a gel based on aloe vera that prolongs the conservation of fresh fruits which is tasteless, colorless and odourles natural product that is safe and environmentally friendly alternative to synthetic preservatives such as sulfur dioxide.

Valverde *et al*., (2005) reported aloe vera gel as the promising bio preservative which has been identified as a novel coating agent with good antimicrobial properties.

Aloe vera extract has moisture conditioning (Martinez *et al.,* 2006) and bio-preservative (Shupe, 2003) properties, essential for formulating edible surface coatings.

According to the Serrano *et al*., (2006) the aloe vera gel operates through a combination of mechanisms, forming a protective layer against the oxygen and moisture of the air and inhibiting the action of micro-organisms that cause food borne illnesses through its various antibacterial and antifungal compounds.

Aloe vera is a shrubby or arborescent, perennial succulent plant of Liliacea family with turgid pea-green leaves joined at the stem in a rosette pattern and is characterized by stem less large, thick, fleshy leaves that are lance shaped and have a sharp apex and a spiny margin (Steenkamp and Stewart, 2007).

Chauhan *et al.,* (2007) described aloe vera as a 'Natures Gift' being a vast resource of carbohydrates in the form of glucomannans, antioxidants and secondary metabolites with bio-preservative functionality.

According to Surjushe *et al.,* (2008) aloe vera gel is a clear jelly-like substance that is obtained from the thin walled sticky cells of the inner portion of the leaf, which contains 99 % water and rest is made of glucomannans, amino acids, lipids, sterols and vitamins.

Liu *et al.*, (2013) stated that the plant has been known and used for its health, beauty, medicinal and skin care properties since 6000 years B.C and scientific investigations on aloe vera gained more attention from the last several decades due to its reputable medicinal properties.

Aloe vera is known as "plant of immortality" by the Egyptians due to its beneficial effect on human health (Jawadul *et al.*, 2014).

According to Simple and Tripti (2014) the two major liquid components of aloe vera are a yellow latex (exudate) and clear gel (mucilage), which proceeds from the large leaf parenchymatic cells.

Aloe vera gel has been proven one of the best edible and biologically safe preservative coatings for different types of foods because of its film-forming properties, antimicrobial actions, biodegradability and biochemical properties and it is composed mainly of polysaccharides and acts as a natural barrier to moisture and oxygen, which are the main agents of deterioration of fruits and vegetables (Jawadul *et al.*, 2014).

2.8.2. Chemical constituents in aloe vera gel

Raw pulp of aloe vera contains 98.5 % water, while the mucilage or gel consists of about 99.5 % water (Eshun and He, 2004).

According *to* Dureja *et al.*, (2005) aloe vera contains as many as 75 nutrients and 200 active compounds including sugar, anthraquinones, saponins, vitamins, enzymes, minerals, lignin, salicylic acid and amino acids.

According to Zhiliang, (2008) aloe vera skin contains a large number of polysaccharides, the polysaccharide is stored in the palisade tissue of the epidermal keratinocytes.

Ahlawat and Khatkar (2011) reported that on dry matter basis aloe vera gel consists of polysaccharides (55 %), sugars (17 %), minerals (16%), proteins (7 %), lipids (4 %) and phenolic compounds (1 %) with some seasonal fluctuation.

Liu *et al.*, (2013) reported that aloe vera parenchyma tissue or pulp contains proteins, lipids, amino acids, vitamins, enzymes, inorganic compounds and small organic compounds in addition to the different carbohydrates.

2. 8. 3. Antimicrobial property of *Aloe vera* gel

Shelton (1991) reported antibacterial activity for aloe vera gel against some food borne pathogenic microorganisms such as *Bacillus cereus, Salmonella typhimurium, Escherichia coli, Klebsialla pneumonia* etc.

Agarry *et al.,* (2005) tested antimicrobial activities of aloe vera gel and leaf by the appearance of zones of inhibition and antimicrobial susceptibility test showed that both the gel and the leaf inhibited the growth of *Staphylococcus aureus* (18.0 and 4.0 mm, respectively).

Habeeb *et al.,* (2007) observed that the antimicrobial activity of aloe vera gel is due to the presence of a wide range of constituents in gel and it also inhibits the growth of both gram positive and gram negative bacteria.

Nidiry *et al.,* (2011) reported the antifungal activity of aloe vera gel against several fungi including *Colletotrichum* sp.

Emodine, the antimicrobial constituent present in aloe vera gel has been reported to be effective against several gram positive bacteria (Cock, 2008).

Hammam, (2008) and Lone *et al.,* (2009) revealed that the anthraquinones present in aloe vera gel resulted in the antimicrobial activity against *Staphylococcus aureus* strains and *Escherichia coli*, through inhibition of solute transport in membranes.

According to Athmaselvi *et al.,* (2013) aloe vera gel appears to contain various antibiotic and antifungal compounds that can potentially delay or inhibit microorganisms that are responsible for food borne illness in humans as well as food spoilage.

Brishti *et al.* (2013) observed 100% disease incidence in uncoated papaya fruits at the end of storage, whereas for aloe gel coated fruits disease incidence was only 27%.

Jawadul *et al.,* (2014) defined antimicrobial as a substance that kills or inhibits the growth of microbes such as bacteria (antibacterial activity), fungi (antifungal activity), viruses (antiviral activity), or parasites (anti-parasitic activity).

2.8.4. Application of aloe vera gel in different fruits and vegetables

Valverde *et al*., (2005) reported aloe vera gel as a means of preservation to maintain the quality and safety of cv. Crimson seedless table grapes during cold storage and subsequent shelf life.

The use of aloe gel as an edible surface coating has been reported to prolong the shelf life and to delay changes in parameters related to deterioration of quality in table grapes (Serrano *et al.,* 2006).

Aloe vera gel-based edible coatings have been shown to prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning and reduce microorganism proliferation in fruits such as sweet cherries (Martinez *et al.,* 2006), table grapes (Castilo *et al.,* 2010),and nectarines (Ahmed *et al.,* 2009).

Aloe vera as an edible coating remains a viabie alternative to delay the ripening of tomato (Athmaselvi *et al.,* 2013).

Sophia *et al*., (2014) reported the potential of using aloe gel as a coating for improved postharvest shelf life and maintaining quality of mango fruits and hence reduced postharvest losses. According to Goyal *et al.,* (2017*)* aloe gel applied as an edible coating on tomatoes has a positive effect in retarding the ripening process and microbial action on it.

2.9. Additives or thickening agents

Alginates and carrageenans can be used to prepare edible coatings and alginates are the salts of alginic acid, which is a linear copolymer of D-mannuronic and L-guluronic acid monomers.

Alginate coating formation is based on the ability of alginates to react with di-valent and tri-valent cations such as calcium, ferrum, or magnesium which are added as gelling agents (Cha and Chinnan, 2004).

Tapia *et al.,* (2008) reported that the addition of ascorbic acid (1% w/v) to the alginate and gellan based edible coatings helped to preserve the natural ascorbic acid content in papaya, thus helping to maintain its nutritional quality throughout storage.

Zapata *et al.*, (2009) found that alginate edible coating including a mixture of essential oils (thymol, menthol, eugenol, carvacrol) had a better effect in reducing ripening processes in tomato compared to alginate alone at 1%.

Girard (2011) reported that an edible coating comprising of sodium alginate and pectin along with several additives: antimicrobials, flavoring agent, antioxidant was patented for covering fruit and vegetables by immersing them in the solution.

2.10. Plant leaf extracts as antimicrobials

The antimicrobial properties of plant extracts from various species have been proven to affect fungal development in vitro and in vivo (Montes-Belmont *et al.,* 2000).

According to Banos *et al.,* (2000), spore formation and germination, mycelia growth and infection can sometimes be stimulated or inhibited by plant extracts. In postharvest studies, dipping fruit in plant extracts inhibited rot development during storage and the effects of different plant leaf extracts were listed below:

2.10.1. Papaya leaves

Papaya (*Carica papaya L.*) is a popular and economically important fruit of tropical and subtropical countries and ranks first among 13 to 17 fresh fruits for vitamin C content per 100 grams edible tissue (Gebhardt and Thomas, 2002).

Aqueous extracts of leaves of papaya (*Carica papapya*) showed important fungistatic effects against *Rhizopus stolonifer* and *Colletotrichum gloeosporioides* in mango (*Mangifera indica*) during fruit storage (Banos *et al.,* 2002).

Marpudi *et al.,* (2011) revealed that papaya leaf extract incorporated aloe vera gel coating controlled physiological loss in weight, ripening process (chemical changes, colour development, softening of fruit tissues) and decay to a great extent in papaya fruits and thereby extended the shelf life.

Brishti *et al.*, (2013) revealed that extracts of papaya leaf can be incorporated into aloe vera gel to enhance the effectiveness of the anti-fungal activity of aloe vera gel matrix.

2.10.2. Ocimum leaves

Tewari and Nayak (1991); Mohamed *et al.*, (1996), reported on the antifungal properties from the essential oil of *Ocimum sanctum.*

Ocimum sanctum termed as the 'queen of herbs' or 'the mother medicine of nature' revealed that the antimicrobial property tested against a variety of microorganisms like *Candida albicans, Staphyloccus aureus,* enteric pathogens like *Klebisella, Escherichia coli* and *Proteus* (Geetha *et al.*, 2001).

'Tulsi' is widely distributed in India, and the availability ranges from Himalayas to Andaman and Nicobar Islands (Girard, 2016).

Agarwal *et al.*, (2010) conducted a study using different concentrations of ocimum extract and it was found that 4% concentration exhibited a zone of inhibition of 22 mm against *Staphylococus mutans.*

Ocimum sanctum L. has been widely accepted to possess anticancer, antidiabetic, antimicrobial, hepatoprotective, analgesic, antifertility, anti-inflammatory, anti ulcer and antihypertensive actions (Pandey and Madhuri, 2010; Bhattacharyya and Bishayee, 2013).

2.10.3. Guava leaves

Hoque *et al.*, (2007) reported the antibacterial activity of guava extracts against 21 strains of food borne pathogens *viz.*, *Listeria monocytogenes* (five strains), *Staphylococcus aureus* (four strains), *Escherichia coli* (six strains), *Salmonella Enteritidis* (four strains), *Vibrio parahaemolyticus* and *Bacillus cereus*, and five food spoilage bacteria: *Pseudomonas aeroginosa*, *P. putida*, *Alcaligenes faecalis*, and *Aeromonas hydrophila* (two strains).

Nair *et al.*, (2007) revealed four antibacterial flavonoids (morin-3-O-lyxoside, morin-3-O-arabinoside, quercetin, and quercetin-3-O-arabinoside) isolated from *Psidium guajava* leaves showed higher antimicrobial activity against Gram-positive bacterial and fungal strains.

Psidium guajava contains a number of active ingredients such as flavonoids, guayavolic acid, guavanoic acid, guajadial, and guajaverin responsible for antimicrobial property (Gutierrez *et al.,* 2008).

Chen *et al.,* (2009) reported that the budding leaves of *Psidium guajava* contained huge amounts of soluble polyphenolics including gallic acid, catechin, epicatechin, rutin, quercetin and rutin having antimicrobial action.

Psidium guajava commonly known as guava, belong to the family of Myrtaceae grows in the tropical and subtropical areas of the world, and adapted to different climatic conditions but prefers dry climates (Wang *et al.,* 2014).

2.11. Importance of Storage

2.11.1. Optimum low Temperature Storage

Storage in the value chain is required to ensure uninterrupted supply of raw materials for processors and storage extends the length of the processing season and helps to provide continuity of product supply throughout the seasons. Tomato has very high moisture content and therefore is very difficult to store at ambient temperatures for a long time.

Cold storage plays an important role in storage of fruits and vegetables in many countries. Low temperature prolongs the shelf life probably due to the reduction of various gases (O_2, CO_2) exchange from the inner and outer atmosphere as well as slowing down the hydrolysis process (Uddin and Hossain, 1993).

Nyalala and Wainwright (1998) studied the shelf life of two tomato cultivars stored at 4.5°C, room temperature (18-25°C) and at 30°C and it was found that weight loss was significantly higher at increased temperatures and there was an interaction between cultivar and temperature and also stated that loss of fruit firmness was greatest at the two higher temperatures.

Temperature is the most important factor affecting fruit storage life because all the physiological processes leading to senescence viz., respiration and ethylene production are controlled by temperature (Wills *et al.*, 1998).

According to Roberts *et al.*, (2002), postharvest recommendations indicate that tomatoes, including cherry and grape tomatoes, should be stored at 10°C or higher to avoid chilling injury.

According to Roberts *et al.*, (2002), postharvest recommendations indicate that tomatoes, including cherry and grape tomatoes, should be stored at 10°C or higher to avoid chilling injury.

For short-term storage (up to a week), tomato fruits can be stored at ambient conditions (Shewfelt *et al.,* 1987) if there is enough ventilation to reduce the accumulation of heat from respiration, while for long term storage, ripe tomatoes are to be stored at temperatures of about 10–15^{0}C and 85–95% relative humidity (Castro *et al.,* 2005).

Hossain (2007) observed that weight loss of fruit was significantly affected by modified atmospheric storage and low temperature storage and fruits held at low temperature had lowest weight loss whereas it was highest in control.

2.12. Packaging

2.12.1. Importance of packaging

The ideal pack consist of a tight fill without a bulge in a filled container having sufficient stacking strength to protect the contents under all handling conditions (Adsule, 1996).

Packaging for transportation and handling requires consideration to protect the produce from suffocation, bruising, vibration and the weight of other stacked containers (Lal and Fageria, (2004).

Singh *et al.,* (2015) reported that packaging materials help in creating the modified micro environment around the fruits and vegetables which helps in extending the shelf life with controlled physiological changes.

2.12.2. Corrugated Fibre Board Box (CFB)

Roy and Pal (2000) also suggested the use of CFB boxes as fruits packaging material for minimizing loss.

Krishnamurthy and Rao (2001) revealed t the use of alternate packages like corrugated fibre board boxes have to be encouraged because CFB boxes are hygienic, light in weight and are recyclable.

According to Lal and Fageria (2004) ber fruits packed in CFB boxes maintained the maximum TSS (13.75%), acidity (0.153%) and vitamin C (68.76 mg/100 g pulp) compared to the fruits packed in gunny bags lined with polythene.

Choudhary, (2006) revealed that ventilated CFB box which contains ventilated partitions developed at the IARI was found to be ideal for the packaging and transportation of fruits, owing to the comparably minimal level of bruising observed in these boxes.

Singh *et al.*, (2015) reported that the shelf life of hybrid and open pollinated tomato varieties are limited to 15-20 days of storage in CFB boxes at room temperature.

2.12.3. Importance of cushioning materials/ liners in packages

Cushioning materials used in the packaging of fruits and vegetables in wooden boxes include dry grass, paddy straw, leaves, sawdust, paper shreds etc all of which end up as garbage and add to environmental pollution in cities.

Peleg (1985) describes good interior packaging as that which treats a fruit as separate units, avoids fruit-to-fruit contact, absorbs the impact energy and is practical.

According to Bollen (2001) corrugated board wrapping adequately protects fresh fruit from impact and compression forces.

The inherent affinity of corrugated board to moisture, as with any paper-based packaging material, compromises its strength and cushioning capabilities and however, because of its expedient degradability, high recycling rate and low cost of the recycled paper, corrugated board holds good potential as a cushioning material (TISTR, 2002). Moulded trays or cardboard partitions used in CFB boxes are however easily recycled (Choudhary, 2006).

Mechanical damage can be reduced from 26.3% to 12.9% using 8-mm thick Styrofoam sheets as a cushioning material between banana bunch layers for the bulk packaging of bananas placed onto trucks for long-distance transport in comparison to the present conventional transport method (Wasala *et al.*, 2015).

2.13. Transportation

Production wasted due to damage in the chain between the grower and the consumer is estimated at around 30–40% (Peleg and Hinga, 1986).

Sitke (1986) reported that the reasons for mechanical injuries are numerous, which are often broadly grouped as impact, abrasion, compression and vibration damage, based on the type of force acting on the fruit.

The main types of damage to fruit are bruising and tearing of skin (external) and internal damage (Mohsenin, 1987; Olounda and Tung, 1985; Ogut *et al.*, 1999).

Lallu *et al.*, (1999) described that in the transport of kiwi fruit vibration generally resulted in abrasion of the skin, with a smaller amount of compression damage and little impact injury.

Vursavus and Ozgoven (2004) commented that the vibrations due to transportation are influenced by road roughness, distance, speed, packaging and some characteristics of the truck suspension and the number of axles.

Modified atmospheric packaged produce has been transported in CA containers at suitable temperatures and relative humidities which resulted in extending shelf life, retaining fresh produce quality and reducing losses. Mangoes stored in controlled atmosphere of 3–5% O2 and 5–8% CO_2 at 10°C (ripe) Shelf life extended up to 20 days, when compared to 5–7 days for control fruit (Sirivatanapa., 2006).

According to Acican *et al.*, (2007) among different causes of damage to fruits, vibration generated by vehicles during road transport has an important role on the damage process to the agricultural products, particularly soft fruits.

Zeebroeck *et al.*, (2007) stated that mechanical damage that occur during different stages of fruit harvest and post harvest represents a serious hazard to quality and has the potential to significantly reduce the value of product.

Transport is a crucial phase in the distribution of fresh food products, from the harvesting operation to the consumer. However, during transport and handling, fresh products may suffer considerable damage and also transporting tomatoes in refrigerated trucks are not only convenient, but also effective in preserving the quality of fruits (Springael *et al.*, 2018).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "*Aloe vera* based edible film coating for shelf life extension in tomato (*Solanum lycopersicum*)" was undertaken at the Department of Post Harvest Technology, College of Agriculture, Vellayani, during the period 2014-2017, with the objectives to standardise an Aloe vera gel based edible film coating for tomato fruits to withstand storage and transportation losses, thereby formulating a viable and efficient postharvest management practice for extending shelf life of tomato.

Experiments were carried out as five different continuous steps.

1. Preliminary trial for preparation and standardization of aloe extract
2. Standardization of aloe gel as edible film for extension of shelf life
3. Evaluation of plant leaf extract incorporated aloe gel for extension of shelf life
4. Quality evaluation of film coated tomato
5. Efficiency of aloe based edible film in reducing postharvest loss during storage and transportation

3.1. PRELIMINARY TRIAL FOR PREPARATION AND STANDARDIZATION OF ALOE EXTRACT.

A preliminary trial was conducted for standardization of aloe extract, as the present study is the first to assess the efficiency of using *Aloe vera* gel based edible film in extending shelf life of any tropical vegetable in Kerala.

Good quality fresh ripe tomato fruits free from visual defects and relatively uniform size, weight and colour were collected from vegetable fields of Kalliyoor panchayat at Thiruvananthapuram were used for carrying out the preliminary trial.

Good quality fresh *Aloe vera* leaves were procured from the local market. Aloe gel matrix which lies underneath the green outer rind was manually separated from the outer cortex of leaves and this colorless hydro parenchyma was homogenized in a blender. The resulting homogenate was then filtered to remove the fibres to form 100 percent fresh aloe gel. The filtered aloe gel was pasteurized at 70^0C for 45 minutes (Maughan,1984) and then cooled immediately to ambient temperature after maintaining pH at 4 by adding citric acid (0.5-1gl^{-1}) and ascorbic acid (0.1- 0.50 gl^{-1}).

The gel was thickened for the purpose of skin coating using the following four different gelling agents at 1% concentration.

INS 401

INS 402

INS 440

INS 508

The mixtures were stored in brown amber colored bottles in deep freezer, till use. The prepared gel thickened with each gelling agent was applied by dipping tomato fruits at seven different concentrations for five different durations for standardization of aloe gel extract.

Concentrations:

C1 - 1%

C2 - 2%

C3 - 5%

C4 - 10%

C5 - 15%

C6 - 25%

C7- 35%

Durations:

T1 – 1 minute

T2 – 2 minutes

T3 – 5 minutes

T4 – 10 minutes

T5 – 15 minutes

Number of gelling agents-4

Concentrations – 7

Duration - 5

Total number of treatments- 140 (4x7x5)

Replication- 2

Design- CRD

Weight of fruits per replication – 100-150g

Tomato fruits dipped in the prepared gels were drained and kept in polystyrene trays under ambient storage conditions [temperature (28- 32^{0}C), RH (90-95%) for recording observations.

3.1.1 Physiological loss in weight (PLW)

Physiological loss in weight was determined on initial weight basis by weighing the treated tomato fruits on the first to last day of storage, using a laboratory level digital electronic weighing balance having 0.01g accuracy. Physiological loss in weight was calculated using the following formula and expressed as percentage.

$$PLW = \frac{\text{Initial weight- Final weight}}{\text{Initial weight}} \times 100$$

3.1.2. Shelf life

Shelf life was calculated as number of days from harvest till the fruits remained marketable. The fruits were rated not marketable when more than 50 percent of the fruits in a lot showed incidence of spoilage, browning and microbial growth (O'Hare, 1995).

Based on the physiological loss in weight and shelf life obtained, 12 superior treatment combinations were selected for further studies.

3.2. STANDARDIZATION OF ALOE GEL AS EDIBLE FILM FOR EXTENSION OF SHELF LIFE.

Shelf life of tomato fruit is greatly influenced by the harvest maturity stage and harvest maturity plays an important role in determining the market requirements of tomato. Six different maturity stages are recognized in tomato as mature green, breaker, turning, pink, light red and red. Generally fruits are harvested at mature green stage for distant market transport and at firm ripe stage for local market and hence the experiment was designed separately for mature green and firm ripe maturity stages.

The experiment was conducted to select the best combination of aloe gel coating from the superior 12 treatment combinations selected from part 3.1 of the experiment. Tomato plants of variety Akshaya, the first indeterminate high yielding tomato variety released from Kerala Agricultural University were raised in grow bags as per KAU POP (2016) under rain shelter and harvested at two different maturity stages. Akshaya is a bacterial wilt resistant variety, suitable for cultivation both in rain shelter and in open field, with average per plant yield of 3.54 kg and 2.48kg respectively. Fully mature fruits are greenish white; medium sized, flat round, corrugated and exhibit uniform ripening.

The harvested tomato fruits were washed, subjected to surface sanitization using 2 ppm ozonized water for 10 minutes, air dried, dipped in twelve superior treatment combinations selected from first part of the experiment (3.1) and compared with untreated fruits.

Total number of treatments -13 (12 superior treatments selected from 3.1 + 1 control)

Replication- 2

Design - CRD.

Fruit weight per replication – 100-150g

The treated tomato fruits were air dried at room temperature so that a thin uniform layer of skin coating was formed on the fruits. The treated and untreated fruits were weighed, placed in polystyrene trays and stored under ambient condition for recording observations.

The following physiological, chemical, microbial and physical quality parameters of tomato fruits were recorded initially on the day of storage, and at weekly intervals till it had lost its shelf life.

3.2.1. PHYSIOLOGICAL PARAMETERS

Physiological parameters of treated tomato fruits were recorded on the day of coating and at weekly intervals till they had lost their shelf life.

3.2.1.1. Physiological loss in weight (PLW)

Physiological loss in weight of tomato fruits was calculated as described in 3.1.1.

3.2.1.2. Respiration rate

150g of coated tomato fruits were packed in 150 gauge LDPE pouches and and sealed by using heat sealing machine (Seapack machine with 240 AC volts and 380 WATTS). Respiration of fruits was measured by noting the concentration of CO_2 using a Checkpoint Portable Gas Analyzer (Plate. 1) by inserting the needle through the septum fixed on the LDPE pouch and expressed in %.

3.2.1.3. Membrane Integrity

Uniform sized tomato pieces of approximately 1 g weight were excised from the outer pericarp of gel coated fruits, immersed in 20 ml distilled water for three hours and absorbance was read in a UV spectrophotometer at 273 nm. The immersed peel pieces were heated in a water bath at 100^0C for 20 minutes, filtered; filtrate was made up to 20 ml, the absorbance was read again in UV spectrophotometer at 273 nm. The loss of membrane integrity was expressed in per cent ion leakage which was calculated using the formula and expressed as percentage.

Plate 1. Gas Analyzer

$$\text{Percent Leakage} = \frac{\text{Initial absorbance value of bathing medium}}{\text{Final absorbance value of bathing medium}} \times 100$$

3.2.2. CHEMICAL PARAMETERS

Following chemical parameters of coated tomato fruits were recorded on the day of skin coating and at weekly intervals till they had lost their shelf life.

3.2.2.1. Total Soluble Solids

Total Soluble Solids (TSS) of coated fruits was recorded directly using a Digital Refractometer and expressed in degree brix (°B).

3.2.2.2. pH

pH of coated tomato fruits was recorded using portable hand pH meter (Saini *et al.*, 2001)

3.2.2.3. Vitamin C content

Vitamin C content of treated fruits was estimated quantitatively by 2, 6-dichloro phenol indophenol (DIP) dye method (Saini *et al.*, 2001) and expressed as $mg100g^{-1}$.

3.2.2.4. Titratable acidity

Titratable acidity of tomato fruits was estimated by titrating 1 ml of fruit juice in 25 ml distilled water against 0.1 N NaOH (Saini *et al.*, 2001) and expressed as percentage.

3.2.2.5. Lycopene

Ten gram of fruit sample was mixed with acetone (10 ml) to extract the fruit juice and the fruit juice was then transferred to a separating funnel containing 20 ml of petroleum ether. Upper phase petroleum ether extract containing lycopene was collected from the separating funnel and made up to 100 ml with petroleum ether, absorbance was measured at 503 nm using petroleum ether as blank (Ranganna, 2004) and lycopene content was expressed in $\mu g\ g^{-1}$.

3.2.3. ENUMERATION OF TOTAL MICROBIAL LOAD

The quantitative assay of the microflora in pre and post treated tomato fruits were carried out by serial dilution spread plate technique. Nutrient Agar and Rose Bengal Agar medium were used for the enumeration of bacterial and fungal population of tomato fruits respectively.

The separated fruit peel of one cm^2 area was suspended in 100 ml sterile distilled water and shaken thoroughly for two minutes to get 10^{-1} dilution. 100 μl of the supernatant was accurately pipetted out into eppendroff tube containing 900 μl of sterile distilled water to get 10^{-2} dilution. This procedure was repeated so as to get dilutions upto 10^{-6}.

100μl aliquot each from 10^{-2}, 10^{-4} and 10^{-6} dilutions, was used for the enumeration of total bacterial count and 10^{-2}, 10^{-3} and 10^{-4} for the total fungal count. Bacterial count was recorded continuously for three days from the first day of inoculation whereas fungal count was noted from three days after inoculation. Number of microorganisms (bacteria and fungi) per cm^2 of pre and post treated sample was calculated as per the following formula:

$$\text{No. of colony forming units per cm}^2\text{ of the sample} = \frac{\text{Total number of colony formed x dilution factor}}{\text{Aliquot plated}}$$

3.2.4. PHYSICAL PARAMETERS

Physical parameters like colour, texture, appearance, flavor and taste of the tomato fruits were evaluated on the day of coating and at weekly intervals by conducting a sensory evaluation by a 30 member semi - trained panel. The panel was asked to evaluate the sensory attributes by organoleptic scoring using a nine point hedonic scale (**Appendix.I**).

Like extremely	-	9
Like very much	–	8
Like moderately	–	7
Like slightly	–	6
Neither like or dislike	–	5
Dislike slightly	–	4
Dislike moderately	–	3
Dislike very much	–	2
Dislike extremely	-	1

The scores given by the judges in the panel were statistically analyzed using the non-parametric anova (Kruskall Wallis test) and mean ranks and critical values were calculated for the quality parameters evaluated.

3.2.5. COST OF PRODUCTION

Cost of production of the selected aloe gel formulation for coating tomato fruits was calculated based on the current market price. Based on the observations the best aloe gel based edible film was selected for skin coating, so as to extend the shelf life of tomato fruits and this treatment was utilized in the third part (3.3) of the experiment.

3.3. EVALUATION OF PLANT LEAF EXTRACT INCORPORATED ALOE GEL (PLEAG) FOR EXTENSION OF SHELF LIFE

This experiment was formulated independently for two harvest maturity stages viz., mature green and firm ripe stage with the objective of studying the possibility of increasing the efficiency of pure aloe gel based formulation selected from 3.2 of the experiment by incorporation of natural and cheap plant extracts for shelf life extension in tomato. Substitution of aloe gel with plant leaf extract incorporated aloe gel (PLEAG) was tried with the objective to reduce the cost of preparation of edible films without affecting the efficiency in increasing the shelf life of tomato.

Preparation of plant leaf extract incorported aloe gels (PLEAG).

Disease free fresh leaves of papaya (Carica papaya), guava (Psidium guajava) and ocimum (Ocimum sanctum) were collected from Instructional Farm, Vellayani. Leaves were surface sterilized for 5 minutes in 2 ppm ozonized water, washed thoroughly with distilled water and crushed along with aloe gel. Plant leaf and aloe gel were mixed in 1:1 and 1:2 ratio on w/w basis. The extract was filtered to formulate plant leaf extract incorporated Aloe gel (PLEAG) (Marpudi *et al.*, 2011).

Plant leaf extract incorporated aloe gel (PLEAG) was mixed with 1% gelling agent standardized in second part of the experiment. Treatments were fixed with the concentration and duration as standardized from second part (3.2) of the experiment and compared with the control. Pure aloe gel selected from part 2 of the experiment (3.2) was used as control.

T_1 - Aloe gel + papaya leaf extract (1:1)
T_2 - Aloe gel + guava leaf extract (1:1)
T_3 - Aloe gel + ocimum leaf extract (1:1)
T_4 - Aloe gel + papaya leaf extract (1:2)
T_5 - Aloe gel + guava leaf extract (1:2)
T_6 - Aloe gel + ocimum leaf extract (1:2)
T_7 – Aloe gel selected from second part (3.2) [Control]

The treated tomato fruits were air dried and stored in polystyrene trays under ambient condition.

Total number of treatments – 7

Replication- 2

Design- CRD

Weight of fruits per replication -- 100-150g (2-3 fruits)

The following physiological, chemical microbial and physical quality parameters of the skin coated tomato fruits were recorded at weekly intervals from the day of storage till they lost their shelf life.

3.3.1. PHYSIOLOGICAL PARAMETERS

Physiological parameters of the treated / coated fruits were recorded on the day of coating and at weekly intervals till they had lost their shelf life.

3.3.1.1. Physiological loss in weight (PLW)

Physiological weight loss of treated fruits was calculated as described in 3.2.1.1

3.3.1.2. Respiration rate

Respiration rate of treated tomato fruits was calculated as described in 3.2.1.2

3.3.1.3. Membrane Integrity

Membrane integrity of fruits was calculated as described in 3.2.1.3.

3.3.2. CHEMICAL PARAMETERS

Following chemical parameters of treated tomato fruits were recorded on the day of storage and at weekly intervals till they lost their marketability.

3.3.2.1. Total Soluble Solids

Total soluble solids of fruits was recorded as described in 3.2.2.1

3.3.2.2. pH

pH of tomato fruits was recorded as described in 3.2.2.2

3.3.2.3. Vitamin C content

Vitamin C content of fruits was calculated as described in 3.2.2.3

3.3.2.4. Titratable acidity

Titratable acidity of tomato fruits was calculated as described in 3.2.2.4.

3.3.2.5. Lycopene

Lycopene content of fruits was calculated as described in 3.2.2.5.

3.3.3. ENUMERATION OF TOTAL MICROBIAL LOAD

Total microbial load on the surface of treated tomato fruits were enumerated as described in 3.2.3.

3.3.4. PHYSICAL PARAMETERS

Physical parameters like colour, texture, appearance, flavor and taste of the treated tomatoes were examined on the day of storage and at weekly intervals by conducting a sensory evaluation performed by a member semi - trained panel using a nine point hedonic scale as described in 3.2.4 above.

Based on physical, physiological, chemical and microbial parameters a plant leaf extract incorporated aloe gel (PLEAG) was selected and subjected to the following quality evaluation.

3.3.5. COST OF PRODUCTION

Cost of production of the selected plant leaf extract incorporated aloe gel (PLEAG) based formulation for coating tomato fruits was calculated based on the current market price.

3.4. QUALITY EVALUATION OF FILM COATED TOMATO

This experiment was conducted separately for the fruits of two different harvest maturity stages viz., mature green and firm ripe tomato.

Good quality fresh tomato fruits were harvested, washed, surface sanitized in 2 ppm ozonized water for 10 minutes, air dried and then treated by dipping in the edible coating treatments (aloe based extracts) selected from part 2 and 3 of the experiment.

T1- aloe gel based edible coating (selected from part 3.2)

T2- plant leaf extract incorporated aloe gel (PLEAG) (selected from part 3.3).

Total no. of treatments – 2

Replication – 3

Design – CRD

Fruits per replication – 100-150g (2-3 fruits)

The treated tomato fruits were air dried at room temperature, weighed, stored in polystyrene trays under ambient condition for recording observations. The gel coated fruits were analyzed in detail so as to select the most efficient treatment capable of increasing the shelf life of tomato. The following observations were recorded from the day of storage till it had lost its shelf life.

3.4.1. PHYSICAL PARAMETERS.

3.4.1.1. Fruit Firmness and Bio yield point.

Empirical tests viz., the fruit firmness and bio yield point of the coated/ skin treated tomato samples were measured by generating force deformation curves using a Texture Analyser TA. HD Plus (Stable Microsystems, UK) using the compression mode test (Plate 2). The machine was calibrated using the test conditions as mentioned below:

Pre test speed - 1.5mm/sec

Test speed - 1.5mm/sec

Post test speed - 10mm/sec

Distance - 5mm

Trigger type - auto 5g

Data acquisition rate - 200pps

Typical test time - 150 sec

After calibration of the experiment the treated tomato fruit was positioned centrally on the blank plate of the platform. The penetration test was carried out using 2mm needle (P/2) to plot a corresponding force deformation curve. Data reported are the pressure required to cause 5 mm of deformation in whole fruits. Three measurements were taken on each fruit.

Once a trigger force of 0.049 N has been achieved the probe proceeds to move down onto the sample, tomato fruit and an initial rapid rise in force is observed. During this stage the sample was deformed under the applied force, with no tissue puncturing. This stage ends abruptly when the probe punctures through the skin and begins to penetrate into the sample flesh, which is represented by the sudden change in slope, called the 'Bio yield point'. The bio yield point occurs when the probe

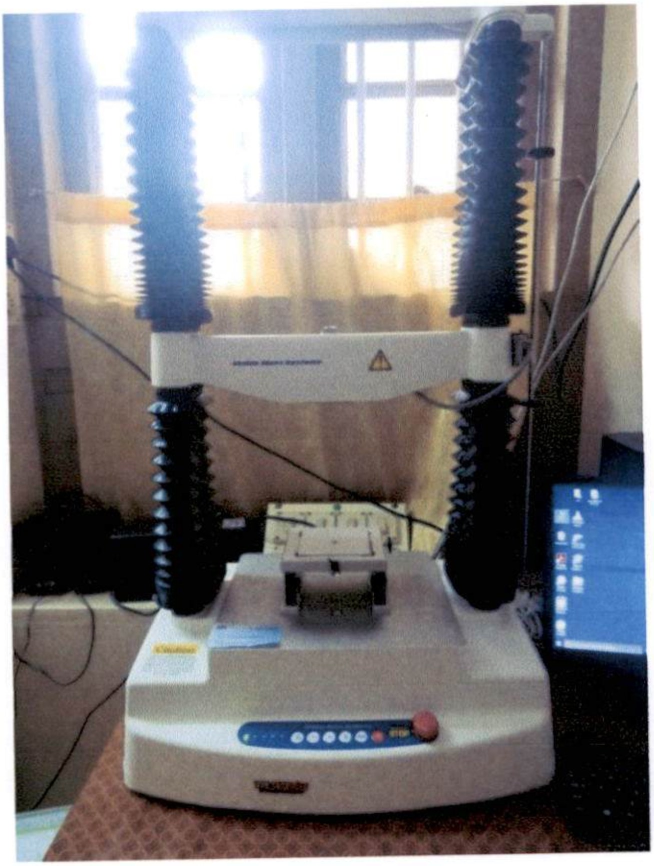


Plate 2. Texture Analyzer

begins to penetrate into the fruit causing irreversible damage. The third phase of the puncture test, namely, the plateau of force after the bio yield point is an indication of the underlying flesh firmness of the fruit.

3.4.2. Sensory perception of textural properties

The sensory perception of textural properties includes finger feel characters and mouth feel or oral textural characters.

Tomato fruits after coating were evaluated for textural properties on the day of treatment and at weekly intervals by conducting a sensory evaluation trial by a 30 member semi - trained panel **(Appendix II).**

The finger feel (Tactile) characters of tomato include firmness, skin tightness, coating characters like oily, sticky, gelatinous and skin roughness. The various quality parameters assessed and the scoring used was given below:

Parameters	Description	Scores given
A. FINGER FEELCHARACTERS		
1.Fruit Firmness	**Reaction to stress/gentle squeeze between fingers**	
a. Firm	ability to hold the shape	3
b. Firm with give	ability to rebound the shape	2
c. Soft	lost ability to hold the shape	1
2.Skin Tightness		
a. Compact	Small cells with tiny intercellular spaces	3
b. Spongy	Large cells with large intercellular spaces	2
c. Loose	Cells extended to feel a wrinkled appearance	1
3.Nature of coating materials	**Feeling of coating viz., oily/sticky/gelatinous**	
a. None		3
b. Slightly		2
c. Clearly Visible		1
4.Roughness of skin	**Feeling /Appearance of material deposition on external surface**	
a. Smooth		2
b. Rough		1
A. MOUTH FEEL CHARACTERS		
1. Oral texture	**Experienced during mastication**	
a. Hard		2
b. Soft		1
2.Tomato juiciness	**Assessment of structural integrity**	
a. Juicy	Release of cell content into mouth when chewed three times between molasses	2
b. Dry		1
C.TEXTURAL APPEARANCE		
1.Glossiness	Shiny/lustrous appearance for superficial attraction	
a. High		3
b. Medium		2
c. Low		1

3.4.3. CHEMICAL PARAMETERS

3.4.3.1. Total Solids

Total solids are a measure of all the suspended, colloidal, and dissolved solids in a sample of tomatoes. Sugars are the major soluble solids in any fruit juice. Other soluble materials include organic and amino acids, soluble pectin etc.

A known mass of fine tomato paste (2g) was taken in a clean porcelain evaporation dish and placed in hot air oven at 105^0 C to evaporate, cooled the container and then weighed it as soon as it had cooled, to avoid absorption of moisture (Lamb, 1977). Total Solids was calculated as follows:

$$\text{Total Solids (mg/L)} = \frac{(A-B) \times 1000\text{mL/L}}{\text{Sample volume (mL)}}$$

A = weight of dried residue + dish after 24 hrs at 105^0C (mg)

B = weight of dish (mg)

3.4.3.2. Total insoluble solids

Total insoluble solids content represents the higher molecular weight cell wall and middle lamella components that are important determinates of consistency.

Total insoluble solids are determined by subtracting the percent total soluble solids from the percent total solids (Lamb, 1977)

$$\text{Total Insoluble Solids (mg/L)} = \frac{100\,[\text{Total solids- total soluble solids})}{100 - \text{total soluble solids}}$$

3.4.3.3. Alcohol-insoluble solids (AIS)

Twenty gram of the ground sample was macerated with 150 ml of 85% ethanol for 5 minutes. The solid material was filtered off, thoroughly washed with 85 percent ethanol, dried overnight at 95^0C and weighed (Moyer and Holgate, 1948).

3.4.3.4. Activity of texture affecting enzymes.

3.4.3.4.1. Pectin methyl esterase

Twenty grams of fruit pulp was blended in 60–100 ml 0.15 M NaCl solution, filtered through two layers of cheese-cloth, centrifuged at 2,000 rpm for 30 min at 4 °C. As there is direct correlation between pH and salt concentration used, the pH of the titration was constantly maintained at 7.0 for 0.15 M of NaCl solution for maximum PME activity. The supernatant was used as an enzyme source.

Pectin methyl esterase activity in tomato was determined by adding 2 ml of 1.5M NaCl to 10ml of 1 percent pectin solution and it was mixed by bubbling in CO_2 free air. A few drops of Hinton's indicator was added and titrated to pH 7.5 with 0.02N NaOH. This was transferred to a constant temperature water bath maintained at 30^0C. When the pectin solution has attained the temperature of the water bath, the enzyme and distilled water were added to adjust the volume to 20ml, immediately the time was recorded and the volume of alkali required for maintaining the pH at the constant volume was noted. The concentration of enzyme was adjusted so as to require about 1 – 3ml of 0.02N alkali in 10 minutes and the result was expressed in pectin – methyl esterase units as given below (Awang *et al.*, 2013)

$$\text{PE. U/g} = \frac{\text{ml of 0.02N NaOH consumed x 3.11}}{\text{ml of enzyme prepared x total time of determination in minute}}$$

3.4.3.4.2. Polygalactouranase Enzyme

Exo-polygalacturonase (exo-PG) activity was assayed by determining the liberated reducing-end products in a reaction solution (2 mL) containing 0.4mL of 1% PGA, 1.4 mL of 100 mM citrate–phosphate buffer (pH 4.0) and 0.1 mL of enzyme solution. It was incubated for 20 min at 37 °C in a water bath. The number of reducing groups, expressed as galacturonic acid released by enzymatic action, was quantified by the DNS method (Martins *et al.*, 2013). Three mL of dinitrosalicylic acid (DNSA) reagent was added and volume was made 6 mL by addition of 1 mL of distilled water. The solution was boiled for 10 min in a water bath, cooled and absorbance was read at 575 nm in a colorimeter. A control was simultaneously prepared taking thermally denatured enzyme. The concentration of the product (galacturonic acid) was compared to a galacturonic acid standard curve. One unit of enzyme activity (U) was defined as the amount of enzyme releasing 1 mol of galacturonic acid per minute under the assay conditions. Each data point was an average of triplicate measurements with standard deviation less than 5%.

3.4.3.5. Total Pectin

Total pectin was estimated based on the principle that galacturonic acid is reacted with carbazole in the presence of H_2SO_4 and the color developed is measured at 520nm.

Extraction and purification of pectin

100g macerated sample was transferred to a pre-weighed beaker containing 400mL water, 1.2g freshly ground sodium hexa meta phosphate added, pH adjusted to 4.5 and heated with stirring at 90-95°C for 1h. pH was checked every 15min and maintained at 4.5 with citric acid. Water lost by evaporation was replaced at intervals. 4g filter aid and 4g ground paper pulp were added and filtered rapidly through a fast filter paper coated with 3g moistened fast filter aid. 200mL of the filtrate was collected in a pre-weighed container, cooled rapidly, weight recorded, poured in to three volumes of ethanol containing 0.5N HCl and the slurry should be at pH 0.7-1. Stirred for 30min, centrifuged and washed the precipitate with ethanol containing HCl. (The filtrate is to be concentrated under vacuum if the filtrate contains less than 0.2% pectin). It was washed repeatedly with 70% alcohol until the precipitate was essentially chloride-free or the pH is above 4. The precipitate was dehydrated further in 400mL acetone and dried overnight in vacuum with a slow stream of dry air passing through the oven and used for analysis.

Standard

120.5mg galacturonic acid monohydrate (from a sample vacuum dried for 5h at 30°C) was transferred to a 1L volumetric flask, 10mL 0.05N NaOH was added, diluted to volume with water, allowed it to stand overnight. Diluted 10, 20, 40, 50, 60 and 80mL of this standard solution to 100mL with water. 2mL of these solutions were added for color developing and proceeded as in the case of the sample. Standard curve was drawn as absorbance versus concentration

Procedure

100 mg of standard pectin was dissolved in 100ml of 0.05N NaOH and then allowed it to stand for 30 minutes to deesterify the pectin. About 2 ml of this solution was taken and made up to 100 ml with distilled water. Then pipetted out 2 ml of deeseterified pectin solution and added 1ml Carbazole reagent which resulted in the formation of a white precipitate. Then 12 ml of conc. H_2SO4 was added to it with constant stirring, after that the tubes were closed with rubber stoppers and allowed to stand for 10 minutes to develop the color. One 1ml of purified ethyl alcohol was added in the place of Carbazole reagent to set as blank. Then the colour was recorded at 525 nm against blank exactly 15 minutes after the addition of acid, and then read the concentrtion of the anhydrogalacturonic acid corresponding to the reading of the sample (Ranganna, 1979) and total pectin was calculated as follows:

$$\%\ \text{anhydrogalacturonic acid} = \frac{\text{mg of anhydrogalacturonic acid in the aliquot x dilution x 100}}{\text{ml taken for estimation x wt of pectin sample x 1,000,000}}$$

3.4.4. MICROBIAL PARAMETERS

The experiment was planned separately for the two maturity stages.

3.4.4.1. Antimicrobial activity of extracts against Erwinia and Rhizopus

3.4.4.1.1. Isolation of Erwinia and Rhizopus from tomato

Bacterial soft rot (Erwinia) and Rhizopus rot (Rhizopus stolonifer) infected tomato fruits were collected from local markets. Small symptomatic portions of bacterial soft rot and Rhizopus affected fruits were isolated and streaked into petri plates containing Nutrient Agar and Potato Dextrose Agar respectively and both were incubated under room temperature for observing the colonies developed.

Continuous re-inoculations and re-isolations were carried out on tomato fruits to confirm pathogenicity of the isolates. An isolate of the pathogen grown in pure culture was maintained on Nutrient Agar plates and Potato Dextrose Agar culture tubes and were used as stock cultures of *Erwinia* and *Rhizopus* respectively throughout the study.

3.4.4.1.2. In vitro antibacterial assay of plant extracts

The antimicrobial activity of the two aloe based extracts viz, pure aloe based edible coating and PLEAG selected from part 2 and 3 of the experiment respectively was assessed against the microbial isolates viz., *Erwinia* and *Rhizopus* by modified media method and paper disc assay.

a. Modified media method

The selected two aloe extracts were mixed with the Nutrient Agar and poured to the sterile petri plates for antibacterial assay. Concentrations of the extracts were chosen as per the results of previous part of the experiment. The control sets were prepared by mixing sterile distilled water with Nutrient Agar avoiding aloe based extracts. A five mm diameter agar disk taken from the pure culture of *Erwinia* was placed in the center of all the Nutrient agar plates containing (1) Pure aloe based extracts (2) Plant leaf extract incorporated aloe gel based extract and (3) Control plates with Nutrient Agar only. The Nutrient Agar plates were incubated at room temperature for recording the observations. The observations were recorded in terms of resistance of growth in centimeters by measuring the colony diameter by taking average reading from four directions.

The experiment was done in the similar manner using PDA for assessing antifungal activity of the extracts against *Rhizopus*.

b) Paper disc assay

Sterile filter paper discs of six mm diameter were dipped in the selected aloe based extracts and plant leaf extract incorporated aloe gels selected from part 2 and 3 of the experiment for one minute. Nutrient Agar media was poured into sterile petri plates and *Erwinia* colonies isolated from the stock culture were swabbed onto the Nutrient Agar media.

After the carrier solvents (aloe based extracts and PLEAG) evaporated from the filter paper discs, they were placed on the surface of the inoculated medium and the plates with discs were incubated at room temperature. The diameter of inhibition growth zone was measured and the degree of inhibition of the bacterial growth was recorded on a 0-4 scale as follows (Amare, 2002).

0 - No inhibition zone visible

1 - Inhibition zone barely distinct

2 - Inhibition zone well distinct

3 - Inhibition zone with sparse growth

4 - Inhibition zone free of visible growth

The Nutrient Agar medium was replaced with PDA medium and Rhizopus spores isolated from stock culture was point inoculated onto PDA for assessment of antifungal activity of the selected extracts against Rhizopus.

3.4.4.2. Artificial inoculation studies or in vivo antimicrobial assay of aloe based extracts

Aloe based formulations selected from Part 2 and 3 of the study were prepared and tested for their antimicrobial effect on bacterial soft rot development on tomato fruits.

Good quality pesticide free tomato fruits of comparable size and color were collected and used for the experiment. Tomato fruits were surface-sterilized by dipping in 2ppm ozonized water for 15 minutes. The fruits were skin coated by dipping in two aloe based gel as per the standardized procedures and freshly harvested fruits without any skin coating was set as the control.

The treated and control fruits were inoculated by evenly spraying with the bacterial suspension of Erwinia and stored under room temperature for 5 days. Severity of soft rot was recorded and disease index calculated.

Similarly surface sterilized tomato fruits were sprayed with Rhizopus spore suspension for recording the severity of Rhizopus rot.

3.4.4.2.1. Disease index for Bacterial soft rot and Rhizopus rot.

The disease index was calculated to check the ability of the aloe based extract to prevent the fruit infection by visual examination. Disease incidence was recorded at the end of the storage period, by assessing the percentage of fruits with bacterial soft rot and Rhizopus rot.

Disease severity of each individual tomato fruit was recorded according to the area affected, using a 1-5 visual rating scale (Maharaj and Sankat, 1990).

1. Zero percent (no disease symptoms)
2. Trace - 1-10 percent disease symptoms (spot appearing first)
3. Slight - 11-25 percent disease symptoms (spots increasing in size as number)
4. Moderate - 26-50 percent disease symptoms (small to large brownish sunken spots with slight to moderate mycelium growth)
5. Severe - 51 percent to more than 75 percent disease symptoms (large spots with wide spread mycelium growth and fruit is partially or completely rotten)

Based on quality parameters, the best aloe gel based skin coating treatment was selected for testing its efficiency in reducing the post harvest loss during storage and transportation.

3.5. EFFICIENCY OF ALOE BASED EDIBLE FILM IN REDUCING POST HARVEST LOSS DURING STORAGE AND TRANSPORTATION

This experiment was formulated to evaluate the efficiency of the best aloe gel based edible film selected from Part 3.4 of the study in reducing post harvest loss during storage and transportation of tomato fruits. As in previous parts, the experiment was conducted separately for tomato fruits harvested at two different maturity stages.

Fruits were harvested and washed thoroughly, surface sanitized with 2ppm ozonized water for 15 minutes, coated by dipping in edible film coating, air dried and packaged in two different packaging materials/systems.

Tomato fruits were coated with the selected aloe based extract and were compared with a commercial edible wax formulation. Uncoated fruits were kept for comparison as control.

No. of edible films – 3

1. aloe based extract (selected from part 3.4)
2. Commercial wax formulation
3. Uncoated fruits

No. of packaging systems – 2

1. Packaging in 5% ventilated CFB boxes
2. Packaging in 5% ventilated CFB box with molded tray as inserts

Two sets of tomato fruits were packaged; one set was subjected to storage study and the second set to transportation study, after evaluating quality parameters.

3.5.1. EFFICIENCY IN EXTENDING STORAGE LIFE.

Experiment was designed separately for two different maturity stages. Coated and uncoated tomato fruits were packaged in two different systems as described above and they were subjected to the following two different storage conditions for evaluating the possibility of extension of storage life of tomato.

No. of edible films – 3

No. of packaging systems – 2

No. of storage conditions– 2

S_1 - Ambient temperature

S_2 -Optimum low temperature storage (Cold storage)

Optimum low temperature for mature green tomato fruits: $12^0 – 20^0$C (Plate.3)

Optimum low temperature for firm ripe tomato fruits: 10^0-15^0C

Total no. of treatments: 12

No. of replication: 2

No. of fruits per replication: 15 no.

Physiological, chemical microbial and physical parameters of tomatoes were recorded initially and changes during storage were recorded at weekly intervals till they had lost their shelf life.

3.5.1.1. PHYSIOLOGICAL PARAMETERS

Physiological parameters of skin coated tomato fruits were recorded on the day of storage and at weekly intervals till they had lost their shelf life.

3.5.1.1.1. Physiological loss in weight (PLW)

Physiological weight loss of tomato fruits was calculated as described in 3.2.1.1

3.5.1.1.2. Respiration rate

Respiration rate of fruits was calculated as described in 3.2.1.2.

3.5.1.1.3. Membrane Integrity

Membrane integrity of fruits was calculated as described in 3.2.1.3

Cold Storage

Packaged fruits under low temperature storage

Plate 3. Optimum low temperature storage of tomatoes

3.5.1.2. CHEMICAL PARAMETERS

Following chemical parameters of treated and untreated tomato fruits were recorded on the initial day of storage and at weekly intervals till they had lost their shelf life.

3.5.1.2.1. Total Soluble Solids

Total soluble solids of fruits was recorded as described in 3.2.2.1

3.5.1.2.2. pH

pH of stored tomato fruits was recorded as described in 3.2.2.2

3.5.1.2.3. Vitamin C content

Vitamin C content of stored tomato fruits was calculated as described in 3.2.2.3

3.5.1.2.4. Titratable acidity

Titratable acidity of treated fruits was calculated as described in 3.2.2.4

3.5.1.3.5. Lycopene

Lycopene content of stored tomato fruits was calculated as described in 3.2.2.5

3.5.1.3. ENUMERATION OF TOTAL MICROBIAL LOAD

Total microbial load on the surface of treated and untreated tomato fruits were enumerated as described in 3.2.3.

3.5.1.4. PHYSICAL PARAMETERS

Physical parameters like colour, texture, appearance, flavor and taste of the treated tomatoes were examined on the day of storage and at weekly intervals by conducting a sensory evaluation performed by a 30 member semi - trained panel using a nine point hedonic scale as described in 3.2.4.above.

3.5.2. EFFICIENCY IN WITHSTANDING TRANSPORTATION HAZARDS.

This experiment was formulated to analyze the efficiency of the aloe based extract selected from Part 3.4 of the experiment in withstanding transportation hazards.

As in previous parts, the experiment was planned as two separate independent study for two maturity stages.

Good quality tomato fruits were coated with the above mentioned three edible film coatings and packaged in two packaging systems as mentioned in 3.5 and these packaged fruits were transported to distant and local market to analyze the efficiency of coatings in withstanding transportation hazards. Tomato fruits without any skin coating were set as control.

Mature green tomatoes were transported to 512 km distance to represent a distant market in a reefer cargo van maintained at a temperature of 18^0C (Plate. 4).

Ripe fruits were transported to 128 km to represent a local market in a cargo van without refrigeration.

No. of edible films – 3

1. Aloe based extract (selected from part 3.4)
2. Commercial wax formulation
3. Uncoated fruits

No. of packaging systems - 2

1. Packaging in 5% ventilated CFB boxes
2. Packaging in 5% ventilated CFB box with molded tray as inserts

Total no. of treatments – 6

No. of replication – 2

No. of fruits per replication – 15 no.

Physiological, chemical, microbial and physical quality parameters of coated and packaged tomatoes were recorded before and after subjecting to transportation and physical damage due to transportation if any was assessed.

3.5.2.1. PHYSIOLOGICAL PARAMETERS

Physiological parameters of packaged skin coated tomatoes were recorded before and after transportation to analyze their efficiency to withstand transportation hazards.

Reefer van for distant market transport

Packaged mature green tomato fruits in reefer van

Plate 4. Distant market transportation of mature green tomatoes

3.5.2.1.1. Physiological loss in weight (PLW)

Physiological weight loss of tomato fruits was calculated as described in 3.2.1.1

3.5.2.1.2. Respiration rate

Respiration rate of fruits was calculated as described in 3.2.1.2

3.5.2.1.3. Membrane Integrity

Membrane integrity of tomato fruits were calculated as described in 3.2.1.

3.5.2.2. CHEMICAL PARAMETERS

Following chemical parameters of packaged and treated tomato fruits were recorded before and after transportation to analyze their efficiency to withstand transportation hazards.

3.5.2.2.1. Total Soluble Solids

Total soluble solids of fruits was recorded as described in 3.2.2.1

3.5.2.2.2. pH

pH of fruits was recorded as described in 3.2.2.2

3.5.2.2.3. Vitamin C content

Vitamin C content of fruits was calculated as described in 3.2.2.3

3.5.2.2.4. Titratable acidity

Titratable acidity of fruits was calculated as described in 3.2.2.4

3.5.2.2.5. Lycopene

Lycopene content of fruits was calculated as described in 3.2.2.5

3.5.2.3. ENUMERATION OF TOTAL MICROBIAL LOAD

Total microbial load on the surface of treated tomato fruits were enumerated before and after transportation as described in 3.2.3.

3.5.2.4. PHYSICAL PARAMETERS

Physical parameters like colour, texture, appearance, flavor and taste of the treated tomatoes were examined before and after transportation by conducting a sensory evaluation trial performed by a 30 member semi - trained panel using a nine point hedonic scale as described in 3.2.4.above.

3.5.2.5. COST OF PRODUCTION

Cost of production of the selected aloe gel formulation for coating tomato fruits was calculated based on the current market price and compared with that of the commercial formulation.

Based on the efficiency and economics, an efficient post harvest management system incorporating aloe gel based skin treatment, packaging and storage system was standardized for increasing the shelf life of tomato fruits harvested at two different maturity stages.

3.6. STATISTICAL ANALYSIS.

The first part of the experiment was statistically analyzed using Duncan's Multiple Range Test, and observations of the second, third, fourth and fifth parts of the experiment were analyzed statistically in a Completely Randomized Design and significance was tested using analysis of variance technique and Least Significant Difference (LSD) at 5% probability level were used for mean comparison (Gomez and Gomez, 1984).

In organoleptic analysis, the different preferences given by the 30 judges in the sensory panel were analyzed using the Kruskall - Wallis test to get the mean rank values for all the treatments.

RESULTS

4. RESULTS

The experimental data collected from the investigation on "*Aloe vera* based edible film coating for shelf life extension in tomato (*Solanum lycopersicum*)" were analyzed and the results are presented in this chapter under the following headings.

1. Preliminary trial for preparation and standardization of aloe extract
2. Standardization of aloe gel as edible film for extension of shelf life
3. Evaluation of plant leaf extract incorporated aloe gel for extension of shelf life
4. Quality evaluation of film coated tomato
5. Efficiency of aloe based edible film in reducing postharvest loss during storage and transportation

4.1. PRELIMINARY TRIAL FOR PREPARATION AND STANDARDIZATION OF ALOE EXTRACT

Prices of perishables come down drastically during glut to consumer's relief, while farmers are hit by low prices. This is considered as a regular and serious problem with regard to tomatoes grown in Palakkad district of Kerala, where the favourable climatic conditions lead to bumper yield from hybrid varieties of tomato and farmers are forced to sell their produce at a cheap rate. Hence a study was needed to develop a postharvest management practice for extending the shelf life of tomato in order to preserve them during glut period.

As the present study was the first attempt to assess the efficiency of using *Aloe vera* gel based edible film in extending shelf life of any tropical vegetable in Kerala, a preliminary trial was conducted for standardization of aloe extract.

Good quality fresh ripe tomato fruits free from visual defects and relatively uniform size, weight and colour were collected and aloe gel was prepared as described in 3.1. The gel prepared with four different gelling agents was applied to tomato fruits in seven different concentrations for five different durations for standardization of aloe gel extract.

The fruits treated with the prepared gels were kept in polystyrene trays under ambient storage conditions [temperature (28- 32^{0}C), RH (90-95%)] and observations like shelf life and physiological loss in weight were recorded till it had lost its shelf life.

4.1.1. Shelf life

The shelf life of the treated fruits under ambient storage was recorded and shown in Table 1.

There was no significant difference between the shelf life of the tomato fruits treated with the 140 treatment combinations.

4.1.2. Physiological Loss in Weight (PLW)

The physiological loss in weight (PLW) of the tomato fruits treated with the 140 different aloe gel combinations was recorded at weekly intervals; the average worked out and is shown in Table 2 to Table 8.

The 140 different aloe gel treatment combinations (gelling agent x concentration x duration) used were non-significant in influencing the physiological loss in weight (PLW) of the treated tomato fruits on storage (Table 2). As all the treatment combinations or three factor interactions were equally effective in maintaining the physiological loss in weight, single and two factor interactions were considered for finding the 12 best superior treatment combinations,

When the effect of different gelling agents was assessed (Table 3), all the four gelling agents were significantly different from one another. Least PLW (16.13%) was recorded by the fruits dipped in aloe gel mixed with INS 402 as gelling agent, which was followed by aloe gel added with INS 401 (18.01%). Highest PLW (20.60%) was recorded by fruits treated with aloe gel having INS 508 as gelling agent.

Table 1. Effect of gelling agents x concentration x duration on the shelf life of tomatoes

Coatings	Shelf life (days)	Coatings	Shelf life (days)	Coatings	Shelf life (days)	Coatings	Shelf life (days)	Coatings	Shelf life (days)	Coatings	Shelf life (days)
T1	87	T26	87	T51	93	T76	82	T101	82	T126	83
T2	87	T27	87	T52	90	T77	80	T102	83	T127	82
T3	89	T28	88	T53	88	T78	77	T103	82	T128	90
T4	90	T29	89	T54	89	T79	80	T104	82	T129	83
T5	88	T30	90	T55	90	T80	82	T105	92	T130	83
T6	86	T31	90	T56	92	T81	82	T106	88	T131	90
T7	89	T32	91	T57	93	T82	82	T107	87	T132	83
T8	90	T33	89	T58	90	T83	83	T108	86	T133	88
T9	89	T34	88	T59	88	T84	84	T109	87	T134	89
T10	88	T35	87	T60	90	T85	80	T110	89	T135	87
T11	87	T36	90	T61	92	T86	81	T111	90	T136	86
T12	86	T37	93	T62	90	T87	80	T112	83	T137	86
T13	85	T38	93	T63	87	T88	82	T113	82	T138	87
T14	87	T39	94	T64	90	T89	82	T114	80	T139	88
T15	89	T40	90	T65	92	T90	83	T115	90	T140	89
T16	90	T41	89	T66	94	T91	80	T116	87		
T17	87	T42	93	T67	90	T92	82	T117	88		
T18	89	T43	90	T68	89	T93	80	T118	90		
T19	90	T44	87	T69	90	T94	82	T119	87		
T20	87	T45	88	T70	82	T95	91	T120	93		
T21	92	T46	89	T71	83	T96	82	T121	84		
T22	85	T47	90	T72	86	T97	83	T122	90		
T23	86	T48	92	T73	86	T98	83	T123	92		
T24	87	T49	91	T74	85	T99	80	T124	89		
T25	89	T50	92	T75	80	T100	83	T125	86		
CD (0.05) NS											

Table 2. Effect of gelling agents x concentration x duration on the PLW of tomatoes

Coatings	PLW (%)	Coatings	PLW (%)	Coatings	PLW (%)	Coatings	PLW (%)	Coatings	PLW (%)	Coatings	PLW (%)
T1	15.52	T26	22.96	T51	14.99	T76	19.34	T101	19.57	T126	20.80
T2	14.00	T27	20.20	T52	14.48	T77	19.08	T102	19.20	T127	21.85
T3	13.65	T28	20.75	T53	15.54	T78	21.21	T103	19.80	T128	19.76
T4	19.04	T29	20.62	T54	16.59	T79	19.51	T104	17.46	T129	18.50
T5	18.65	T30	21.24	T55	15.43	T80	19.46	T105	20.33	T130	21.57
T6	16.35	T31	18.56	T56	17.06	T81	20.82	T106	16.73	T131	17.25
T7	16.59	T32	16.74	T57	16.87	T82	19.83	T107	20.62	T132	18.22
T8	19.62	T33	22.24	T58	14.69	T83	20.61	T108	18.38	T133	21.98
T9	16.16	T34	21.82	T59	15.24	T84	22.45	T109	21.21	T134	20.57
T10	12.01	T35	19.43	T60	16.70	T85	24.36	T110	19.65	T135	19.03
T11	15.27	T36	15.34	T61	15.75	T86	26.05	T111	15.10	T136	24.99
T12	19.13	T37	16.40	T62	15.62	T87	20.29	T112	15.72	T137	19.95
T13	14.17	T38	16.07	T63	16.44	T88	21.56	T113	20.00	T138	20.49
T14	16.28	T39	15.48	T64	16.67	T89	19.76	T114	20.21	T139	20.57
T15	16.74	T40	15.73	T65	18.26	T90	20.28	T115	18.06	T140	19.88
T16	18.84	T41	15.54	T66	18.96	T91	21.01	T116	18.47		
T17	13.56	T42	15.41	T67	18.12	T92	20.78	T117	18.26		
T18	19.78	T43	16.09	T68	17.16	T93	21.42	T118	19.42		
T19	20.33	T44	14.67	T69	17.99	T94	20.86	T119	21.62		
T20	17.29	T45	15.15	T70	17.01	T95	20.07	T120	16.15		
T21	19.62	T46	15.03	T71	21.92	T96	19.06	T121	16.80		
T22	16.16	T47	15.70	T72	20.60	T97	21.30	T122	19.65		
T23	12.01	T48	21.43	T73	22.86	T98	20.19	T123	21.90		
T24	19.92	T49	15.64	T74	18.74	T99	19.76	T124	17.85		
T25	21.42	T50	14.24	T75	18.66	T100	18.86	T125	17.65		
CD (0.05) NS											

When the durations of the aloe gel treatments were compared, fruits dipped for one minute recorded the least PLW(17.58%) which was on par with the fruits dipped for two (18.01%) and five minutes (18.07%) (Table 4).

No significant differences were observed among the PLW of tomato fruits dipped in various concentrations (1%, 2%, 5%, 10%, 15%, 25% and 35%). However least PLW (18.01%) was recorded by fruits dipped in 1% followed by 2% (18.31%) (Table 5).

When comparison was made among combinations of gelling agents and duration, the least PLW was recorded by fruits dipped in aloe gel +INS 402 for ten minutes (15.47%) which was on par with fruits treated with aloe gel + INS 402 for one(15.71%), two (16.25%) and five (15.48%) minutes and aloe gel+ INS 401 for one (16.26%) and two (15.81%) minutes (Table 6).

Among combinations of gelling agents and concentrations (Table 7), least PLW (15.25%) was recorded by fruits coated with aloe gel + INS 402 at 1% concentration which was on par with fruits coated with the same treatments at 2%, 5%, 10%, 15%, 35% and with aloe +INS 401 at 5%. Highest PLW (21.61%) was recorded by fruits coated with aloe gel mixed with INS 508 at 1% concentration.

While comparing among combinations of different concentrations and durations, the least PLW (16.17%) was recorded by fruits dipped in aloe gel @ 2% for one minute which was on par with fruits dipped in 2% aloe gel for two (16.70%) and five minutes (16.58%), 1% aloe gel for one (17.38%), two (16.88%) and five minutes (17.00%), and 5% aloe gel for one minute (17.40%) (Table 8).

Considering all the single and two factor interactions, INS 401and INS 402 were selected as the two best gelling agents for maintaining a thick consistency of aloe gel to act as an edible film. As the seven different concentrations were found equally effective, the least concentrations viz., 1% and 2% were selected, considering the economics of treatments. When comparison was made among the five different durations, one, two and five minutes were found equally effective in reducing the PLW.

Table 3. Effect of gelling agents on the PLW of tomatoes

Gelling Agents	PLW (%)
INS 401	18.01
INS 402	16.13
INS 440	19.28
INS 508	20.60
CD (0.05)	**0.47**

Table 4. Effect of durations on the PLW of tomatoes

Durations	PLW (%)
1 min	17.58
2 min	18.01
5 min	18.07
10 min	19.08
15min	19.47
CD (0.05)	**0.54**

Table 5. Effect of concentrations of aloe gel on the PLW of tomatoes

Concentrations of aloe gel	PLW (%)
1%	18.01
2%	18.31
5%	18.39
10%	18.83
15%	18.74
25%	18.59
35%	18.66
CD (0.05)	**NS**

Table 6. Effect of (gelling agents x durations) on the PLW of tomatoes

Treatments	PLW (%)	Treatments	PLW (%)
Aloe gel + INS 440 (1 min)	18.20	Aloe gel +INS 402 (1 min)	15.71
Aloe gel +INS 440 (2 min)	19.44	Aloe gel +INS 402 (2 min)	16.25
Aloe gel +INS 440 (5 min)	18.11	Aloe gel +INS 402 (5 min)	15.48
Aloe gel +INS 440 (10 min)	19.88	Aloe gel +INS 402 (10 min)	15.47
Aloe gel +INS 440 (15 min)	20.79	Aloe gel +INS 402 (1 5min)	17.74
Aloe gel +INS 401 (1 min)	16.26	Aloe gel +INS 508 (1 min)	20.17
Aloe gel +INS 401 (2 min)	15.81	Aloe gel +INS 508 (2 min)	20.56
Aloe gel +INS 401 (5 min)	17.44	Aloe gel +INS 508 (5 min)	22.48
Aloe gel +INS 401 (10 min)	20.45	Aloe gel +INS 508 (10 min)	20.53
Aloe gel +INS 401 (15 min)	20.09	Aloe gel +INS 508 (15 min)	19.29
CD (0.05) - 1.07			

Table 7. Effect of (gelling agents x concentrations) on the PLW of tomatoes

Treatments	PLW (%)	Treatments	PLW (%)
Aloe gel + INS 440 (1%)	18.26	Aloe gel +INS 402 (1%)	15.25
Aloe gel +INS 440 (2%)	19.29	Aloe gel +INS 402 (2%)	15.80
Aloe gel +INS 440 (5%)	19.92	Aloe gel +INS 402 (5%)	15.98
Aloe gel +INS 440 (10%)	20.62	Aloe gel +INS 402(10%)	16.17
Aloe gel +INS 440 (15%)	18.70	Aloe gel +INS 402 (15%)	16.19
Aloe gel +INS 440 (25%)	18.19	Aloe gel +INS 402 (25%)	17.21
Aloe gel +INS 440 (35%)	20.00	Aloe gel +INS 402 (35%)	16.31
Aloe gel +INS 401 (1%)	18.13	Aloe gel +INS 508 (1%)	21.61
Aloe gel +INS 401 (2%)	18.00	Aloe gel +INS 508 (2%)	21.29
Aloe gel +INS 401 (5%)	15.54	Aloe gel +INS 508 (5%)	20.61
Aloe gel +INS 401 (10%)	18.45	Aloe gel +INS508 (10%)	20.08
Aloe gel +INS 401 (15%)	20.66	Aloe gel +INS 508 (15%)	19.42
Aloe gel +INS 401 (25%)	17.57	Aloe gel +INS 508 (25%)	20.60
Aloe gel +INS 401 (35%)	17.72	Aloe gel +INS 508 (35%)	20.61
CD (0.05) - 1.27			

Table 8. Effect of (concentrations x durations) on the PLW of tomatoes

Treatments	PLW (%)	Treatments	PLW (%)	Treatments	PLW (%)
Aloe gel +1% (1 min)	17.38	Aloe gel +5% (5 min)	18.41	Aloe gel +15% (15 min)	19.94
Aloe gel +1% (2 min)	16.88	Aloe gel +5% (10 min)	19.00	Aloe gel +25% (1 min)	18.76
Aloe gel +1% (5 min)	17.00	Aloe gel +5% (15 min)	17.91	Aloe gel +25% (2 min)	18.84
Aloe gel +1% (10 min)	18.62	Aloe gel +10% (1 min)	19.17	Aloe gel +25% (5 min)	19.84
Aloe gel +1% (15min)	18.17	Aloe gel +10% (2 min)	17.74	Aloe gel +25% (10 min)	19.41
Aloe gel +2% (1 min)	16.17	Aloe gel +10% (5 min)	19.69	Aloe gel +25% (15 min)	19.35
Aloe gel +2% (2 min)	16.70	Aloe gel +10% (10 min)	18.63	Aloe gel +35% (1 min)	20.52
Aloe gel +2% (5 min)	16.58	Aloe gel +10% (15min)	18.66	Aloe gel +35% (2 min)	18.50
Aloe gel +2% (10 min)	17.64	Aloe gel +15% (1 min)	18.60	Aloe gel +35% (5 min)	19.92
Aloe gel +2% (15min)	19.23	Aloe gel +15% (2 min)	18.67	Aloe gel +35% (10 min)	19.46
Aloe gel +5% (1 min)	17.40	Aloe gel +15% (5 min)	18.90	Aloe gel +35% (15 min)	19.16
Aloe gel +5% (2min)	18.23	Aloe gel +15% (10 min)	18.63		
CD (0.05) - 1.42					

Hence they were selected for dipping the fruits. By combining all these parameters, the following 12 superior treatment combinations were selected for further studies as detailed below.

Superior treatment combinations selected from the preliminary trial	
T1	Aloe gel + INS 401 (1% for 1 min)
T2	Aloe gel + INS 401 (1% for 2 min)
T3	Aloe gel + INS 401 (1% for 5 min)
T4	Aloe gel + INS 401 (2% for 1 min)
T5	Aloe gel + INS 401 (2% for 2 min)
T6	Aloe gel + INS 401 (2% for 5 min)
T7	Aloe gel + INS 402 (1% for 1 min)
T8	Aloe gel + INS 402 (1% for 2 min)
T9	Aloe gel + INS 402 (1% for 5 min)
T10	Aloe gel + INS 402 (2% for 1 min)
T11	Aloe gel + INS 402 (2% for 2 min)
T12	Aloe gel + INS 402 (2% for 5 min)

4.2. STANDARDIZATION OF ALOE GEL AS EDIBLE FILM FOR EXTENSION OF SHELF LIFE

The experiment was conducted to select the best aloe gel formulation from the superior 12 treatment combinations chosen from part 1 of the experiment. The study was conducted separately for two different maturity stages *viz.*, mature green and firm ripe.

4.2.1. MATURE GREEN TOMATO

Mature green tomatoes coated with the selected 12 different aloe based edible film formulations were stored under ambient condition along with uncoated one and effect of different edible film coatings on physical, physiological, chemical and microbial quality parameters of tomatoes was analyzed at 12 days interval.

In mature green tomatoes, as all the untreated fruits got damaged after 24th day of storage, comparison was made only among the treated fruits on 36th day of storage. The treated fruits were decayed after the third interval, 36th day was considered as the final day of storage for taking observations.

4.2.1.1. Physiological parameters

Effect of aloe gel based edible film coating on physiological parameters of mature green tomatoes was recorded at 12 days interval till it had lost its marketability.

4.2.1.1.1. Physiological Loss in Weight (PLW)

Effect of aloe gel based edible film coatings on the physiological loss in weight (PLW) of mature green tomatoes under ambient storage condition is shown in Table 9.

There was no significant difference in PLW between the treated and untreated fruit samples on 12th day of storage.

On the 24thday of storage, physiological loss in weight was least (3.85%) for mature green tomato fruits dipped in 2 % (aloe gel + INS 402) for two minutes. This treatment was on par with dipping in 2% (aloe gel + INS 402) for one and five minutes (4.18% and 4.34%), 1% (aloe gel + INS 402) dipped for one, two and five minutes (4.43%, 4.76% and 4.19%) and 2% aloe gel + INS 401 for 5 minutes (4.85%). The highest weight loss (14.23%) was recorded by the untreated/uncoated tomato fruits.

When comparison was made among the fruits coated with different treatments on 36th day of storage, fruits dipped in 2% (aloe gel + INS 402) for two minutes recorded the least PLW (5.92%), which was on par with the fruits dipped in 2% (aloe gel + INS 402) for five minutes (6.12%) and 1% (aloe gel + INS 402)for one minute (6.61%). The PLW was highest for tomato fruits dipped in 1% (aloe gel + INS 401) for five minutes (10.07%).

4.2.1.1.2. Respiration rate

Respiration rate of treated and untreated mature green tomatoes were compared in terms of the amount of CO_2 evolved. The effect of aloe gel based edible film coating on the respiration rate of mature green tomato is shown in Table 10.

There was no significant difference in respiration rate between the treated and untreated fruit samples on the initial day.

On the 12th day of storage, the least respiration rate (5.40%) was recorded by mature green tomato fruits dipped in 2% (aloe gel + INS 402)for two minutes, which was on par with all other treatments except fruits coated with 2% (aloe gel + INS 401)for one and five minutes (7.20%). Respiration rate was maximum for the uncoated fruits (9.10%).

Mature green tomato fruits dipped in 2% (aloe gel + INS 402) for five minutes recorded the least respiration rate (4.00%) on 24th day of storage which was on par with 2% (aloe gel + INS 402)for one and two minutes (4.50%) and 1% (aloe gel + INS 401) for one minute(4.90%) and five minutes (5.00%). Highest respiration rate was recorded by the untreated tomato samples (6.90%).

There were no significant differences among the treated/coated tomato fruits and all the coated fruits had similar respiration rate on 36th day of storage.

4.2.1.1.3. Membrane integrity

The effect of aloe gel based edible coatings on the membrane integrity of mature green tomatoes is shown in Table 11. Membrane integrity was measured in terms of percent leakage.

Mature green tomato fruits dipped in 2% (aloe gel + INS 402) for one minute recorded the least percent leakage (63.08%) on the initial day of storage, which was on par with fruits dipped in 1% (aloe gel + INS 402) for five and one minute (63.40% and 65.18% respectively) and 2% (aloe gel + INS 402) for two and five minutes (65.05% and 65.37% respectively). Percent leakage was highest recorded by untreated tomato fruits (68.18%).

Table 9. Effect of aloe gel coating on the PLW of mature green tomatoes

Treatments	Physiological loss in weight (%)		
	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	4.31	6.24	8.85
Aloe gel + INS 401 (1%, 2 min)	3.40	4.97	7.75
Aloe gel + INS 401 (1%, 5 min)	3.32	6.17	10.07
Aloe gel + INS 401 (2%, 1 min)	3.88	5.30	8.13
Aloe gel + INS 401 (2%, 2 min)	3.82	5.37	7.85
Aloe gel + INS 401 (2%, 5 min)	3.03	4.85	8.57
Aloe gel + INS 402 (1%, 1 min)	2.93	4.43	6.61
Aloe gel + INS 402 (1%, 2 min)	3.59	4.76	8.31
Aloe gel + INS 402 (1%, 5 min)	3.21	4.19	7.30
Aloe gel + INS 402 (2%, 1 min)	2.41	4.18	7.06
Aloe gel + INS 402 (2%, 2 min)	2.24	3.85	5.92
Aloe gel + INS 402 (2%, 5 min)	3.17	4.34	6.12
Control (Untreated)	5.79	14.23	-
CD (0.05)	**NS**	**1.00**	**0.82**

Table 10. Effect of aloe gel coating on the respiration rate of mature green tomatoes

Treatments	Respiration Rate (% CO_2 evolved)			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	7.90	6.90	5.50	5.20
Aloe gel + INS 401 (1%, 2 min)	8.30	7.00	5.60	5.20
Aloe gel + INS 401 (1%, 5 min)	7.30	7.00	5.50	5.00
Aloe gel + INS 401 (2%, 1 min)	8.10	7.20	5.60	5.00
Aloe gel + INS 401 (2%, 2 min)	7.90	7.10	5.50	4.90
Aloe gel + INS 401 (2%, 5 min)	8.20	7.20	5.60	5.20
Aloe gel + INS 402 (1%, 1 min)	8.30	6.90	4.90	4.40
Aloe gel + INS 402 (1%, 2 min)	7.80	6.70	5.10	4.90
Aloe gel + INS 402 (1%, 5 min)	7.70	6.90	5.00	4.40
Aloe gel + INS 402 (2%, 1 min)	7.80	6.50	4.50	4.60
Aloe gel + INS 402 (2%, 2 min)	7.30	5.40	4.50	3.80
Aloe gel + INS 402 (2%, 5 min)	7.70	6.70	4.00	4.30
Control (Untreated)	8.40	9.10	6.90	-
CD (0.05)	**NS**	**1.78**	**1.09**	**NS**

On the 12th day of storage least percent leakage (57.03%) was for the fruits dipped in 2% (aloe gel + INS 402) for two minutes. Percent leakage was highest (62.28%) for the untreated tomato fruits.

Mature green tomato fruits dipped in 2% (aloe gel +INS 402) for five minutes recorded the least percent leakage (74.35%) on 24th day of storage, which was on par with the fruits dipped in 2% (aloe gel + INS 402)for two minutes (74.76%) and 1% (aloe gel + INS 402)for five and one minute (76.13%, 76.22%). Highest percent leakage (86.84%) was recorded by untreated mature green fruits.

On 36th day of storage, the least percent leakage (87.22%) was for the fruits dipped in 2% (aloe gel + INS 402)for two minutes, which was on par 2% (aloe gel + INS 402)for five (87.28%) and one minute (87.82%), 1% (aloe gel + INS 402) for one minute (87.44%), five minutes (87.72%) and two minutes (88.67%). Highest percent leakage (92.39%) was found in fruits dipped in 1% (aloe gel + INS 401) for five minutes.

4.2.1.2. Chemical parameters

Effect of different aloe gel based edible film coatings on chemical quality parameters of mature green tomatoes was measured along with untreated fruits from the initial day of storage till it had lost its shelf life. As all the untreated fruits were damaged after 24th day of storage, comparison was made only between treated fruits on 36th day of storage.

4.2.1.2.1. Total Soluble Solids (TSS)

The effect of aloe gel based edible film coating on the total soluble solids of mature green tomato during storage is shown in Table 12.

Total soluble solids (TSS) remained similar on the initial day of storage for all the tomato samples whether coated or not.

TSS of mature green tomato was highest recorded by fruits dipped in 2% (aloe gel + INS 402) for two and five minutes (4.75^0B) on 12th day of storage, which was on par with all the other treated fruits except those dipped in 1% (aloe gel + INS 401) for two minutes (4.50^0B). Least TSS was for the untreated tomatoes (4.30^0B).

Table 11. Effect of aloe gel coating on the percent leakage of mature green tomatoes

Treatments	Percent Leakage (%)			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel + INS 401 (1%, 1 min)	67.83	60.38	83.15	90.20
Aloe gel + INS 401 (1%, 2 min)	67.27	60.36	81.61	89.23
Aloe gel + INS 401 (1%, 5 min)	66.77	59.64	80.61	92.39
Aloe gel + INS 401 (2%, 1 min)	67.02	59.41	80.83	89.22
Aloe gel + INS 401 (2%, 2 min)	66.48	59.52	83.17	91.27
Aloe gel + INS 401 (2%, 5 min)	66.61	60.21	78.73	90.06
Aloe gel + INS 402 (1%, 1 min)	65.18	59.17	76.22	87.44
Aloe gel + INS 402 (1%, 2 min)	66.51	59.22	81.83	88.67
Aloe gel + INS 402 (1%, 5 min)	63.40	59.16	76.13	87.72
Aloe gel + INS 402 (2%, 1 min)	63.08	58.54	77.93	87.82
Aloe gel + INS 402 (2%, 2 min)	65.05	57.03	74.76	87.22
Aloe gel + INS 402 (2%, 5 min)	65.37	59.16	74.35	87.28
Control (Untreated)	68.18	62.28	86.84	-
CD (0.05)	**2.76**	**1.18**	**1.92**	**1.92**

Table12. Effect of aloe gel coating on the TSS of mature green tomatoes

Treatments	Total Soluble Solids (TSS) (^{0}B)			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel + INS 401 (1%, 1 min)	4.35	4.55	4.90	5.05
Aloe gel + INS 401 (1%, 2 min)	4.35	4.50	4.85	4.85
Aloe gel + INS 401 (1%, 5 min)	4.30	4.55	4.85	5.05
Aloe gel + INS 401 (2%, 1 min)	4.35	4.55	4.90	5.10
Aloe gel + INS 401 (2%, 2 min)	4.30	4.55	4.80	4.95
Aloe gel + INS 401 (2%, 5 min)	4.30	4.55	5.00	5.00
Aloe gel + INS 402 (1%, 1 min)	4.35	4.60	5.05	4.95
Aloe gel + INS 402 (1%, 2 min)	4.35	4.60	5.15	4.85
Aloe gel + INS 402 (1%, 5 min)	4.35	4.70	5.05	5.00
Aloe gel + INS 402 (2%, 1 min)	4.25	4.60	5.00	5.00
Aloe gel + INS 402 (2%, 2 min)	4.35	4.75	5.00	5.00
Aloe gel + INS 402 (2%, 5 min)	4.30	4.75	5.25	5.20
Control (Untreated)	4.25	4.30	4.45	-
CD (0.05)	**NS**	**0.22**	**0.33**	**NS**

On 24th day of storage, highest TSS was observed in fruits dipped in 2% (aloe gel + INS 402) for five minutes (5.25^{0}B), which was on par with all the treated samples except fruits dipped in 2% and 1% (aloe gel +INS 401) for one and two minutes (4.90^{0}B), 1% (aloe gel +INS 401) for two and five minutes (4.85^{0}B) and 2% (aloe gel + INS 401) for two minutes (4.80^{0}B). TSS was least recorded by the untreated fruits (4.45^{0}B).

When comparison was made among the different coated fruits on 36th day of storage, there was no significant difference between TSS content of different treated fruits.

4.2.1.2.2. pH

The effect of aloe gel based edible film coatings on pH of mature green tomato is shown in Table 13.

On the initial day and on 12th day of storage, mature green tomatoes had similar pH value whether treated or untreated.

On 24th day of storage the least pH (4.80) was recorded for the tomato fruits dipped in 1% (aloe gel + INS 402) for two minutes and 2% (aloe gel + INS 402) for two and five minutes which was on par with fruits dipped in 1% (aloe gel + INS 402) for one and five minutes and 2% (aloe gel + INS 402) for one minute (4.90). The untreated tomato fruits recorded the highest pH (5.40).

pH of all the treated mature green fruits were similar on 36th day of storage.

4.2.1.2.3. Vitamin C content

The effect of aloe gel based edible coatings on the vitamin C content of mature green tomatoes under ambient storage is shown in Table 14.

Vitamin C content of mature green tomatoes was similar for all the treated and untreated fruits on the initial and on 12th day of storage. On 24th day of storage the vitamin C content was highest in fruits dipped in 2% (aloe gel + INS 402) for two

Table 13. Effect of aloe gel coating on the pH of mature green tomatoes

Treatments	pH			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	4.45	4.70	5.20	5.30
Aloe gel + INS 401 (1%, 2 min)	4.55	4.70	5.20	5.40
Aloe gel + INS 401 (1%, 5 min)	4.55	4.70	5.10	5.30
Aloe gel + INS 401 (2%, 1 min)	4.45	4.70	5.20	5.20
Aloe gel + INS 401 (2%, 2 min)	4.45	4.80	5.05	5.30
Aloe gel + INS 401 (2%, 5 min)	4.50	4.70	5.10	5.20
Aloe gel + INS 402 (1%, 1 min)	4.50	4.80	4.90	5.30
Aloe gel + INS 402 (1%, 2 min)	4.55	4.70	4.80	5.20
Aloe gel + INS 402 (1%, 5 min)	4.55	4.80	4.90	5.30
Aloe gel + INS 402 (2%, 1 min)	4.55	4.70	4.90	5.30
Aloe gel + INS 402 (2%, 2 min)	4.55	4.60	4.80	5.10
Aloe gel + INS 402 (2%, 5 min)	4.50	4.60	4.80	5.10
Control (Untreated)	4.55	4.75	4.75	-
CD (0.05)	**NS**	**NS**	**0.24**	**NS**

Table 14. Effect of aloe gel coating on the vitamin C content of mature green tomatoes

Treatments	Vitamin C content (mg $100g^{-1}$)			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	14.37	14.82	14.89	15.00
Aloe gel + INS 401 (1%, 2 min)	14.55	14.63	14.92	15.01
Aloe gel + INS 401 (1%, 5 min)	14.67	14.68	14.90	15.01
Aloe gel + INS 401 (2%, 1 min)	14.82	14.78	14.94	15.00
Aloe gel + INS 401 (2%, 2 min)	14.61	14.89	14.98	15.01
Aloe gel + INS 401 (2%, 5 min)	14.51	14.73	14.96	15.02
Aloe gel + INS 402 (1%, 1 min)	14.39	14.72	15.00	15.00
Aloe gel + INS 402 (1%, 2 min)	14.61	14.73	14.99	15.01
Aloe gel + INS 402 (1%, 5 min)	14.50	14.78	14.99	15.01
Aloe gel + INS 402 (2%, 1 min)	14.61	14.73	14.98	15.01
Aloe gel + INS 402 (2%, 2 min)	14.55	14.73	15.01	15.00
Aloe gel + INS 402 (2%, 5 min)	14.50	14.84	14.99	15.02
Control (Untreated)	14.37	14.62	14.79	-
CD (0.05)	**NS**	**NS**	**0.04**	**NS**

minutes (15.01 mg $100g^{-1}$), and this was on par with all the treatments except 1% (aloe gel + INS 401)for one, two and five minutes (14.89 mg $100g^{-1}$,14.92 mg $100g^{-1}$ and 14.90 mg $100g^{-1}$ respectively) and 2% (aloe gel + INS 401) for one and five minutes (14.94 mg $100g^{-1}$and 14.96 mg $100g^{-1}$ respectively). Lowest vitamin C was observed in the untreated mature green tomatoes (14.79mg $100g^{-1}$).

Vitamin C content was similar for all the aloe gel based edible film coated tomato fruits on the 36th day of storage.

4.2.1.2.4. Titratable acidity

The effect of aloe gel based edible film coating on the titratable acidity of mature green tomato is shown in Table 15.

No significant difference was found between the titratable acidity of treated and untreated mature green tomatoes on the initial day and on the 12th day of storage.

On the 24th day of storage highest titratable acidity was for mature green tomatoes dipped in 2% (aloe gel + INS 402) for one minute (0.714%) which was on par with tomato fruits dipped in 1% (aloe gel + INS 402) for one minute (0.713%) and 2% (aloe gel + INS 402) for two and five minutes (0.712%). Least titratable acidity was recorded by the untreated tomato fruits (0.657%).

When treated/coated fruits were compared on 36th day of storage, titratable acidity remained similar for all the treatments.

4.2.1.2.5. Lycopene content

The effect of aloe gel based edible film coatings on the lycopene content of mature green tomato is shown in Table 16.

On the initial day, no significant difference was observed between lycopene content of treated and untreated mature green tomatoes.

On 12th day of storage the lycopene content of treated fruits was found significantly different from that of untreated fruits. The lycopene content was least (0.81 $\mu g g^{-1}$) recorded by mature green tomatoes dipped in 2% (aloe gel + INS 402) for five minutes which was on par with all the other treatments except fruits dipped in 2%

(aloe gel + INS 401) for two minutes (0.96μgg^{-1}) and 1% (aloe gel + INS 401) for five minutes (0.98 μgg^{-1}). Highest lycopene content (7.84μgg^{-1}) was recorded by the untreated tomato fruits.

Significant difference was observed between the lycopene content of treated and untreated fruits on 24th day of storage. Lycopene content was least (32.88 μgg^{-1}) in the tomato fruits dipped in 2% (aloe gel + INS 402)for two minutes which was on par with the fruits dipped in 2% (aloe gel + INS 402)for one and five minutes (34.22 μgg^{-i}, 33.95 μgg^{-1})and 1% (aloe gel + INS 402) for one minute (35.56 μgg^{-1}). Lycopene content was highest (51.17 μgg^{-1}) recorded in the untreated fruits.

Lycopene content was similar for all the treated mature green tomato fruits on 36th day of storage.

4.2.1.3. Enumeration of total microbial load

Effect of edible coatings on the bacterial count observed on the fruit surface is shown in Table 17.

Total bacteria was too less to count (TLTC) in the case of mature green tomato fruits dipped in the 12 superior aloe gel based treatments and bacteria was too numerous to count (TNTC) on the untreated tomato fruits during the initial day.

The bacterial count was too numerous in the case of untreated fruits during the entire storage period and there was no significant difference among the different aloe gel based coatings on the bacterial population.

4.2.1.4. Physical parameters

Effects of different aloe gel based edible film coatings on physical quality parameters of mature green tomatoes were judged along with uncoated fruits by the sensory panel at 12 days interval and they are shown in Table 18 to Table 23.

As there was no significant difference between treatment means, the treatments with high mean sensory scores were considered to have efficiency in extension of shelf life. Initially all the fruits including untreated one had similar physical parameters with almost similar mean scores.

Table 15. Effect of aloe gel coating on the titratable acidity of mature green tomatoes

Treatments	Titratable Acidity (%)			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	0.685	0.682	0.698	0.600
Aloe gel + INS 401 (1%, 2 min)	0.688	0.683	0.697	0.679
Aloe gel + INS 401 (1%, 5 min)	0.686	0.683	0.699	0.694
Aloe gel + INS 401 (2%, 1 min)	0.686	0.687	0.699	0.690
Aloe gel + INS 401 (2%, 2 min)	0.688	0.689	0.699	0.688
Aloe gel + INS 401 (2%, 5 min)	0.686	0.689	0.699	0.690
Aloe gel + INS 402 (1%, 1 min)	0.68	0.687	0.713	0.691
Aloe gel + INS 402 (1%, 2 min)	0.687	0.675	0.706	0.687
Aloe gel + INS 402 (1%, 5 min)	0.687	0.672	0.700	0.686
Aloe gel + INS 402 (2%, 1 min)	0.69	0.681	0.714	0.692
Aloe gel + INS 402 (2%, 2 min)	0.687	0.684	0.712	0.699
Aloe gel + INS 402 (2%, 5 min)	0.685	0.679	0.712	0.698
Control (Untreated)	0.687	0.676	0.657	-
CD (0.05)	**NS**	**NS**	**0.007**	**NS**

Table 16. Effect of aloe gel coating on the lycopene content of mature green tomatoes

Treatments	Lycopene content (µgg^{-1})			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	0.64	0.92	38.54	48.31
Aloe gel + INS 401 (1%, 2 min)	0.64	0.89	41.00	49.33
Aloe gel + INS 401 (1%, 5 min)	0.65	0.98	43.52	50.93
Aloe gel + INS 401 (2%, 1 min)	0.65	0.87	36.82	47.28
Aloe gel + INS 401 (2%, 2 min)	0.67	0.96	40.65	47.06
Aloe gel + INS 401 (2%, 5 min)	0.68	0.87	39.82	45.61
Aloe gel + INS 402 (1%, 1 min)	0.66	0.87	35.56	48.22
Aloe gel + INS 402 (1%, 2 min)	0.64	0.94	38.78	48.28
Aloe gel + INS 402 (1%, 5 min)	0.65	0.88	35.77	47.98
Aloe gel + INS 402 (2%, 1 min)	0.65	0.89	34.22	44.95
Aloe gel + INS 402 (2%, 2 min)	0.66	0.85	32.88	44.56
Aloe gel + INS 402 (2%, 5 min)	0.67	0.81	33.95	43.06
Control (Untreated)	0.68	7.84	51.17	-
CD (0.05)	**NS**	**0.14**	**2.86**	**NS**

Table 17. Effect of aloe gel coating on the microbial load of mature green tomatoes

Treatments	Bacterial count x 10^2cfu/g			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel + INS 401 (1%, 1 min)	TLTC	3.55	4.45	4.40
Aloe gel + INS 401 (1%, 2 min)	TLTC	3.55	4.60	4.95
Aloe gel + INS 401 (1%, 5 min)	TLTC	4.05	4.30	4.65
Aloe gel + INS 401 (2%, 1 min)	TLTC	3.65	4.50	4.60
Aloe gel + INS 401 (2%, 2 min)	TLTC	4.25	4.10	5.00
Aloe gel + INS 401 (2%, 5 min)	TLTC	3.50	4.30	4.30
Aloe gel + INS 402 (1%, 1 min)	TLTC	3.55	4.40	4.60
Aloe gel + INS 402 (1%, 2 min)	TLTC	3.65	4.50	4.30
Aloe gel + INS 402 (1%, 5 min)	TLTC	3.70	4.40	4.50
Aloe gel + INS 402 (2%, 1 min)	TLTC	3.60	4.45	4.40
Aloe gel + INS 402 (2%, 2 min)	TLTC	3.65	4.35	4.20
Aloe gel + INS 402 (2%, 5 min)	TLTC	3.85	4.20	4.30
CD (0.05)		**NS**	**NS**	**NS**
Control (Untreated)	TNTC	TNTC	TNTC	TNTC

*TLTC – Too Less To Count

*TNTC – Too Numerous To Count

All the untreated fruits got decayed after 24th day of storage and hence comparison was made only between the treated fruits on 36th day of storage.

4.2.1.4.1 Appearance

Effect of aloe gel based edible film coatings on the appearance of mature green tomatoes under ambient storage condition is shown in Table 18. There was no significant difference between the sensory scores for appearance.

Initially all the aloe gel formulations had almost similar mean scores from 8.00 to 8.07.

On 12th day of storage mature green tomato fruits dipped in 2% (aloe gel +INS 402) for five minutes scored highest mean score for appearance (8.00). Mature green fruits dipped in 2% (aloe gel +INS 402) for two minutes scored highest mean scores of appearance on 24th (7.87) and 36th (7.67) day of storage.

4.2.1.4.2. Colour

Effect of aloe gel based edible film coating on the colour of mature green tomato under ambient storage condition is shown in Table 19.There was no significant difference between the sensory scores for colour. Initially fruits coated with the aloe gel formulations had mean scores ranging from 8.00 to 8.13.

Mature green fruits dipped in 2% (aloe gel +INS 402) for two and five minutes scored highest mean score of color (8.00) on 12th day of storage. On 24th day of storage tomato fruits dipped in 2% (aloe gel +INS 402) for five minutes scored highest mean score of 7.87 for colour. Those fruits scored highest mean score for colour (7.67) during 36th day also.

4.2.1.4.3. Flavour

Effect of aloe gel based edible film coatings on the flavour of mature green tomato under ambient storage condition is shown in Table 20. There was no significant difference between the sensory scores for flavor of tomatoes.

Initially all the aloe gel formulations had mean scores ranging from 8.00 to 8.13. Mature green fruits dipped in 2% (aloe gel + INS 402) for two and five minutes

Table 18. Effect of aloe gel coating on the appearance of mature green tomatoes

Treatments	Appearance			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.43	7.20	7.15
Aloe gel + INS 401 (1%, 2 min)	8.00	7.33	7.40	7.07
Aloe gel + INS 401 (1%, 5 min)	8.07	7.53	7.40	7.13
Aloe gel + INS 401 (2%, 1 min)	8.00	7.53	7.33	7.00
Aloe gel + INS 401 (2%, 2 min)	8.00	7.47	7.22	7.00
Aloe gel + INS 401 (2%, 5 min)	8.00	7.60	7.45	7.00
Aloe gel + INS 402 (1%, 1 min)	8.00	7.87	7.56	7.33
Aloe gel + INS 402 (1%, 2 min)	8.07	7.70	7.47	7.13
Aloe gel + INS 402 (1%, 5 min)	8.07	7.77	7.45	7.20
Aloe gel + INS 402 (2%, 1 min)	8.07	7.80	7.47	7.27
Aloe gel + INS 402 (2%, 2 min)	8.07	7.93	7.87	7.67
Aloe gel + INS 402 (2%, 5 min)	8.07	8.00	7.60	7.40
Control (Untreated)	8.00	7.23	7.07	
χ^2 value	11.33	11.49	11.19	9.88
KW value	**NS**			**NS**

Table 19. Effect of aloe gel coating on the colour of mature green tomatoes

Treatments	Colour			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel + INS 401 (1%, 1 min)	8.00	7.78	7.47	7.17
Aloe gel + INS 401 (1%, 2 min)	8.00	7.43	7.27	7.13
Aloe gel + INS 401 (1%, 5 min)	8.00	7.67	7.20	7.13
Aloe gel + INS 401 (2%, 1 min)	8.00	7.47	7.20	7.13
Aloe gel + INS 401 (2%, 2 min)	8.00	7.48	7.20	6.73
Aloe gel + INS 401 (2%, 5 min)	8.00	7.54	7.30	6.89
Aloe gel + INS 402 (1%, 1 min)	8.00	7.63	7.53	7.27
Aloe gel + INS 402 (1%, 2 min)	8.03	7.87	7.53	7.29
Aloe gel + INS 402 (1%, 5 min)	8.07	7.85	7.33	7.20
Aloe gel + INS 402 (2%, 1 min)	8.07	7.80	7.50	7.17
Aloe gel + INS 402 (2%, 2 min)	8.13	8.00	7.73	7.40
Aloe gel + INS 402 (2%, 5 min)	8.13	8.00	7.87	7.67
Control (Untreated)	8.00	7.34	7.17	-
χ^2 value	16.78	13.62	14.23	10.60
KW value	**NS**			**NS**

had highest mean score 7.93 for flavour on 12th day of storage. On 24th and 36th day of storage fruits dipped in 2% (aloe gel +INS 402) for two minutes scored highest mean score for flavour (7.80 and 7.67 respectively).

4.2.1.4.4. Taste

Effect of aloe gel based edible film coating on the taste of mature green tomato under ambient storage condition is shown in Table 21.There was no significant difference between the sensory scores for taste. Initially all the treatments had mean scores ranging from 8.00 to 8.07.

On 12th day of storage mature green fruits dipped in 2% (aloe gel + INS 402) for two minutes scored highest mean score of 7.93 for taste. Mature green fruits dipped in 2% (aloe gel + INS 402) for two and five minutes scored highest mean score (7.87) on the 24th day of storage. On 36th day of storage fruits dipped in 2% (aloe gel + INS 402) for two minutes scored highest mean score for taste (7.73).

4.2.1.4.5. Texture

Effect of aloe gel based edible film coating on the texture of mature green tomato under ambient storage condition is shown in Table 22. There was no significant difference between the sensory scores for texture.

Initially all the aloe gel formulations had mean scores ranging from 8.00 to 8.20. Fruits dipped in 2% (aloe gel + INS 402) for two minutes had highest mean score (8.20) during the initial day of storage.

Mature green fruits treated with 2% (aloe gel + INS 402) for two and five minutes scored highest mean score (7.92) for texture on 12th day of storage. On 24th day of storage highest score for texture was for fruits dipped in 2% (aloe gel + INS 402) for two minutes with mean score of 7.89.

When comparison was made between the different treatments on 36th day of storage, mature green fruits dipped in 2% (aloe gel + INS 402) for two and five minutes scored highest mean score (7.73) for texture.

Table 20. Effect of aloe gel coating on the flavour of mature green tomatoes

Treatments	Flavour			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	8.00	7.67	7.53	7.27
Aloe gel + INS 401 (1%, 2 min)	8.00	7.53	7.47	7.28
Aloe gel + INS 401 (1%, 5 min)	8.07	7.67	7.47	7.26
Aloe gel + INS 401 (2%, 1 min)	8.07	7.67	7.33	7.20
Aloe gel + INS 401 (2%, 2 min)	8.07	7.67	7.53	7.20
Aloe gel + INS 401 (2%, 5 min)	8.07	7.65	7.47	7.27
Aloe gel + INS 402 (1%, 1 min)	8.00	7.80	7.67	7.33
Aloe gel + INS 402 (1%, 2 min)	8.13	7.68	7.60	7.47
Aloe gel + INS 402 (1%, 5 min)	8.07	7.73	7.60	7.53
Aloe gel + INS 402 (2%, 1 min)	8.07	7.87	7.57	7.34
Aloe gel + INS 402 (2%, 2 min)	8.07	7.93	7.80	7.67
Aloe gel + INS 402 (2%, 5 min)	8.07	7.93	7.70	7.60
Control (Untreated)	8.00	7.57	7.30	-
χ^2 value	10.25	8.24	15.26	13.10
KW value		**NS**		**NS**

Table 21. Effect of aloe gel coating on the taste of mature green tomatoes

Treatments	Taste			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.67	7.54	7.27
Aloe gel + INS 401 (1%, 2 min)	8.00	7.47	7.33	7.27
Aloe gel + INS 401 (1%, 5 min)	8.07	7.53	7.33	7.20
Aloe gel + INS 401 (2%, 1 min)	8.00	7.60	7.53	7.37
Aloe gel + INS 401 (2%, 2 min)	8.00	7.67	7.40	7.13
Aloe gel + INS 401 (2%, 5 min)	8.00	7.63	7.47	7.33
Aloe gel + INS 402 (1%, 1 min)	8.00	7.90	7.73	7.63
Aloe gel + INS 402 (1%, 2 min)	8.07	7.73	7.70	7.63
Aloe gel + INS 402 (1%, 5 min)	8.00	7.67	7.57	7.40
Aloe gel + INS 402 (2%, 1 min)	8.00	7.87	7.60	7.27
Aloe gel + INS 402 (2%, 2 min)	8.07	7.93	7.87	7.73
Aloe gel + INS 402 (2%, 5 min)	8.07	7.92	7.87	7.67
Control (Untreated)	8.00	7.45	7.30	-
χ^2 value	8.17	6.08	19.61	14.28
KW value		**NS**		**NS**

4.2.1.4.6. Overall acceptability

Effect of aloe gel based edible film coatings on the overall acceptability of mature green tomatoes under ambient storage condition is shown in Table 23.There was no significant difference between the sensory scores for overall acceptability. All fruits had almost similar score for overall acceptability ranging from 8.00 to 8.07 during the initial day of storage.

On 12th day of storage, mature green fruits dipped in 2% (aloe gel + INS 402) for two and five minutes obtained highest mean score of 7.87 for overall acceptability. On 24th and 36th day of storage highest scores for overall acceptability were for the fruits dipped in 2% (aloe gel +INS 402) for two minutes (7.75 and 7.62 respectively).

Considering the efficiency in maintaining the physiological quality parameters and superior scores for the physical parameters analyzed, 2% (aloe gel +INS 402) dipped for two minutes was selected as the best aloe gel based edible film coating formulation for maintaining the shelf life of mature green tomato for 36 days and it was selected for the further study of the experiment.

4.2.2. FIRM RIPE TOMATO

Firm ripe tomatoes coated with the 12 different aloe based edible film formulations were stored under ambient condition along with uncoated one and effect of different edible film coatings on physical, physiological, chemical and microbial quality parameters of tomatoes was analyzed at 12 days interval.

In firm ripe tomatoes, as all the untreated fruits were damaged after 12th day of storage, comparison was made only between the treated fruits on 24th day of storage. The treated fruits were decayed after the second interval of storage, 24th day was considered as the final day of storage for taking observations.

Table 22. Effect of aloe gel coating on the texture of mature green tomatoes

Treatments	Texture			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.73	7.57	7.27
Aloe gel + INS 401 (1%, 2 min)	8.13	7.77	7.52	7.27
Aloe gel + INS 401 (1%, 5 min)	8.07	7.73	7.43	7.40
Aloe gel + INS 401 (2%, 1 min)	8.13	7.60	7.33	6.53
Aloe gel + INS 401 (2%, 2 min)	8.07	7.73	7.46	7.13
Aloe gel + INS 401 (2%, 5 min)	8.07	7.73	7.47	6.93
Aloe gel + INS 402 (1%, 1 min)	8.07	7.87	7.80	7.33
Aloe gel + INS 402 (1%, 2 min)	8.07	7.80	7.59	7.40
Aloe gel + INS 402 (1%, 5 min)	8.13	7.67	7.60	7.59
Aloe gel + INS 402 (2%, 1 min)	8.07	7.80	7.73	7.67
Aloe gel + INS 402 (2%, 2 min)	8.20	7.92	7.89	7.73
Aloe gel + INS 402 (2%, 5 min)	8.13	7.92	7.88	7.73
Control (Untreated)	8.00	7.26	7.12	-
χ^2 value	5.60	6.18	18.08	16.26
KW value		**NS**		**NS**

Table 23. Effect of aloe gel coating on the overall acceptability of mature green tomatoes

Treatments	Overall Acceptability			
	0th day	12th day	24th day	36th day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.63	7.53	7.46
Aloe gel + INS 401 (1%, 2 min)	8.00	7.57	7.47	7.00
Aloe gel + INS 401 (1%, 5 min)	8.07	7.66	7.58	7.50
Aloe gel + INS 401 (2%, 1 min)	8.00	7.60	7.33	7.27
Aloe gel + INS 401 (2%, 2 min)	8.00	7.65	7.54	7.33
Aloe gel + INS 401 (2%, 5 min)	8.07	7.63	7.50	7.47
Aloe gel + INS 402 (1%, 1 min)	8.00	7.80	7.70	7.59
Aloe gel + INS 402 (1%, 2 min)	8.07	7.67	7.63	7.57
Aloe gel + INS 402 (1%, 5 min)	8.07	7.67	7.62	7.57
Aloe gel + INS 402 (2%, 1 min)	8.00	7.73	7.57	7.50
Aloe gel + INS 402 (2%, 2 min)	8.07	7.87	7.75	7.62
Aloe gel + INS 402 (2%, 5 min)	8.07	7.87	7.72	7.60
Control (Untreated)	8.07	7.40	7.28	-
χ^2 value	8.47	8.34	13.30	10.43
KW value		**NS**		**NS**

4.2.2.1. Physiological parameters

Effect of aloe gel based edible film coatings on physiological parameters of firm ripe tomatoes was recorded at 12 days interval from the initial day of storage till it had lost its shelf life.

4.2.2.1.1. Physiological Loss in Weight (PLW)

The effect of aloe gel based edible film coatings on the physiological loss in weight of firm ripe tomatoes is shown in Table 24.

On 12thday of storage, physiological loss in weight of firm ripe tomatoes was least (3.72%) for tomato fruits dipped in 1% (aloe gel + INS 402) for one minute which was on par with the fruits dipped in 1% (aloe gel + INS 402) for five minutes (5.12%). Highest weight loss (15.25%) was recorded by the untreated firm ripe tomatoes.

When different treatments were compared on 24th day, physiological loss in weight was least (5.84%) for firm ripe tomatoes dipped in 1% (aloe gel + INS 402) for one minute which was on par with the fruits dipped in 1% (aloe gel + INS 402) for five minutes (6.43%) and 2% (aloe gel + INS 402) for two minutes (7.50%).

4.2.2.1.2. Respiration rate

Respiration rate of treated and untreated firm ripe tomatoes were compared in terms of the amount of CO_2 evolved. The effect of aloe gel based edible film coatings on the respiration rate of firm ripe tomato is shown in Table 25.

There was no significant difference between the respiration rates of treated and untreated fruit samples on the initial day of storage.

On 12th day of storage, the least respiration rate (5.70%) was recorded by firm ripe tomato fruits dipped in 1% and 2% (aloe gel + INS 402) for one and two minutes which were on par with all other treated fruits except those treated with 1% (aloe gel + INS 401) for two (7.40%) and five minutes (7.60%) and 2% (aloe gel + INS 401) for one minute (7.40%) and the untreated fruits (8.80%).

On 24th day of storage the respiration rate was least (6.80%) for firm ripe tomatoes dipped in 1% (aloe gel + INS 402) for one and five minutes which were on

Table 24. Effect of aloe gel coating on the PLW of firm ripe tomatoes

Treatments	Physiological Loss in Weight (%)	
	12^{th} day	24^{th} day
Aloe gel + INS 401 (1%, 1 min)	7.51	9.54
Aloe gel + INS 401 (1%, 2 min)	10.86	13.17
Aloe gel + INS 401 (1%, 5 min)	6.65	10.44
Aloe gel + INS 401 (2%, 1 min)	7.26	10.23
Aloe gel + INS 401 (2%, 2 min)	9.93	12.43
Aloe gel + INS 401 (2%, 5 min)	8.97	10.62
Aloe gel + INS 402 (1%, 1 min)	3.72	5.84
Aloe gel + INS 402 (1%, 2 min)	6.67	8.61
Aloe gel + INS 402 (1%, 5 min)	5.12	6.43
Aloe gel + INS 402 (2%, 1 min)	6.11	8.54
Aloe gel + INS 402 (2%, 2 min)	6.05	7.50
Aloe gel + INS 402 (2%, 5 min)	5.79	9.06
Control (Untreated)	15.25	-
CD (0.05)	**1.75**	**1.88**

Table 25. Effect of aloe gel coating on the respiration rate of firm ripe tomatoes

Treatments	Respiration Rate (% CO2 evolved)		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel + INS 401 (1%, 1 min)	4.20	6.70	9.10
Aloe gel + INS 401 (1%, 2 min)	4.90	7.40	9.10
Aloe gel + INS 401 (1%, 5 min)	4.40	7.60	11.10
Aloe gel + INS 401 (2%, 1 min)	4.40	7.40	10.80
Aloe gel + INS 401 (2%, 2 min)	4.50	6.80	8.40
Aloe gel + INS 401 (2%, 5 min)	4.00	6.60	10.80
Aloe gel + INS 402 (1%, 1 min)	4.70	5.70	6.80
Aloe gel + INS 402 (1%, 2 min)	4.60	6.60	8.50
Aloe gel + INS 402 (1%, 5 min)	4.70	5.90	6.80
Aloe gel + INS 402 (2%, 1 min)	4.60	6.50	7.00
Aloe gel + INS 402 (2%, 2 min)	4.45	5.70	7.00
Aloe gel + INS 402 (2%, 5 min)	4.25	5.90	7.50
Control (Untreated)	4.30	8.80	-
CD (0.05)	**NS**	**1.50**	**0.96**

par with the fruits dipped in 2% (aloe gel + INS 402) for one, two and five minutes (7.00%, 7.00%, 7.50% respectively).

4.2.2.1.3. Membrane integrity

The effect of aloe gel based edible film coating on the membrane integrity of firm ripe tomato fruits is shown as percent leakage in Table 26.

On the initial day, percent leakage was least in the firm ripe tomatoes dipped in 1% (aloe gel + INS 402) for five minutes (70.27%) which was on par with fruits dipped in 2% (aloe gel + INS 402) for one, two and five (70.81%, 71.89% and 72.02% respectively) minutes and 1% (aloe gel +INS 402) for one and two minutes (71.06%, 71.43%). Percent leakage was highest recorded by the untreated tomato fruits (76.12%).

On 12th day of storage significant difference was noticed between the treated and control fruits. Least percent leakage (73.30%) was for the firm ripe tomato fruits dipped in 1% (aloe gel + INS 402) for one minute which was on par with the fruits dipped in 1% (aloe gel + INS 402) for two and five minutes (73.95%, 73.48%) and 2% (aloe gel + INS 402)for one, two and five minutes (73.45%, 74.81%, 74.92% respectively). Percent leakage was highest (80.32%) recorded by the untreated fruits.

On 24th day of storage, percent leakage was least (83.48%) for the firm ripe tomato fruits dipped in 1% (aloe gel + INS 402) for one minute which was on par with the fruits dipped in 1% (aloe gel + INS 402) for two and five minutes (84.90%, 84.17%) and 2% (aloe gel + INS 402) for one, two and five minutes (84.36%, 84.24%, 84.41% respectively).

4.2.2.2. Chemical parameters

Effect of aloe gel based edible film coatings on chemical quality parameters of firm ripe tomatoes was recorded from the initial day of storage till it had lost its shelf life and is shown from Table 27-31.

Table 26. Effect of aloe gel coating on the percent leakage of firm ripe tomatoes

Treatments	Percent Leakage (%)		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	72.56	76.25	86.66
Aloe gel + INS 401 (1%, 2 min)	73.22	77.22	86.27
Aloe gel + INS 401 (1%, 5 min)	72.22	76.60	88.91
Aloe gel + INS 401 (2%, 1 min)	72.61	77.26	87.86
Aloe gel + INS 401 (2%, 2 min)	74.84	79.36	88.87
Aloe gel + INS 401 (2%, 5 min)	75.21	78.76	88.84
Aloe gel + INS 402 (1%, 1 min)	71.06	73.30	83.48
Aloe gel + INS 402 (1%, 2 min)	71.43	73.95	84.90
Aloe gel + INS 402 (1%, 5 min)	70.27	73.48	84.17
Aloe gel + INS 402 (2%, 1 min)	70.81	73.45	84.36
Aloe gel + INS 402 (2%, 2 min)	71.89	74.81	84.24
Aloe gel + INS 402 (2%, 5 min)	72.02	74.92	84.41
Control (Untreated)	76.12	80.32	-
CD (0.05)	**1.77**	**1.79**	**1.60**

All the untreated (without coating) fruits got decayed after 12[th] day of storage and before 24[th] day of storage and hence comparison could be made only between the different treated fruits on 24[th] day of storage.

4.2.2.2.1. Total Soluble Solids

The effect of aloe gel based edible film coatings on the TSS of firm ripe tomato is shown in Table 27.

The total soluble solids were similar for the treated and untreated firm ripe tomatoes on the initial day of storage. Highest TSS (4.35^0B) was recorded for the tomato fruits dipped in 2% (aloe gel + INS 402) for two minutes which was on par with fruits dipped in 1% (aloe gel + INS 402) for one, two and five minutes (4.15^0B) and 2% (aloe gel + INS 402) for one and five minutes (4.30^0Band 4.25^0B respectively) on 12[th] day of storage. Least TSS (3.80^0B) was recorded by the untreated fruits.

There was no significant difference between the TSS content of fruits coated with aloe based treatments on 24[th] day of storage.

4.2.2.2.2. pH

The effect of aloe gel based edible film coatings on the pH of firm ripe tomato fruits is shown in Table 28.

On the initial day of storage, the pH of all the firm ripe tomatoes remained similar whether treated or untreated.

On 12[th] day of storage the least pH (5.20) was recorded in firm ripe tomatoes dipped in 1% (aloe gel + INS 402) for five minutes which was on par with all the other treated fruits except those dipped in 1% (aloe gel + INS 401)for one and five minutes (5.40).

There was no significant difference between the pH of treated fruits on the 24[th] day of storage.

Table 27. Effect of aloe gel coating on the TSS of firm ripe tomatoes

Treatments	TSS (^{0}Brix)		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	3.90	4.05	4.30
Aloe gel + INS 401 (1%, 2 min)	4.05	4.05	4.30
Aloe gel + INS 401 (1%, 5 min)	4.15	3.95	4.30
Aloe gel + INS 401 (2%, 1 min)	3.90	4.05	4.30
Aloe gel + INS 401 (2%, 2 min)	3.85	4.00	4.35
Aloe gel + INS 401 (2%, 5 min)	3.85	4.05	4.35
Aloe gel + INS 402 (1%, 1 min)	4.00	4.15	4.35
Aloe gel + INS 402 (1%, 2 min)	3.80	4.15	4.30
Aloe gel + INS 402 (1%, 5 min)	3.70	4.15	4.40
Aloe gel + INS 402 (2%, 1 min)	3.70	4.30	4.35
Aloe gel + INS 402 (2%, 2 min)	3.95	4.35	4.35
Aloe gel + INS 402 (2%, 5 min)	4.05	4.25	4.35
Control (Untreated)	4.00	3.80	-
CD (0.05)	**NS**	**0.25**	**NS**

Table 28. Effect of aloe gel coating on the pH of firm ripe tomatoes

Treatments	pH		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	5.20	5.40	5.55
Aloe gel + INS 401 (1%, 2 min)	5.25	5.35	5.50
Aloe gel + INS 401 (1%, 5 min)	5.25	5.40	5.40
Aloe gel + INS 401 (2%, 1 min)	5.10	5.25	5.45
Aloe gel + INS 401 (2%, 2 min)	5.20	5.25	5.40
Aloe gel + INS 401 (2%, 5 min)	5.20	5.25	5.40
Aloe gel + INS 402 (1%, 1 min)	5.20	5.25	5.35
Aloe gel + INS 402 (1%, 2 min)	5.25	5.35	5.35
Aloe gel + INS 402 (1%, 5 min)	5.25	5.20	5.45
Aloe gel + INS 402 (2%, 1 min)	5.20	5.30	5.45
Aloe gel + INS 402 (2%, 2 min)	5.05	5.25	5.40
Aloe gel + INS 402 (2%, 5 min)	5.25	5.30	5.45
Control (Untreated)	5.25	5.15	-
CD (0.05)	**NS**	**0.19**	**NS**

4.2.2.2.3. Vitamin C content

The effect of aloe gel based edible film coatings on the vitamin C content of firm ripe tomato is shown in Table 29.

Vitamin C content of firm ripe tomatoes remained the similar on the initial day of storage whether they are treated or untreated.

On 12th day of storage, significant difference was noticed between vitamin C content of treated and untreated fruits. All the aloe based coatings were equally effective in maintaining a high vitamin C content in firm ripe tomatoes compared to untreated fruits. The least vitamin C (10.91 mg $100g^{-1}$) was recorded for untreated fruits.

When comparison was made among the treated fruits on 24th day of storage there was no significant difference between the vitamin C content of treated firm ripe tomatoes.

4.2.2.2.4. Titratable acidity

The effect of aloe gel based edible film coatings on the titratable acidity of firm ripe tomatoes is shown in Table 30.

Titratable acidity was similar for the firm ripe tomatoes on the initial and 12th day of storage, whether treated or not treated.

When treated fruits were compared on 24th day of storage, there was no significant difference between the titratable acidity of coated tomato fruits.

4.2.2.2.5. Lycopene content

The effect of aloe gel based edible film coating on the lycopene content of firm ripe tomato is shown in Table 31.

On the initial day of storage the lycopene content was least in fruits dipped in 1% (aloe gel + INS 402)for five minutes (43.27μgg^{-1}) which was on par with all the other treated fruits except the fruits dipped in 2% (aloe gel + INS 401) for two minutes (48.71μgg^{-1}) and untreated fruits (49.39μgg^{-1}).

Table 29. Effect of aloe gel coating on the vitamin C content of firm ripe tomatoes

Treatments	Vitamin C content (mg 100g^{-1})		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	16.37	12.73	10.91
Aloe gel + INS 401 (1%, 2 min)	12.73	12.73	10.91
Aloe gel + INS 401 (1%, 5 min)	14.55	14.55	10.91
Aloe gel + INS 401 (2%, 1 min)	16.37	12.73	12.73
Aloe gel + INS 401 (2%, 2 min)	16.37	12.73	12.73
Aloe gel + INS 401 (2%, 5 min)	16.37	12.73	12.73
Aloe gel + INS 402 (1%, 1 min)	18.18	14.55	14.55
Aloe gel + INS 402 (1%, 2 min)	16.37	12.73	12.73
Aloe gel + INS 402 (1%, 5 min)	16.37	14.55	14.55
Aloe gel + INS 402 (2%, 1 min)	18.18	14.55	12.73
Aloe gel + INS 402 (2%, 2 min)	12.73	14.55	12.73
Aloe gel + INS 402 (2%, 5 min)	16.37	14.55	12.73
Control (Untreated)	12.73	10.91	-
CD (0.05)	**NS**	**3.44**	**NS**

Table 30. Effect of aloe gel coating on the titratable acidity of firm ripe tomatoes

Treatments	Titratable acidity (%)		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	0.545	0.465	0.443
Aloe gel + INS 401 (1%, 2 min)	0.540	0.540	0.450
Aloe gel + INS 401 (1%, 5 min)	0.545	0.545	0.430
Aloe gel + INS 401 (2%, 1 min)	0.545	0.435	0.460
Aloe gel + INS 401 (2%, 2 min)	0.545	0.495	0.480
Aloe gel + INS 401 (2%, 5 min)	0.540	0.500	0.445
Aloe gel + INS 402 (1%, 1 min)	0.535	0.460	0.530
Aloe gel + INS 402 (1%, 2 min)	0.555	0.480	0.425
Aloe gel + INS 402 (1%, 5 min)	0.545	0.430	0.530
Aloe gel + INS 402 (2%, 1 min)	0.540	0.475	0.425
Aloe gel + INS 402 (2%, 2 min)	0.540	0.450	0.445
Aloe gel + INS 402 (2%, 5 min)	0.545	0.455	0.475
Control (Untreated)	0.550	0.440	-
CD (0.05)	**NS**	**NS**	**NS**

On 12th day of storage, the treated fruits had significantly different lycopene content from control fruits. Aloe gel based coatings were equally effective in maintaining a low and similar lycopene content in firm ripe tomatoes, however the least lycopene content was recorded by fruits dipped in 1% (aloe gel +INS 402) for one minute (50.37 $\mu g g^{-1}$). Highest lycopene cntent (63.26$\mu g g^{-1}$) was recorded by the untreated fruits.

On 24th day of storage there was no significant difference between the lycopene content of treated tomatoes.

4.2.2.3. Microbial parameters

Effect of bacterial count on the surface of the coated and uncoated firm ripe tomato fruits is shown in Table 32.

Total bacteria was too less to count (TLTC) on the surface of firm ripe tomato fruits dipped in the 12 superior aloe gel based coatings and the count was too numerous (TNTC) on the untreated tomato fruits during the initial day of storage.

The bacterial count was too numerous in the case of control fruits and all the aloe gel based treatments were equally effective in reducing the bacterial population on the surface of the fruits during the entire storage period.

4.2.2.4. Physical parameters

Effect of different aloe gel based edible film coatings on physical quality parameters of firm ripe tomatoes was judged by the sensory panel at 12 days interval and is shown in Table 33 to Table 38.

As there was no significant difference between treatment means, the treatments with high mean sensory scores were considered to have efficiency in extension of shelf life. Initially all the fruits including untreated one had similar physical parameters with almost similar mean scores. As the untreated fruits were damaged before 24th day of storage, comparison could be made only between treated fruits on 24th day of storage.

Table 31. Effect of aloe gel coating on the lycopene content of firm ripe tomatoes

Treatments	Lycopene content ($\mu g g^{-1}$)		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	47.11	53.63	59.82
Aloe gel + INS 401 (1%, 2 min)	47.21	54.13	59.83
Aloe gel + INS 401 (1%, 5 min)	47.37	54.79	60.20
Aloe gel + INS 401 (2%, 1 min)	46.42	54.12	60.39
Aloe gel + INS 401 (2%, 2 min)	48.71	53.99	60.66
Aloe gel + INS 401 (2%, 5 min)	45.97	53.71	60.60
Aloe gel + INS 402 (1%, 1 min)	43.96	50.37	57.42
Aloe gel + INS 402 (1%, 2 min)	45.82	51.42	59.20
Aloe gel + INS 402 (1%, 5 min)	43.27	52.71	58.16
Aloe gel + INS 402 (2%, 1 min)	44.71	53.51	59.42
Aloe gel + INS 402 (2%, 2 min)	47.26	53.51	59.41
Aloe gel + INS 402 (2%, 5 min)	46.10	53.15	58.42
Control (Untreated)	49.39	63.26	-
CD (0.05)	**5.39**	**4.57**	**NS**

Table 32. Effect of aloe gel coating on the microbial load of firm ripe tomatoes

Treatments	Bacterial count x 10^2cfu/g		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	TLTC	36.50	36.50
Aloe gel + INS 401 (1%, 2 min)	TLTC	48.00	51.00
Aloe gel + INS 401 (1%, 5 min)	TLTC	35.00	38.00
Aloe gel + INS 401 (2%, 1 min)	TLTC	50.00	52.00
Aloe gel + INS 401 (2%, 2 min)	TLTC	38.50	37.50
Aloe gel + INS 401 (2%, 5 min)	TLTC	48.00	51.00
Aloe gel + INS 402 (1%, 1 min)	TLTC	33.50	36.00
Aloe gel + INS 402 (1%, 2 min)	TLTC	48.00	51.00
Aloe gel + INS 402 (1%, 5 min)	TLTC	35.00	37.50
Aloe gel + INS 402 (2%, 1 min)	TLTC	35.00	52.00
Aloe gel + INS 402 (2%, 2 min)	TLTC	35.50	39.50
Aloe gel + INS 402 (2%, 5 min)	TLTC	36.50	53.00
CD (0.05)		**NS**	**NS**
Control (Untreated)	TNTC	TNTC	TNTC

*TLTC – Too Less To Count

*TNTC – Too Numerous To Count

4.2.2.4.1. Appearance

Effect of different aloe gel based edible film coatings on the appearance of firm ripe tomatoes was judged by sensory panel at 12 days interval and shown in Table 33.

Initially all the treatments had almost similar mean scores with 8.00 to 8.13. Firm ripe fruits dipped in 1% (aloe gel + INS 402) for one minute and 2% (aloe gel + INS 402) for five minutes recorded highest mean sensory score for appearance on the 12th day (7.67). On 24th day of storage firm ripe fruits dipped in 1% (aloe gel + INS 402) for one and five minutes recorded highest mean score of 7.53for appearance.

4.2.2.4.2. Colour

Effect of different aloe gel based edible film coatings on the colour of firm ripe tomato was judged by sensory panel at 12 days interval and is shown in Table 34.

Initially all the treatments had almost similar mean scores ranging from 8.20 to 8.27. On 12th day of storage, firm ripe fruits dipped in 1% (aloe gel + INS 402) for one and two minutes recorded the highest sensory score of 7.60 for colour. On 24th day of storage fruits dipped in 1% (aloe gel + INS 402) for one and five minutes scored highest (7.47) for colour.

4.2.2.4.3. Flavour

Effect of different aloe gel based edible film coatings on the flavour of firm ripe tomatoes was judged by the sensory panel at 12 days interval and is shown in Table 35.

Initially all the treatments had mean scores ranging from 8.07 to 8.13. On 12th and 24th day of storage firm ripe fruits dipped in 1% (aloe gel + INS 402) for one and five minutes and 2% (aloe gel + INS 402) for two minutes recorded the highest mean scores (7.67 and 7.53 respectively) for flavour .

4.2.2.4.4. Taste

Effect of different aloe gel based edible film coatings on the taste of firm ripe tomato as judged by sensory panel at 12 days interval is shown in Table 36.

Initially all the treatments had almost similar mean scores from 8.00 to 8.07. On 12th day of storage firm ripe fruits dipped in 1% (aloe gel + INS 402) for one and five minutes and 2% (aloe gel +INS 402) for five minutes recorded the highest mean score for taste (7.67). On 24th day of storage firm ripe fruits dipped in 1% (aloe gel + INS 402) for one minute recorded the highest sensory score for taste (7.53).

4.2.2.4.5. Texture

Effect of different aloe gel based edible film coatings on the texture of firm ripe tomato was judged by sensory panel at 12 days interval and shown in Table 37.

Initially all the treatments had almost similar mean scores from 8.07 to 8.13. On 12th day of storage firm ripe fruits dipped in 1% (aloe gel + INS 402) for one and five minutes recorded the highest score for texture (7.64). On 24th day of storage firm ripe fruits dipped in 1% (aloe gel + INS 402) for one minute recorded the highest sensory score for texture with mean value of 7.60.

4.2.2.4.6. Overall acceptability

Effect of different aloe gel based edible film coatings on the overall acceptability of firm ripe tomato as judged by sensory panel at 12 days interval is shown in Table 38. Initially all the treatments had almost similar mean scores ranging from 8.07 to 8.13.

On 12th and 24thday of storage, firm ripe fruits dipped in 1% (aloe gel + INS 402) for one minute recorded the highest mean sensory score for overall acceptability (7.87 and 7.80 respectively). On the 24th day of storage least score was for the fruits dipped in 1% and 2% (aloe gel +INS 401) for five and one minutes respectively with mean value of 7.53.

Considering the efficiency in maintaining the physiological quality parameters and higher scores for the physical parameters analyzed, 1% (aloe gel +INS 402) dipped for one minute was selected as the best aloe gel based edible film coating formulation for extending the shelf life of firm ripe tomatoes for 24 days and it was selected for the further study of the experiment.

Table 33. Effect of aloe gel coating on the appearance of firm ripe tomatoes

Treatments	Appearance		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	8.13	7.47	7.27
Aloe gel + INS 401 (1%, 2 min)	8.13	7.27	7.13
Aloe gel + INS 401 (1%, 5 min)	8.13	7.40	7.13
Aloe gel + INS 401 (2%, 1 min)	8.10	7.33	7.07
Aloe gel + INS 401 (2%, 2 min)	8.10	7.47	7.33
Aloe gel + INS 401 (2%, 5 min)	8.13	7.47	7.20
Aloe gel + INS 402 (1%, 1 min)	8.13	7.67	7.53
Aloe gel + INS 402 (1%, 2 min)	8.10	7.53	7.47
Aloe gel + INS 402 (1%, 5 min)	8.13	7.53	7.53
Aloe gel + INS 402 (2%, 1 min)	8.13	7.60	7.40
Aloe gel + INS 402 (2%, 2 min)	8.13	7.53	7.47
Aloe gel + INS 402 (2%, 5 min)	8.13	7.67	7.40
Control (Untreated)	8.13	7.20	-
χ^2 value	7.19	13.41	5.57
KW value	**NS**		**NS**

Table 34. Effect of aloe gel coating on the colour of firm ripe tomatoes

Treatments	Colour		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	8.27	7.23	7.27
Aloe gel + INS 401 (1%, 2 min)	8.27	7.20	7.20
Aloe gel + INS 401 (1%, 5 min)	8.27	7.47	7.33
Aloe gel + INS 401 (2%, 1 min)	8.20	7.40	7.27
Aloe gel + INS 401 (2%, 2 min)	8.27	7.40	7.33
Aloe gel + INS 401 (2%, 5 min)	8.27	7.40	7.13
Aloe gel + INS 402 (1%, 1 min)	8.20	7.60	7.47
Aloe gel + INS 402 (1%, 2 min)	8.27	7.60	7.33
Aloe gel + INS 402 (1%, 5 min)	8.27	7.53	7.47
Aloe gel + INS 402 (2%, 1 min)	8.27	7.50	7.33
Aloe gel + INS 402 (2%, 2 min)	8.27	7.53	7.40
Aloe gel + INS 402 (2%, 5 min)	8.27	7.53	7.40
Control (Untreated)	8.20	7.07	-
χ^2 value	5.46	17.03	14.36
KW value	**NS**		**NS**

Table 35. Effect of aloe gel coating on the flavour of firm ripe tomatoes

Treatments	Flavour		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.44	7.42
Aloe gel + INS 401 (1%, 2 min)	8.07	7.48	7.45
Aloe gel + INS 401 (1%, 5 min)	8.07	7.50	7.46
Aloe gel + INS 401 (2%, 1 min)	8.13	7.53	7.40
Aloe gel + INS 401 (2%, 2 min)	8.07	7.33	7.30
Aloe gel + INS 401 (2%, 5 min)	8.07	7.33	7.30
Aloe gel + INS 402 (1%, 1 min)	8.07	7.67	7.53
Aloe gel + INS 402 (1%, 2 min)	8.13	7.60	7.50
Aloe gel + INS 402 (1%, 5 min)	8.07	7.67	7.53
Aloe gel + INS 402 (2%, 1 min)	8.07	7.60	7.50
Aloe gel + INS 402 (2%, 2 min)	8.13	7.67	7.53
Aloe gel + INS 402 (2%, 5 min)	8.13	7.63	7.50
Control (Untreated)	8.07	7.00	-
χ^2 value	5.32	14.64	11.40
KW value	**NS**		**NS**

Table 36. Effect of aloe gel coating on the taste of firm ripe tomatoes

Treatments	Taste		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.47	7.32
Aloe gel + INS 401 (1%, 2 min)	8.00	7.47	7.33
Aloe gel + INS 401 (1%, 5 min)	8.07	7.48	7.43
Aloe gel + INS 401 (2%, 1 min)	8.07	7.50	7.33
Aloe gel + INS 401 (2%, 2 min)	8.00	7.49	7.34
Aloe gel + INS 401 (2%, 5 min)	8.00	7.50	7.47
Aloe gel + INS 402 (1%, 1 min)	8.07	7.67	7.53
Aloe gel + INS 402 (1%, 2 min)	8.07	7.57	7.50
Aloe gel + INS 402 (1%, 5 min)	8.07	7.67	7.54
Aloe gel + INS 402 (2%, 1 min)	8.07	7.53	7.50
Aloe gel + INS 402 (2%, 2 min)	8.00	7.53	7.50
Aloe gel + INS 402 (2%, 5 min)	8.00	7.67	7.52
Control (Untreated)	8.00	7.40	-
χ^2 value	6.08	18.08	14.28
KW value	**NS**		**NS**

Table 37. Effect of aloe gel coating on the texture of firm ripe tomatoes

Treatments	Texture		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.55	7.53
Aloe gel + INS 401 (1%, 2 min)	8.13	7.34	7.32
Aloe gel + INS 401 (1%, 5 min)	8.07	7.34	7.29
Aloe gel + INS 401 (2%, 1 min)	8.13	7.53	7.47
Aloe gel + INS 401 (2%, 2 min)	8.07	7.57	7.54
Aloe gel + INS 401 (2%, 5 min)	8.07	7.53	7.50
Aloe gel + INS 402 (1%, 1 min)	8.07	7.64	7.60
Aloe gel + INS 402 (1%, 2 min)	8.07	7.63	7.57
Aloe gel + INS 402 (1%, 5 min)	8.13	7.64	7.57
Aloe gel + INS 402 (2%, 1 min)	8.07	7.57	7.55
Aloe gel + INS 402 (2%, 2 min)	8.13	7.60	7.56
Aloe gel + INS 402 (2%, 5 min)	8.13	7.61	7.56
Control (Untreated)	8.07	7.00	-
χ^2 value	3.66	6.30	10.43
KW value	**NS**		**NS**

Table 38. Effect of aloe gel coating on the overall acceptability of firm ripe tomatoes

Treatments	Overall acceptability		
	0th day	12th day	24th day
Aloe gel + INS 401 (1%, 1 min)	8.07	7.67	7.60
Aloe gel + INS 401 (1%, 2 min)	8.13	7.67	7.63
Aloe gel + INS 401 (1%, 5 min)	8.07	7.73	7.53
Aloe gel + INS 401 (2%, 1 min)	8.13	7.60	7.53
Aloe gel + INS 401 (2%, 2 min)	8.13	7.71	7.60
Aloe gel + INS 401 (2%, 5 min)	8.07	7.73	7.69
Aloe gel + INS 402 (1%, 1 min)	8.13	7.87	7.80
Aloe gel + INS 402 (1%, 2 min)	8.07	7.70	7.67
Aloe gel + INS 402 (1%, 5 min)	8.13	7.77	7.74
Aloe gel + INS 402 (2%, 1 min)	8.13	7.73	7.69
Aloe gel + INS 402 (2%, 2 min)	8.13	7.73	7.70
Aloe gel + INS 402 (2%, 5 min)	8.13	7.74	7.70
Control (Untreated)	8.07	7.34	-
χ^2 value	8.47	8.34	13.54
KW value	**NS**		**NS**

4.2.5. Cost of production

Cost of preparation of the selected aloe based formulation viz., aloe gel+ INS 402 from 1kg Aloe vera leaves was Rs.47.16/-for mature green tomatoes and it was Rs.48.66/- for firm ripe tomatoes. Cost of dipping 100 kg mature green tomatoes with the selected aloe based formulation was calculated to be Rs55.48/- and it was Rs.28.62/- for 100 Kg firm ripe tomatoes (Table. 39).

Table 39. Cost of production of pure aloe based extracts

Standardized Formulation		**Mature green**	**Firm ripe**
		Aloe gel + INS 402	
Concentration of formulation		2%	1%
Item	*Quantity*	*Cost (Rs)*	*Cost (Rs)*
Aloe vera	1 kg	40.00	40.00
INS 402	1g	0.66	0.66
Citric acid	0.5g	0. 50	0. 50
Ascorbic acid	1g	1.00	1.00
Labour cost	-	5.00	6.50
Qty of formulation that can be prepared		42.5litre	85litre
Total cost for preparation of formulation		47.16	48.66
Quantity of fruits that can be treated		85 kg	170kg
Cost for treating 100 kg fruit		Rs.55.48/-	Rs.28.62/-

4.3. EVALUATION OF PLANT LEAF EXTRACT INCORPORATED ALOE GEL (PLEAG) FOR EXTENSION OF SHELF LIFE.

Based on the superiority in maintaining the quality parameters, the following treatments were selected as aloe gel based edible film coating for extending shelf life of tomato fruits of two maturity stages.

Maturity Stage	Selected aloe gel based treatment
Mature Green Tomato	Dipping in 2% (aloe gel + INS 402) for two minutes
Firm Ripe Tomato	Dipping in 1% (aloe gel + INS 402) for one minute

Tomato fruits were coated with the plant leaf extract incorporated aloe gel (PLEAG) and physiological, chemical, microbial and physical quality parameters of PLEAG treated fruits were compared with that of fruits coated with the aloe gel based film selected from 3.2 of the experiment. For mature green tomato, fruits coated with 2% (aloe gel + INS 402) for two minutes were used as the control and fruits treated with 1% (aloe gel INS 402) for one minute was used as control in case of red ripe tomatoes.

4.3.1. MATURE GREEN TOMATO

Physiological, chemical, microbial and physical quality parameters of mature green tomatoes treated with plant leaf extract incorporated aloe gel at different concentrations and durations were recorded at 12 days interval under ambient storage till they had lost their shelf life and are shown below. Fruits coated with aloe gel + INS 402 were used as the control. All the formulations were prepared in 2% concentration and fruits were dipped for two minutes.

4.3.1.1 Physiological parameters

Effects of different plant leaf extract incorporated aloe gels (PLEAG) on physiological parameters of mature green tomatoes were recorded at 12 days interval till they had lost their shelf life.

4.3.1.1.1. Physiological Loss in Weight (PLW)

Effect of plant leaf extract incorporated aloe gel (PLEAG) coating on the physiological loss in weight (PLW) of mature green tomatoes under ambient storage condition is shown in Table 40.

There was no significant difference between PLW of fruits dipped in PLEAG and aloe based formulations on 12th day of storage.

On 24th and 36th day of storage, PLW was least (1.04%, 1.18% respectively) for mature green tomato fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402. This treatment was on par with fruits coated with papaya leaf extract incorporated aloe gel (1:1) + INS 402 (1.12% and 1.23% respectively) and pure aloe gel + INS 402 (1.12% and 1.33% respectively). The highest weight losses (1.57% and 2.09%) were recorded by the fruits dipped in ocimum leaf extract incorporated aloe gel (1:2) + INS 402.

4.3.1.1.2. Respiration rate

Effect of plant leaf extract incorporated aloe gel (PLEAG) coating on the respiration rate of mature green tomatoes under ambient storage condition is shown in Table 41.

There was no significant difference between the respiration rates of fruits treated with PLEAG and aloe gel during the entire storage period.

4.3.1.1.3. Membrane integrity

The effect of PLEAG coating on the membrane integrity of mature green tomatoes during storage is shown in Table 42.

There was no significant difference between the membrane integrity of PLEAG and pure aloe gel treated mature green tomato fruits on the initial day of storage.

Mature green tomato fruits dipped in papaya leaf extract incorporated aloe gel + INS 402 (1:2) recorded the least (43.66%) percent leakage, which was on par with the fruits dipped in papaya leaf extract incorporated aloe gel (1:1) + INS 402 (44.14%) and aloe gel + INS 402 for two minutes (45.09%) on 12th day of storage. Highest (49.71%) percent leakage was for the fruits dipped in guava leaf incorporated

Table 40. Effect of PLEAG coating on the physiological loss in weight of mature green tomatoes

Treatments @ 2% for 2 minutes	Physiological loss in weight (%)		
	12[th] day	24[th] day	36[th] day
Aloe gel + papaya leaf (1:1) + INS 402	2.01	1.12	1.23
Aloe gel + guava leaf (1:1) + INS 402	2.54	1.38	1.88
Aloe gel + ocimum leaf (1:1) + INS 402	2.01	1.54	1.91
Aloe gel + papaya leaf (1:2) + INS 402	1.88	1.04	1.18
Aloe gel + guava leaf(1:2) + INS 402	2.10	1.50	1.72
Aloe gel + ocimum leaf (1:2) + INS 402	2.11	1.57	2.09
Aloe gel + INS 402	1.99	1.12	1.33
CD (0.05)	NS	0.18	0.38

Table 41. Effect of PLEAG on the respiration rate of mature green tomatoes

Treatments @ 2% for 2 minutes	Respiration Rate (% CO_2 evolved)			
	0[th] day	12[th] day	24[th] day	36[th] day
Aloe gel + papaya leaf (1:1) + INS 402	6.13	7.20	5.93	5.03
Aloe gel + guava leaf (1:1) + INS 402	6.14	7.53	6.56	6.10
Aloe gel + ocimum leaf (1:1) + INS 402	6.21	7.46	6.50	5.87
Aloe gel + papaya leaf (1:2) + INS 402	6.10	6.56	5.70	5.37
Aloe gel + guava leaf(1:2) + INS 402	6.16	8.07	6.17	5.43
Aloe gel + ocimum leaf (1:2) + INS 402	6.18	7.60	6.43	5.33
Aloe gel + INS 402	6.13	7.23	5.90	5.70
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Table 42. Effect of PLEAG coating on the percent leakage of mature green tomatoes

Treatments @ 2% for 2 minutes	Percent Leakage (%)			
	0[th] day	12[th] day	24[th] day	36[th] day
Aloe gel + papaya leaf (1:1) + INS 402	42.06	44.14	55.40	56.93
Aloe gel + guava leaf (1:1) + INS 402	42.17	49.71	56.80	63.33
Aloe gel + ocimum leaf (1:1) + INS 402	42.78	46.56	56.96	60.30
Aloe gel + papaya leaf (1:2) + INS 402	41.29	43.66	54.96	55.93
Aloe gel + guava leaf(1:2) + INS 402	41.67	49.07	55.46	58.47
Aloe gel + ocimum leaf (1:2) + INS 402	42.61	46.78	56.09	60.58
Aloe gel + INS 402	42.50	45.09	55.75	57.06
CD (0.05)	**NS**	**2.08**	**NS**	**3.64**

aloe gel (1:1) +INS 402, which was on par with fruits dipped in guava leaf incorporated aloe gel (1:2) +INS 402 (49.07%).There was no significant difference between the percent leakages of tomato fruits on 24th day of storage.

On 36th day of storage, the least (55.93%) percent leakage was for the fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 and this was on par with the fruits dipped in papaya leaf extract incorporated aloe gel (1:1) +INS 402 (56.93%), aloe gel + INS 402 (57.06) and guava leaf extract incorporated aloe gel (1:2) + INS 402 (58.47%). Highest percent leakage (63.33%) was for the fruits dipped in guava leaf incorporated aloe gel (1:1) + INS 402 which was on par with fruits treated with ocimum leaf incorporated aloe gel in (1:1) (60.30%) and (1:2) ratio (60.58%).

4.3.1.2. Chemical parameters

Effects of plant leaf extract incorporated aloe gel (PLEAG) coatings on chemical quality parameters of mature green tomatoes were recorded during storage till they had lost shelf life and are shown below.

4.3.1.2.1. Total Soluble Solids

The effect of PLEAG coatings on the total soluble solids of mature green tomatoes is shown in Table 43.

Total soluble solids (TSS) remained similar for all the PLEAG treated and pure aloe gel treated fruits during the entire storage period of 36 days.

4.3.1.2.2. pH

Effect of plant leaf extract incorporated aloe gel (PLEAG) coating on the pH of mature green tomatoes under ambient storage condition is shown in Table 44.

No significant difference was observed between the pH of PLEAG treated and aloe gel treated mature green tomatoes for the entire period of storage.

4.3.1.2.3. Vitamin C content

The effect of PLEAG coatings on the vitamin C content of mature green tomatoes is shown in Table 45. There was no significant difference recorded in the vitamin C content of PLEAG and aloe gel treated mature green tomatoes during the entre storage period of 36 days.

Table 43. Effect of PLEAG coating on the TSS of mature green tomatoes

Treatments @ 2% for 2 minutes	Total Soluble Solids (TSS) (^{0}B)			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	4.40	4.50	4.80	4.93
Aloe gel + guava leaf (1:1) + INS 402	4.43	4.46	4.60	4.83
Aloe gel + ocimum leaf (1:1) + INS 402	4.40	4.56	4.73	4.83
Aloe gel + papaya leaf (1:2) + INS 402	4.26	4.53	4.73	4.90
Aloe gel + guava leaf (1:2) + INS 402	4.26	4.46	4.70	4.83
Aloe gel + ocimum leaf (1:2) + INS 402	4.36	4.46	4.63	4.80
Aloe gel + INS 402	4.33	4.46	4.73	5.00
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Table 44. Effect of PLEAG coating on the pH of mature green tomatoes

Treatments @ 2% for 2 minutes	pH			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	4.33	4.56	4.80	5.20
Aloe gel + guava leaf (1:1) + INS 402	4.50	4.77	4.80	5.00
Aloe gel + ocimum leaf (1:1) + INS 402	4.43	4.77	4.70	5.06
Aloe gel + papaya leaf (1:2) + INS 402	4.26	4.60	4.70	4.96
Aloe gel + guava leaf(1:2) + INS 402	4.33	4.83	4.93	5.06
Aloe gel + ocimum leaf (1:2) + INS 402	4.36	4.73	4.73	5.40
Aloe gel + INS 402	4.26	4.60	4.63	5.00
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Table 45.Effect of PLEAG coating on the vitamin C content of mature green tomatoes

Treatments @ 2% for 2 minutes	vitamin C content (mg $100g^{-1}$)			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	13.54	13.54	13.54	11.46
Aloe gel + guava leaf (1:1) + INS 402	13.54	12.50	12.50	9.38
Aloe gel + ocimum leaf (1:1) + INS 402	13.54	12.50	12.50	9.38
Aloe gel + papaya leaf (1:2) + INS 402	13.54	13.54	13.54	11.46
Aloe gel + guava leaf(1:2) + INS 402	13.54	13.54	12.50	10.42
Aloe gel + ocimum leaf (1:2) + INS 402	13.54	13.54	12.50	9.38
Aloe gel + INS 402	14.58	12.50	13.54	11.46
CD (0.05)	NS	NS	NS	NS

4.3.1.2.4. Titratable acidity

The effect of plant leaf extract incorporated aloe gel coating on the titratable acidity of mature green tomatoes is shown in Table 46.

No significant difference was noticed in the titratable acidity of both PLEAG and aloe gel treated mature green tomatoes during storage period.

4.3.1.2.5. Lycopene content

The effect of plant leaf extract incorporated aloe gel coating on the lycopene content of mature green tomatoes is shown in Table 47.

On the initial day, no significant difference was observed between the lycopene content of mature green tomatoes treated with PLEAG and pure aloe gel.

On 12thday of storage the least lycopene content (0.86μgg^{-1})was recorded by the fruits dipped in aloe gel + INS 402 which was on par with all other treated fruits except fruits treated with aloe + guava leaf (1:1) +INS 402 (0.93μgg^{-1}) and aloe gel +ocimum leaf (1:1) + INS 402 (0.91μgg^{-1}).

There was no significant difference between the lycopene content of fruits dipped in PLEAG and pure aloe gel on the 24th and 36th day of storage.

4.3.1.4. Microbial parameters

Effect of plant leaf extract incorporated aloe gel coating on bacterial count recorded on the surface of the coated mature green tomato fruits is shown in Table 48. No significant difference was noticed between the bacterial population seen on the mature green tomato fruits coated with PLEAG and pure aloe gel coatings.

Table 46.Effect of PLEAG coating on the titratable acidity of mature green tomatoes

Treatments @ 2% for 2 minutes	Titratable Acidity (%)			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	0.597	0.597	0.666	0.683
Aloe gel + guava leaf (1:1) + INS 402	0.546	0.580	0.649	0.648
Aloe gel + ocimum leaf (1:1) + INS 402	0.580	0.597	0.631	0.597
Aloe gel + papaya leaf (1:2) + INS 402	0.597	0.631	0.680	0.717
Aloe gel + guava leaf(1:2) + INS 402	0.546	0.597	0.614	0.643
Aloe gel + ocimum leaf (1:2) + INS 402	0.546	0.580	0.614	0.631
Aloe gel + INS 402	0.597	0.597	0.656	0.683
CD (0.05)	NS	NS	NS	NS

Table 47.Effect of PLEAG coating on the lycopene content of mature green tomatoes

Treatments @ 2% for 2 minutes	Lycopene content ($\mu g g^{-1}$)			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	0.66	0.87	27.28	41.22
Aloe gel + guava leaf (1:1) + INS 402	0.67	0.93	29.22	41.39
Aloe gel + ocimum leaf (1:1) + INS 402	0.66	0.91	28.38	43.22
Aloe gel + papaya leaf (1:2) + INS 402	0.67	0.87	27.22	41.12
Aloe gel + guava leaf(1:2) + INS 402	0.66	0.88	29.10	44.64
Aloe gel + ocimum leaf (1:2) + INS 402	0.67	0.88	28.44	45.66
Aloe gel + INS 402	0.66	0.86	27.45	41.39
CD (0.05)	NS	0.04	NS	NS

Table 48. Effect of PLEAG coating on the microbial load of mature green tomatoes

Treatments @ 2% for 2 minutes	Bacterial count x 10^2cfu/g	
	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	4.66	6.80
Aloe gel + guava leaf (1:1) + INS 402	4.63	6.60
Aloe gel + ocimum leaf (1:1) + INS 402	4.63	6.66
Aloe gel + papaya leaf (1:2) + INS 402	4.56	6.43
Aloe gel + guava leaf(1:2) + INS 402	4.63	6.73
Aloe gel + ocimum leaf (1:2) + INS 402	4.60	6.70
Aloe gel + INS 402	4.56	6.63
CD (0.05)	NS	NS

4.3.1.4. Physical parameters.

Effect of different plant leaf extract incorporated aloe gel (PLEAG) coatings on physical quality parameters of mature green tomatoes was judged by the sensory panel at 12 days interval and is shown in Table 49 to 54.

As there was no significant difference between the treatment means of different physical parameters analyzed, the coated fruit with the highest mean sensory score was considered as the best treatment for increasing the efficiency in extension of shelf life in tomato.

4.3.1.4.1. Appearance

Effect of plant leaf extract incorporated aloe gel coatings on the appearance of mature green tomatoes under ambient storage condition is shown in Table 49.

Initially all the fruits had mean score values ranging from 8.00 to 8.07. On 12th, 24th and 36th day of storage mature green tomato fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory scores for appearance (8.00, 7.78 and 7.53 respectively).

4.3.1.4.2. Colour

Effect of plant leaf extract incorporated aloe gel coatings on the colour of mature green tomatoes under ambient storage condition is shown in Table 50.

Initially all the fruits had uniform mean score value of 8.00. Mature green tomato fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory scores for colour (7.93, 7.87 and 7.67) on 12th, 24th and 36th day of storage respectively.

4.3.1.4.3. Flavour

Effect of plant leaf extract incorporated aloe gel coatings on the flavour of mature green tomatoes under ambient storage condition is shown in Table 51.

Initially the fruits had mean score values ranging from 8.07 to 8.29. On 12th day of storage, mature green fruits dipped in papaya leaf incorporated aloe gel in 1:1 ratio and fruits dipped in aloe gel +INS 402 recorded highest mean sensory score for flavour (8.07).

Table 49. Effect of PLEAG coating on the appearance of mature green tomatoes

Treatments @ 2% for 2 minutes	Appearance			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	8.07	7.60	7.46	7.27
Aloe gel + guava leaf (1:1) + INS 402	8.00	7.57	7.40	7.13
Aloe gel + ocimum leaf (1:1) + INS 402	8.00	7.53	7.28	7.00
Aloe gel + papaya leaf (1:2) + INS 402	8.07	8.00	7.78	7.53
Aloe gel + guava leaf(1:2) + INS 402	8.00	7.50	7.28	7.07
Aloe gel + ocimum leaf (1:2) + INS 402	8.07	7.50	7.21	7.00
Aloe gel + INS 402	8.07	7.64	7.43	7.20
χ^2 (0.05)	1.445	6.037	6.617	9.051
KW value	NS			

Table 50. Effect of PLEAG coating on the colour of mature green tomatoes

Treatments @ 2% for 2 minutes	Colour			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	8.00	7.93	7.67	7.63
Aloe gel + guava leaf (1:1) + INS 402	8.00	7.80	7.67	7.53
Aloe gel + ocimum leaf (1:1) + INS 402	8.00	7.64	7.43	7.40
Aloe gel + papaya leaf (1:2) + INS 402	8.00	7.93	7.87	7.67
Aloe gel + guava leaf(1:2) + INS 402	8.00	7.80	7.71	7.60
Aloe gel + ocimum leaf (1:2) + INS 402	8.00	7.79	7.50	7.33
Aloe gel + INS 402	8.00	7.82	7.79	7.64
χ^2 (0.05)	8.21	5.18	7.38	5.74
KW value	NS			

Table 51. Effect of PLEAG coating on the flavour of mature green tomatoes

Treatments @ 2% for 2 minutes	Flavour			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	8.29	8.07	7.93	7.80
Aloe gel + guava leaf (1:1) + INS 402	8.07	7.87	8.00	7.60
Aloe gel + ocimum leaf (1:1) + INS 402	8.07	7.86	7.71	7.60
Aloe gel + papaya leaf (1:2) + INS 402	8.29	8.00	8.13	8.00
Aloe gel + guava leaf(1:2) + INS 402	8.07	7.78	8.00	7.80
Aloe gel + ocimum leaf (1:2) + INS 402	8.07	7.76	7.79	7.56
Aloe gel + INS 402	8.29	8.07	7.89	8.00
χ^2 (0.05)	7.041	7.549	7.567	4.404
KW value	NS			

On 24th and 36th day of storage mature green tomato fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean scores for flavour (8.13 and 8.00 respectively).

4.3.1.4.4. Taste

Effect of plant leaf extract incorporated aloe gel coatings on the taste of mature green tomatoes under ambient storage condition is shown in Table 52. Initially the fruits had mean score values ranging from 8.07 to 8.14.

On 12th and 24th day of storage mature green fruits dipped in papaya leaf incorporated aloe gel in 1:1 ratio + INS 402 recorded highest mean scores for taste (8.07and 7.87).

On 36th day of storage, highest mean sensory score (7.65) was recorded by mature green tomato fruits dipped in papaya leaf incorporated aloe gel in 1:2 + INS 402.

4.3.1.4.5. Texture

Effect of plant leaf extract incorporated aloe gel coatings on the texture of mature green tomatoes under ambient storage condition is shown in Table 53.

Initially all the fruits had mean score values ranging from 8.00 to 8.07. On 12th, 24th and 36th day of storage mature green tomato fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory scores for texture (7.93, 7.79 and 7.67 respectively).

4.3.1.4.6. Overall acceptability

Effect of plant leaf extract incorporated aloe gel coatings on the overall acceptability of mature green tomatoes under ambient storage condition is shown in Table 54.

Initially all the fruits had almost similar mean score values ranging from 8.14 to 8.21. On 12th day of storage mature green fruits dipped in papaya leaf incorporated aloe gel in 1:1 ratio+ INS 402 and (aloe gel + INS 402) recorded highest mean sensory score for overall acceptability (8.07).

Table 52. Effect of PLEAG coating on the taste of mature green tomatoes

Treatments @ 2% for 2 minutes	Taste			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	8.14	8.07	7.87	7.60
Aloe gel + guava leaf (1:1) + INS 402	8.14	7.86	7.65	7.46
Aloe gel + ocimum leaf (1:1) + INS 402	8.07	7.86	7.57	7.33
Aloe gel + papaya leaf (1:2) + INS 402	8.14	8.00	7.71	7.65
Aloe gel + guava leaf (1:2) + INS 402	8.07	7.93	7.57	7.43
Aloe gel + ocimum leaf (1:2) + INS 402	8.07	7.56	7.36	7.30
Aloe gel + INS 402	8.14	7.93	7.71	7.67
χ^2 (0.05)	4.41	6.99	6.68	7.36
KW value	NS			

Table 52. Effect of PLEAG coating on the texture of mature green tomatoes

Treatments @ 2% for 2 minutes	Texture			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	8.07	7.93	7.93	7.60
Aloe gel + guava leaf (1:1) + INS 402	8.07	7.53	7.53	7.47
Aloe gel + ocimum leaf (1:1) + INS 402	8.00	7.57	7.57	7.33
Aloe gel + papaya leaf (1:2) + INS 402	8.07	7.93	7.93	7.67
Aloe gel + guava leaf(1:2) + INS 402	8.07	7.71	7.71	7.33
Aloe gel + ocimum leaf (1:2) + INS 402	8.00	7.57	7.57	7.13
Aloe gel + INS 402	8.07	7.86	7.86	7.58
χ^2 (0.05)	8.34	5.19	5.38	7.34
KW value	NS			

Table 54. Effect of PLEAG coating on the overall acceptability of mature green tomatoes

Treatments @ 2% for 2 minutes	Overall acceptability			
	0th day	12th day	24th day	36th day
Aloe gel + papaya leaf (1:1) + INS 402	8.21	7.93	7.76	7.60
Aloe gel + guava leaf (1:1) + INS 402	8.21	7.71	7.69	7.33
Aloe gel + ocimum leaf (1:1) + INS 402	8.14	7.67	7.57	7.23
Aloe gel + papaya leaf (1:2) + INS 402	8.21	8.07	7.80	7.67
Aloe gel + guava leaf (1:2) + INS 402	8.14	7.86	7.64	7.33
Aloe gel + ocimum leaf (1:2) + INS 402	8.14	7.71	7.29	7.13
Aloe gel + INS 402	8.21	8.07	7.79	7.60
χ^2 (0.05)	1.89	4.34	5.09	7.41
KW value	NS			

On 24th and 36th day of storage, highest mean sensory scores for overall acceptability were recorded by mature green fruits dipped in papaya leaf incorporated aloe gel in 1:2 ratio + INS 402(7.80 and 7.67 respectively).

4.3.2. FIRM RIPE TOMATO

Physiological, chemical, microbial and physical quality parameters of firm ripe tomatoes treated with plant leaf extract incorporated aloe gel (PLEAG) at different concentrations and durations were recorded at 12 days interval under ambient storage till they had lost their shelf life and are shown below. Fruits treated with 1% aloe gel INS 402 was used as control. All the formulations were prepared at 1% concentration and fruits were dipped in the formulations for one minute.

4.3.2.1. Physiological parameters

Effect of different plant leaf extract incorporated aloe gel (PLEAG) coatings on physiological parameters of firm ripe tomato was recorded at 12 days interval till it had lost its shelf life and is shown below.

4.3.2.1.1. Physiological Loss in Weight (PLW)

Effect of plant leaf extract incorporated aloe gel (PLEAG) coating on the physiological loss in weight (PLW) of firm ripe tomatoes under ambient storage condition is shown in Table 55.

There was no significant difference between the PLW of tomato fruits coated with PLEAG +INS 402 and aloe gel +INS 402 both at 1% concentration for one minute duration on 12th day of storage.

On 24th day of storage, physiological loss in weight was least (1.29%) for firm ripe tomato fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402. This treatment was on par with all the other treatments except ocimum leaf incorporated aloe gel (1:2) + INS 402.

4.3.2.1.2. Respiration rate

The effect of respiration rate in terms of CO_2 evolved is shown in Table 56. There was no significant difference between the percentage of CO_2 evolved by firm ripe tomato fruits coated with (PLEAG + INS 402) and (aloe gel +INS 402) during the entire storage period.

4.3.2.1.3. Membrane integrity

The effect of PLEAG coatings on the membrane integrity of firm ripe tomato is shown in Table 57. There was no significant difference between the membrane integrity of PLEAG and pure aloe gel treated firm ripe tomato fruits on the initial day. Firm ripe tomato fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 recorded the least (62.88%) percent leakage on 12^{th} day of storage. Highest percent leakage (65.23%) was recorded by fruits dipped in ocimum leaf incorporated aloe gel (1:2) + INS 402.

On 24^{th} day of storage the least percent leakage (68.84%) was for the fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 which was on par with the fruits dipped in aloe gel + INS 402 (69.53%). Highest percent leakage (71.79%) was observed in firm ripe fruits dipped in guava leaf incorporated aloe gel (1:2) + INS 402.

4.3.2.2. Chemical parameters

Effect of plant leaf extract incorporated aloe gel (PLEAG) coating on chemical quality parameters of firm ripe tomatoes was recorded at 12 days interval till it had lost its shelf life and is shown below.

4.3.2.2.1. Total Soluble Solids

The effect of PLEAG coating on the total soluble solids of firm ripe tomato is shown in Table 58. Total soluble solids (TSS) remained similar for all the PLEAG and aloe gel treated fruit samples on the initial day.

On 12^{th} day of storage, the highest TSS (4.35^{0}B) was recorded by firm ripe fruits dipped in papaya leaf incorporated aloe gel in 1:1 and 1:2 ratio + INS 402. These treatments were on par with fruits treated with aloe gel + INS 402 (4.30^{0}B) and guava leaf incorporated aloe gel (1:1) +INS 402 (4.27^{0}B). Lowest TSS (4.13^{0}B) was recorded by fruits dipped in ocimum leaf incorporated aloe gel (1:1) +INS 402.

Table 55. Effect of PLEAG coating on the PLW of firm ripe tomatoes

Treatments @ 1% for 1 minute	Physiological loss in weight (%)	
	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	1.18	1.32
Aloe gel + guava leaf (1:1) + INS 402	1.81	1.56
Aloe gel + ocimum leaf (1:1) + INS 402	1.39	1.48
Aloe gel + papaya leaf (1:2) + INS 402	1.07	1.29
Aloe gel + guava leaf(1:2) + INS 402	1.19	1.50
Aloe gel + ocimum leaf (1:2) + INS 402	1.90	2.10
Aloe gel + INS 402	1.16	1.38
CD (0.05)	**NS**	**0.51**

Table 56. Effect of PLEAG coating on the respiration rate of firm ripe tomatoes

Treatments @ 1% for 1 minute	Respiration Rate (% CO_2 evolved)		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	6.53	7.37	5.60
Aloe gel + guava leaf (1:1) + INS 402	6.30	8.03	5.63
Aloe gel + ocimum leaf (1:1) + INS 402	6.47	8.03	6.00
Aloe gel + papaya leaf (1:2) + INS 402	6.47	7.20	5.53
Aloe gel + guava leaf(1:2) + INS 402	6.63	8.03	6.53
Aloe gel + ocimum leaf (1:2) + INS 402	6.53	7.87	6.10
Aloe gel + INS 402	6.27	7.47	5.73
CD (0.05)	**NS**	**NS**	**NS**

Table 57. Effect of PLEAG coating on the percent leakage of firm ripe tomatoes

Treatments @ 1% for 1 minute	Percent Leakage (%)		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	51.27	63.88	68.97
Aloe gel + guava leaf (1:1) + INS 402	51.07	65.00	70.58
Aloe gel + ocimum leaf (1:1) + INS 402	52.00	64.82	70.79
Aloe gel + papaya leaf (1:2) + INS 402	52.00	62.88	68.84
Aloe gel + guava leaf(1:2) + INS 402	51.53	65.07	71.79
Aloe gel + ocimum leaf (1:2) + INS 402	52.03	65.23	70.95
Aloe gel + INS 402	52.07	65.00	69.53
CD (0.05)	**NS**	**0.88**	**0.85**

There was no significant difference between the TSS content of firm ripe tomato fruits dipped in PLEAG +INS 402 and aloe gel + INS 402 on the 24^{th} day of storage.

4.3.2.2.2. pH

The effect of PLEAG coating on pH of firm ripe tomato is shown in Table 59. No significant difference was observed between the pH of PLEAG treated and aloe gel treated firm ripe tomato fruits during the entire period of storage.

4.3.2.2.3. Vitamin C content

The effect of PLEAG coatings on vitamin C content of firm ripe tomato is shown in Table 60. There was no significant difference noticed between the vitamin C content of PLEAG and aloe gel treated firm ripe tomatoes during the entire storage period of 24 days.

4.3.2.2.4. Titratable acidity

The effect of plant leaf extract incorporated aloe gel coating on the titratable acidity of firm ripe tomato is shown in Table 61. No significant difference was noticed between the titratable acidity of both PLEAG and aloe gel treated firm ripe tomatoes on the initial day and on 12^{th} and 24^{th} day of storage.

4.3.2.2.5. Lycopene content

The effect of plant leaf extract incorporated aloe gel coating on the lycopene content of firm ripe tomatoes is shown in Table 62. On the initial and 12^{th} day of storage, no significant difference was recorded between the lycopene content of firm ripe tomatoes treated with PLEAG and pure aloe gel based edible films.

On 24^{th} day of storage, the least lycopene content ($58.16 \mu g g^{-1}$) was observed in fruits coated with papaya leaf extract incorporated aloe gel (1:1) +INS 402 which was on par with fruits dipped in papaya leaf incorporated aloe gel (1:2) +INS 402 ($59.12 \mu g g^{-1}$) and aloe gel +INS 402 ($59.44 \mu g g^{-1}$) treated tomato fruits . Highest lycopene content ($62.21 \mu g g^{-1}$) was observed in fruits dipped in ocimum leaf extract incorporated aloe gel (1:2) + INS 402.

Table 58. Effect of PLEAG coating on the TSS of firm ripe tomatoes

Treatments @ 1% for 1 minute	Total Soluble Solids (TSS) (^{0}B)		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	4.55	4.35	4.45
Aloe gel + guava leaf (1:1) + INS 402	4.47	4.27	4.35
Aloe gel + ocimum leaf (1:1) + INS 402	4.55	4.13	4.40
Aloe gel + papaya leaf (1:2) + INS 402	4.55	4.35	4.55
Aloe gel + guava leaf(1:2) + INS 402	4.40	4.20	4.37
Aloe gel + ocimum leaf (1:2) + INS 402	4.55	4.20	4.30
Aloe gel + INS 402	4.45	4.30	4.50
CD (0.05)	**NS**	**0.14**	**NS**

Table 59. Effect of PLEAG coating on the pH of firm ripe tomatoes

Treatments @ 1% for 1 minute	pH		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	5.20	5.20	5.25
Aloe gel + guava leaf (1:1) + INS 402	5.05	5.20	5.45
Aloe gel + ocimum leaf (1:1) + INS 402	5.15	5.20	5.40
Aloe gel + papaya leaf (1:2) + INS 402	5.01	5.20	5.35
Aloe gel + guava leaf(1:2) + INS 402	5.10	5.20	5.45
Aloe gel + ocimum leaf (1:2) + INS 402	5.15	5.20	5.40
Aloe gel + INS 402	5.05	5.30	5.40
CD (0.05)	**NS**	**NS**	**NS**

Table 60. Effect of PLEAG coating on the vitamin C content of firm ripe tomatoes

Treatments @ 1% for 1 minute	vitamin C content (mg 100g^{-1})		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	17.71	17.71	10.92
Aloe gel + guava leaf (1:1) + INS 402	19.79	16.58	11.46
Aloe gel + ocimum leaf (1:1) + INS 402	17.71	17.71	12.50
Aloe gel + papaya leaf (1:2) + INS 402	19.79	18.75	12.38
Aloe gel + guava leaf(1:2) + INS 402	19.79	17.71	11.42
Aloe gel + ocimum leaf (1:2) + INS 402	19.79	16.67	11.46
Aloe gel + INS 402	19.79	17.71	11.46
CD (0.05)	**NS**	**NS**	**NS**

Table 61. Effect of PLEAG coating on the titratable acidity of firm ripe tomatoes

Treatments @ 1% for 1 minute	Titratable Acidity (%)		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	0.60	0.73	0.88
Aloe gel + guava leaf (1:1) + INS 402	0.60	0.68	0.85
Aloe gel + ocimum leaf (1:1) + INS 402	0.56	0.64	0.90
Aloe gel + papaya leaf (1:2) + INS 402	0.60	0.77	0.90
Aloe gel + guava leaf(1:2) + INS 402	0.56	0.73	0.85
Aloe gel + ocimum leaf (1:2) + INS 402	0.60	0.68	0.81
Aloe gel + INS 402	0.56	0.73	0.85
CD (0.05)	**NS**	**NS**	**NS**

Table 62. Effect of PLEAG coating on the lycopene content of firm ripe tomatoes

Treatments @ 1% for 1 minute	Lycopene content ($\mu g g^{-1}$)		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	39.37	53.99	58.16
Aloe gel + guava leaf (1:1) + INS 402	38.83	53.71	59.94
Aloe gel + ocimum leaf (1:1) + INS 402	38.33	53.51	60.40
Aloe gel + papaya leaf (1:2) + INS 402	38.88	52.72	59.12
Aloe gel + guava leaf(1:2) + INS 402	38.36	54.13	60.16
Aloe gel + ocimum leaf (1:2) + INS 402	38.83	56.27	62.21
Aloe gel + INS 402	38.33	53.63	59.44
CD (0.05)	**NS**	**NS**	**1.61**

Table 63. Effect of PLEAG coating on the microbial load of firm ripe tomatoes

Treatments @ 1% for 1 minute	Bacterial count x 10^2 cfu/g	
	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	3.50	5.56
Aloe gel + guava leaf (1:1) + INS 402	3.75	5.50
Aloe gel + ocimum leaf (1:1) + INS 402	3.26	5.70
Aloe gel + papaya leaf (1:2) + INS 402	3.56	5.60
Aloe gel + guava leaf(1:2) + INS 402	3.50	5.56
Aloe gel + ocimum leaf (1:2) + INS 402	3.50	5.46
Aloe gel + INS 402	3.80	5.60
CD (0.05)	**NS**	**NS**

4.3.2.3. Microbial parameters

Effect of plant leaf extract incorporated aloe gel coating on the bacterial count observed on the surface of the coated firm ripe tomato fruits is shown in Table 63. No significant difference was noticed in the bacterial population on the surface of firm ripe tomato fruits with PLEAG and pure aloe gel based coatings.

4.3.2.4. Physical parameters.

Effect of different plant leaf extract incorporated aloe gel (PLEAG) coatings on physical quality parameters of firm ripe tomatoes was judged by the sensory panel at 12 days interval and shown in Table 64 to Table 69.

As there was no significant difference among the treatment means of different physical parameters analyzed, the coatings with highest mean sensory score was considered as the best treatment for increasing the efficiency in extension of shelf life in tomato.

4.3.2.4.1. Appearance

Effect of different plant leaf extract incorporated aloe gel (PLEAG) coatings on the appearance of firm ripe tomato is shown in Table 64. Initially all the coated fruits had mean values for appearance ranging from 8.07 to 8.13. On 12th and 24th day of storage, mature green fruits dipped in papaya leaf incorporated aloe gel (1:2) +INS 402 and aloe gel + INS 402 recorded highest mean sensory scores for appearance (7.80 and 7.67 respectively).

4.3.2.4.2. Colour

Effect of different plant leaf extract incorporated aloe gel (PLEAG) coatings on the colour of firm ripe tomatoes under ambient storage condition is shown in Table 65.

Initially all the coated fruits had mean colour values ranging from 8.07 to 8.13. On 12th day of storage firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:1) + INS 402 and aloe gel +INS 402 recorded highest mean sensory score for colour (8.20).

Table 64. Effect of PLEAG coating on the appearance of firm ripe tomatoes

Treatments @ 1% for 1 minute	Appearance		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	8.07	7.73	7.60
Aloe gel + guava leaf (1:1) + INS 402	8.13	7.60	7.40
Aloe gel + ocimum leaf (1:1) + INS 402	8.07	7.67	7.33
Aloe gel + papaya leaf (1:2) + INS 402	8.07	7.80	7.67
Aloe gel + guava leaf(1:2) + INS 402	8.07	7.67	7.33
Aloe gel + ocimum leaf (1:2) + INS 402	8.07	7.64	7.13
Aloe gel + INS 402	8.13	7.80	7.67
χ^2 value	1.45	6.03	6.62
Kw value	**NS**		

Table 65. Effect of PLEAG coating on the colour of firm ripe tomatoes

Treatments @ 1% for 1 minute	Colour		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	8.13	8.27	8.00
Aloe gel + guava leaf (1:1) + INS 402	8.07	7.93	7.77
Aloe gel + ocimum leaf (1:1) + INS 402	8.07	7.73	7.56
Aloe gel + papaya leaf (1:2) + INS 402	8.13	8.20	7.87
Aloe gel + guava leaf (1:2) + INS 402	8.13	8.20	7.80
Aloe gel + ocimum leaf (1:2) + INS 402	8.13	7.73	7.60
Aloe gel + INS 402	8.07	8.27	8.00
χ^2 value	8.21	5.18	7.38
Kw value	**NS**		

On 24[th] day of storage, firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:1) + Ins 402 and aloe gel + INS 402 recorded highest mean sensory score for colour (8.00).

4.3.2.4.3. Flavour

Effect of plant leaf extract incorporated aloe gel (PLEAG) coatings on the flavour of firm ripe tomatoes under ambient storage condition is shown in Table 66.

Initially all the coated fruits had mean values ranging from 8.07 to 8.13. On 12[th] day of storage, firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory score for flavour (8.07).

On 24[th] day of storage firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:1) and (1:2) + INS 402 scored highest mean sensory scores for flavour (7.73).

4.3.2.4.4. Taste

Effect of plant leaf extract incorporated aloe gel (PLEAG) coatings on the taste of firm ripe tomato under ambient storage condition is shown in Table 67. Initially the coated fruits had mean values ranging from 7.93 to 8.07. On 12[th] day of storage, firm ripe fruits dipped in aloe gel + INS 402 recorded highest mean sensory score for taste (7.87). On 24[th] day of storage, firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory score for texture (7.67).

4.3.2.4.5. Texture

Effect of plant leaf extract incorporated aloe gel (PLEAG) coatings on the texture of firm ripe tomatoes under ambient storage condition is shown in Table 68. Initially the fruits had mean values ranging from 7.93 to 8.13. On 12[th] and 24[th] day of storage, firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory scores for texture (8.27 and 8.00 respectively).

4.3.2.4.6. Overall Acceptability

Effect of plant leaf extract incorporated aloe gel (PLEAG) coatings on the overall acceptability of firm ripe tomatoes under ambient storage condition is shown in Table 69.

Table 66. Effect of PLEAG coating on the flavour of firm ripe tomatoes

Treatments @ 1% for 1 minute	Flavour		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	8.13	7.87	7.73
Aloe gel + guava leaf (1:1) + INS 402	8.07	7.73	7.53
Aloe gel + ocimum leaf (1:1) + INS 402	8.07	7.53	7.33
Aloe gel + papaya leaf (1:2) + INS 402	8.07	8.07	7.73
Aloe gel + guava leaf(1:2) + INS 402	8.07	7.87	7.60
Aloe gel + ocimum leaf (1:2) + INS 402	8.07	7.57	7.24
Aloe gel + INS 402	8.13	7.80	7.60
χ^2 value	7.04	7.55	7.58
Kw value	**NS**		

Table 67. Effect of PLEAG coating on the taste of firm ripe tomatoes

Treatments @ 1% for 1 minute	Taste		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	8.07	7.80	7.40
Aloe gel + guava leaf (1:1) + INS 402	8.07	7.57	7.39
Aloe gel + ocimum leaf (1:1) + INS 402	7.93	7.40	7.20
Aloe gel + papaya leaf (1:2) + INS 402	7.93	7.71	7.67
Aloe gel + guava leaf(1:2) + INS 402	7.93	7.43	7.27
Aloe gel + ocimum leaf (1:2) + INS 402	7.93	7.53	7.13
Aloe gel + INS 402	7.93	7.87	7.60
χ^2 value	4.41	6.99	6.68
Kw value	**12.59**		

Table 68. Effect of PLEAG coating on the texture of firm ripe tomatoes

Treatments @ 1% for 1 minute	Texture		
	0th day	12th day	24th day
Aloe gel + papaya leaf (1:1) + INS 402	8.13	7.80	7.70
Aloe gel + guava leaf (1:1) + INS 402	7.93	8.20	7.54
Aloe gel + ocimum leaf (1:1) + INS 402	7.93	7.07	7.33
Aloe gel + papaya leaf (1:2) + INS 402	8.13	8.27	8.00
Aloe gel + guava leaf(1:2) + INS 402	8.13	7.73	7.43
Aloe gel + ocimum leaf (1:2) + INS 402	7.93	8.00	7.30
Aloe gel + INS 402	8.13	7.87	7.60
χ^2 value	8.34	5.19	5.38
Kw value	**NS**		

Initially the coated fruits had mean values ranging from 7.93 to 8.13. On 12th and 24th day of storage firm ripe fruits dipped in papaya leaf incorporated aloe gel (1:2) + INS 402 recorded highest mean sensory score for overall acceptability (7.93 and 7.53 respectively).

4.3.5. Cost of production

Cost of preparation of the selected papaya leaf extract incorporated aloe gel formulation viz., [papaya leaf extract incorporated aloe gel (1:2) + INS 402] from1kg aloe vera leaves was Rs.48.16/-for mature green tomatoes and it wasRs.49.66/- for firm ripe tomatoes. Cost of dipping 100 kg mature green tomatoes with the selected formulation was calculated to be Rs45.87/- and it was Rs.23.65/- for 100 kg firm ripe tomatoes (Table 70).

When the cost of production of PLEAG based formulation was compared with the cost of production of pure aloe based formulation (Table 39) it was found that the PLEAG based formulation could be prepared at a comparatively cheaper rate.

Considering the efficiency in maintaining the physiological, chemical, microbial and physical parameters, papaya leaf incorporated aloe gel was selected as the effective plant leaf extract incorporated aloe gel (PLEAG) and based on economics, the ratio of papaya leaf extract and aloe gel was selected as 1:2 ratio. It was found that papaya leaf incorporated aloe gel (1:2) + INS 402 was suitable for reducing the cost of preparation of aloe based edible films without affecting the efficiency in increasing the shelf life of tomato.

Table 69. Effect of PLEAG coating on the overall acceptability of firm ripe tomatoes

Treatments @ 1% for 1 minute	Overall Acceptability		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel + papaya leaf (1:1) + INS 402	8.13	7.87	7.27
Aloe gel + guava leaf (1:1) + INS 402	7.93	7.60	7.13
Aloe gel + ocimum leaf (1:1) + INS 402	7.93	7.43	7.00
Aloe gel + papaya leaf (1:2) + INS 402	8.13	7.93	7.53
Aloe gel + guava leaf(1:2) + INS 402	8.13	7.50	7.07
Aloe gel + ocimum leaf (1:2) + INS 402	7.93	7.36	7.00
Aloe gel + INS 402	8.13	7.80	7.20
χ^2 value	1.89	4.34	5.09
Kw value	**12.59**		

Table 70. Cost of production of papaya leaf extract incorporated aloe gel

Standardized Formulation		Mature green	Firm ripe
		Papaya leaf extract incorporated aloe gel (1:2)+ INS 402	
Concentration of formulation		2%	1%
Item	*Quantity*	*Cost (Rs)*	*Cost (Rs)*
Aloe vera	1 kg	40.00	40.00
INS 402	1g	0.66	0.66
Papaya leaf	2 kg	-	-
Citric acid	0.5g	0. 50	0. 50
Ascorbic acid	1g	1.00	1.00
Labour cost	-	6.00	7.50
Qty of formulation that can be prepared		52.5 litre	105 litre
Total cost for preparation of formulation		48.16	49.66
Quantity of fruits that can be treated		105 kg	210kg
Cost for treating 100 kg fruit		Rs.45.87/-	Rs.23.65/-

4.4. QUALITY EVALUATION OF FILM COATED TOMATO

Based on the superiority in maintaining the quality parameters and economics, the following treatments were selected as plant leaf extract incorporated aloe gel film coating for extending shelf life of tomato fruits of two maturity stages.

1. Mature Green tomato - Dipping in 2% papaya leaf extract incorporated aloe gel (1:2) + INS 402 for two minutes
2. Firm ripe tomato - Dipping in 1% papaya leaf extract incorporated aloe gel (1:2) + INS 402 for one minute

Tomato fruits were treated with the pure aloe gel based film coating selected from part 4.2 of the experiment and papaya leaf extract incorporated aloe gel selected from part 4.3 of the experiment. The textural properties and other quality parameters of the treated fruits were analyzed in detail so as to select the most efficient aloe gel based treatment capable of increasing the shelf life of tomato.

4.4.1. MATURE GREEN TOMATO

Mature green fruits were dipped in 2% concentration of aloe gel +INS 402 and papaya leaf extract incorporated aloe gel (1:2) + INS 402, for two minutes. Physical, chemical and antimicrobial parameters of the coated fruits were analyzed at 12 days interval under ambient storage till it had lost its shelf life and details are shown below.

4.4.1.1. Physical parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel treatments on the textural parameters of mature green tomatoes viz., firmness; bio yield point and sensory perception of textural parameters were recorded at 12 days interval till it had lost its shelf life. Both the treatments were thickened using 1% INS 402 and fruits were dipped in 2% concentration of the above formulations for two minutes for conducting empirical tests.

4.4.1.1.1. Fruit firmness

Effect of pure aloe gel and papaya leaf extract incorporated aloe gel coatings on the fruit firmness of mature green tomatoes under ambient storage condition is shown in Table 71. There was no significant difference between the fruit firmness of aloe gel and papaya leaf extract incorporated aloe gel coated mature green tomato fruits on the initial day.

On 12th, 24th and 36th day of storage fruits treated with papaya leaf extract incorporated aloe gel recorded a higher firmness (61.13N, 60.91N and 49.16 N respectively) when compared with aloe gel treated fruits.

4.4.1.1.2. Bio yield point

Effect of aloe gel and papaya leaf extract incorporated aloe gel coating on the bio yield point of mature green tomatoes under ambient storage condition is shown in Table 72. There was no significant difference in the bio yield point of mature green tomatoes subjected to different treatments on the initial and 12th day of storage. On the 24th and 36th day of storage, fruits treated with papaya leaf extract incorporated aloe gel recorded higher bio yield point (126.42N and 137.92N respectively) compared to fruits treated with aloe gel.

4.4.1.1.3. Sensory perception of textural parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel coating on the sensory perception of textural parameters of mature green tomatoes under ambient storage condition is shown in Table 73.

No significant difference was found between the sensory perception of finger feel, mouth feel and textural appearance of mature green fruits treated with aloe gel and papaya leaf extract incorporated aloe gel.

4.4.1.2. Chemical parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel treatments on the chemical parameters like total solids, total insoluble solids, alcohol insoluble solids, activity of texture affecting enzymes and total pectin of mature green fruits were recorded at 12 days interval till it had lost its shelf life and are shown below.

Table 71. Effect of edible coatings on fruit firmness of mature green tomatoes

Treatments @2% for 2 minutes	Fruit firmness (N)			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel	108.38	54.07	53.54	43.93
Papaya leaf extract incorporated aloe gel	109.02	61.13	60.91	49.16
CD (0.05)	**NS**	**6.08**	**6.37**	**4.47**

Table 72. Effect of edible coatings on the bioyield point of mature green tomatoes

Treatments @2% for 2 minutes	Bioyield point (N)			
	0^{th} day	12^{th} day	24^{th} day	36^{th} day
Aloe gel	212.37	99.92	117.72	130.57
papaya leaf extract incorporated aloe gel	210.54	104.46	126.42	137.92
CD (0.05)	**NS**	**NS**	**6.857**	**2.97**

Table 73. Effect of edible coatings on the sensory perception of textural parameters of mature green tomato

SENSORY PERCEPTION OF TEXTURAL CHARACTERS IN TOMATO								
CHARACTERS	0^{th} day		12^{th} day		24^{th} day		36^{th} day	
	Aloe gel	Papaya leaf extract incorporated AG	Aloe gel	Papaya leaf extract incorporated AG	Aloe gel	Papaya leaf extract incorporated AG	Aloe gel	Papaya leaf extract incorporated AG
	Score	Score	Score	Score	Score	Score	Score	Score
A. FINGERFEEL CHARACTERS								
1. Fruit Firmness	3.00	3.00	3.00	3.00	2.66	2.86	2.46	2.60
2. Skin Tightness	3.00	3.00	3.00	3.00	3.00	3.00	2.60	2.60
3. Nature of coating material	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
4. Skin Roughness	3.00	3.00	2.27	2.40	2.33	2.20	2.26	2.26
B. MOUTHFEEL CHARACTERS								
1. Oral Texture	3.00	3.00	3.00	3.00	2.76	2.80	2.26	2.28
2. Tomato Juiciness	3.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00
C. TEXTURAL CHARACTERS								
1. Glossiness	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
KW value	0.58		1.24		1.62		0.49	
X^2 value	**NS**							

4.4.1.2.1. Total solids

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the total solids of mature green tomato under ambient storage condition is shown in Table 74. There was no significant difference between the total solids of mature green tomato fruits coated with edible coatings during the entire storage period.

4.4.1.2.2. Total insoluble Solids

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the total insoluble solids of mature green tomatoes under ambient storage condition is shown in Table 75. No significant difference was found in the total insoluble solids of both aloe gel and papaya leaf extract incorporated aloe gel treated mature green tomatoes during the entire storage period.

4.4.1.2.3. Alcohol insoluble solids

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the alcohol insoluble solids of mature green tomatoes under ambient storage condition is shown in Table 76. Alcohol insoluble solids remained the same for both aloe gel and papaya leaf extract incorporated aloe gel treated fruits during the entire storage period.

4.4.1.2.4. Activity of texture affecting enzymes

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the activity of texture affecting enzymes viz., pectin methyl esterase and poly galacturonase ,were recorded at 12 days interval till it had lost its shelf life and are shown below.

4.4.1.2.4.1. Pectin Methyl Esterase

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the pectin methyl esterase activity of mature green tomatoes under ambient storage condition is shown in Table 77.

No significant difference was found between the pectin methyl esterase enzyme activity of fruits treated with aloe gel and papaya leaf extract incorporated aloe gel on the initial and 12th day of storage. Least enzyme activities (79.24 and

61.88 respectively) were recorded by the papaya leaf extract incorporated aloe gel treated fruits on the 24th and 36th day of storage.

4.4.1.2.4.2. Poly galacturonase

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the poly galacturonase activity of mature green tomatoes under ambient storage condition is shown in Table 78.

Mature green fruits coated with papaya leaf extract incorporated aloe gel recorded the lower poly galacturonase enzyme activity throughout the storage period when compared with the aloe gel treated fruits.

4.4.1.2.5. Total pectin

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the total pectin content of mature green tomatoes under ambient storage condition is shown in Table 79.

On the initial day the pectin content was similar for both aloe gel and papaya leaf extract incorporated aloe gel treated fruits; the total pectin content was higher (11.84, 10.26 and 8.64 respectively) in the papaya leaf extract incorporated aloe gel treated fruits on the 12th, 24th and 36th day of storage.

Table 74. Effect of edible coatings on the total solids of mature green tomatoes

Treatments @2% for 2 minutes	Total solids (mg/L)			
	0th day	12th day	24th day	36th day
Aloe gel	88.14	86.57	83.86	84.14
papaya leaf extract incorporated aloe gel	87.71	86.57	83.43	84.14
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Table 75.Effect of edible coatings on the total insoluble solids of mature green tomatoes

Treatments @2% for 2 minutes	Total insoluble solids (mg/L)			
	0th day	12th day	24th day	36th day
Aloe gel	59.29	58.57	53.71	53.71
papaya leaf extract incorporated aloe gel	59.86	58.71	54.14	53.71
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Table 76. Effect of edible coatings on the alcohol insoluble solids of mature green tomatoes

Treatments @2% for 2 minutes	Alcohol insoluble solids (mg/L)			
	0th day	12th day	24th day	36th day
Aloe gel	62.57	57.47	47.64	34.34
papaya leaf extract incorporated aloe gel	62.36	57.71	47.07	34.79
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Table 77. Effect of edible coatings on the pectin methyl esterase activity of mature green tomatoes

Treatments @2% for 2 minutes	Pectin methyl esterase (U/g)			
	0th day	12th day	24th day	36th day
Aloe gel	75.93	83.87	81.17	63.51
papaya leaf extract incorporated aloe gel	75.70	83.78	79.24	61.88
CD (0.05)	**NS**	**NS**	**1.29**	**0.67**

Table 78. Effect of edible coatings on the poly galacturonase activity of mature green tomatoes

Treatments @2% for 2 minutes	Poly galacturonase (U/ml)			
	0th day	12th day	24th day	36th day
Aloe gel	35.09	39.09	23.95	12.03
papaya leaf extract incorporated aloe gel	33.85	37.97	21.95	9.94
CD (0.05)	**0.63**	**0.69**	**0.73**	**0.65**

Table 79. Effect of edible coatings on the total pectin content of mature green tomatoes

Treatments @2% for 2 minutes	Total pectin (% unhydrogalacturonic acid)			
	0th day	12th day	24th day	36th day
Aloe gel	10.94	10.33	9.64	7.69
papaya leaf extract incorporated aloe gel	10.94	11.84	10.26	8.64
CD (0.05)	**NS**	**0.08**	**0.13**	**0.20**

4.4.1.3. Microbial parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel on the antimicrobial activity of extracts against pathogens and disease index was recorded for two weeks.

4.4.1.3.1. Invitro antimicrobial activity of extracts against Erwinia and Rhizopus

When the antimicrobial activity of aloe gel and papaya leaf extract incorporated aloe gel was assessed by antimicrobial assay, no inhibition zone was formed by the extracts against the pathogens (Plate. 5).

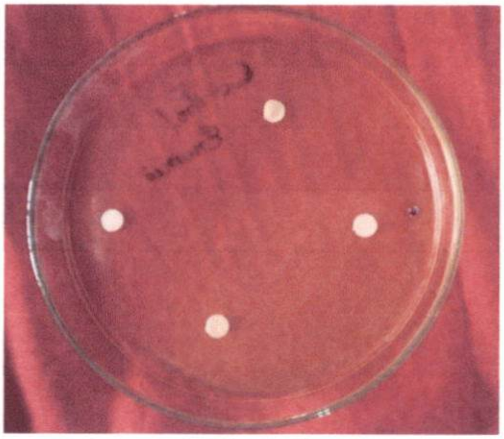
4.4.1.3.2. Artificial inoculation studies or invivo antimicrobial assay of aloe based extracts

4.4.1.3.2.1. Disease index for bacterial soft rot and Rhizopus rot

When aloe gel and papaya leaf extract incorporated aloe gel coated mature green fruits were tested for disease index by inoculating suspension of Erwinia and Rhizopus, no disease symptoms of bacterial soft rot and Rhizopus rot were developed by the coated fruits for a storage period of 14 days (Plate 6).

aloe gel

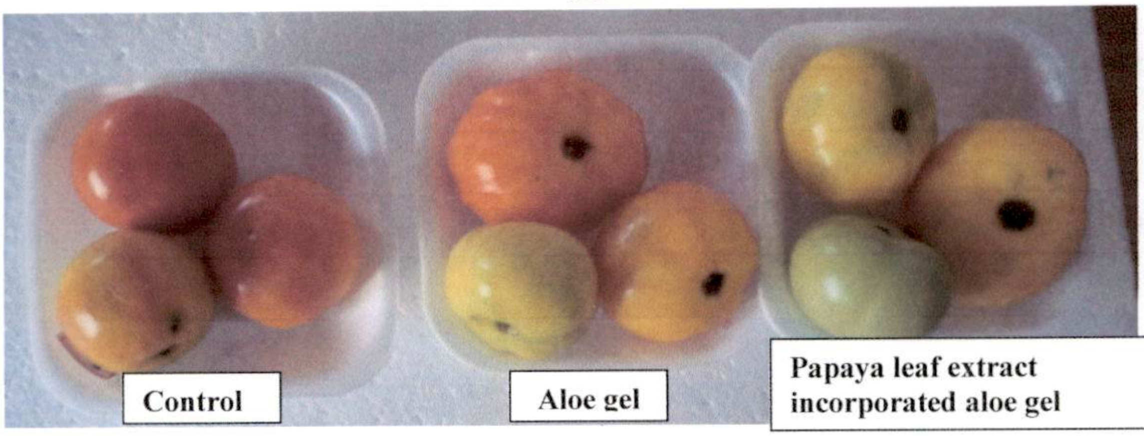
Papaya leaf extract incorporated aloe gel



Control

Plate 5. Antimicrobial activity of *Erwinia*

A



B

Plate 6. Disease development on artificial inoculation with post harvest pathogens on 7th day of storage
A. Erwinia B. Rhizopus

4.4.2. FIRM RIPE TOMATO

Firm ripe fruits were dipped in aloe gel +INS 402 and papaya leaf extract incorporated aloe gel prepared in 1:2 ratio + INS 402, both at 1% concentration for one minute. Physical, chemical and antimicrobial parameters were analyzed at 12 days interval till it had lost its shelf life and details are shown below.

4.4.2.1. Physical parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel treatments on the textural parameters of firm ripe tomatoes viz., fruit firmness, bio yield point and sensory perception of textural parameters were recorded at 12 days interval till it had lost its shelf life and is shown below. Both the treatments were thickened by adding 1% INS 402 and fruits were dipped in 1% formulation for one minute for analyzing the textural parameters.

4.4.2.1.1. Fruit firmness

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the fruit firmness of firm ripe tomatoes under ambient storage condition is shown in Table 80.

There was no significant difference between the aloe gel and papaya leaf extract incorporated aloe gel treated firm ripe tomato fruits on the initial day.

On 12th and 24th day of storage, firm ripe fruits treated with papaya leaf extract incorporated aloe gel recorded higher firmness (36.08N and 32.95N respectively) compared to fruits treated with aloe gel.

4.4.2.1.2. Bio yield point

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the bio yield point of firm ripe tomatoes under ambient storage condition is shown in Table 81. There was no significant difference in the bio yield points of treatments on the initial day of storage. On the 12th and 24th day of storage, fruits treated with

Table 80. Effect of edible coatings on the fruit firmness of firm ripe tomatoes

Treatments @ 1% for 1 minute	Fruit firmness (N)		
	0[th] day	12[th] day	24[th] day
Aloe gel	36.44	31.30	27.51
papaya leaf extract incorporated aloe gel	36.56	36.08	32.95
CD (0.05)	**NS**	**2.92**	**4.64**

Table 81. Effect of edible coatings on the bio yield point of firm ripe tomatoes

Treatments @ 1% for 1 minute	Bio yield point (N)		
	0[th] day	12[th] day	24[th] day
Aloe gel	72.25	74.97	77.66
papaya leaf extract incorporated aloe gel	72.37	81.60	86.75
CD (0.05)	**NS**	**4.11**	**6.27**

papaya leaf extract incorporated aloe gel recorded a higher bio yield point with 81.60N and 86.75N respectively compared to fruits treated with aloe gel.

4.4.2.1.3. Sensory perception of textural parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the sensory perception of textural parameters of firm ripe tomato under ambient storage condition is shown in Table 82. No significant difference was found in the sensory perception of finger feel, mouth feel and textural characters of firm ripe fruits treated with aloe gel and papaya leaf extract incorporated aloe gel.

4.4.2.2. Chemical parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel treatments on the chemical parameters of firm ripe tomatoes viz., total solids, total insoluble solids, alcohol insoluble solids, activity of texture affecting enzymes and total pectin were recorded at 12 days interval till it had lost its shelf life and are shown below.

4.4.2.2.1. Total solids

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the total solids of firm ripe tomatoes under ambient storage condition is shown in Table 83.

There was no significant difference between the total solids of firm ripe tomatoes subjected to both treatments during the entire storage period.

4.4.2.2.2. Total insoluble Solids

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the total insoluble solids of firm ripe tomatoes under ambient storage condition is shown in Table 84.

No significant difference was noticed between the total insoluble solids of both gel treated firm ripe tomatoes on the initial day, 12^{th} and on 24^{th} day of storage.

Table 82. Effect of edible coatings on the sensory perception of textural parameters of firm ripe tomato

SENSORY PERCEPTION OF TEXTURAL CHARACTERS IN TOMATO						
CHARACTERS	0^{th} day		12^{th} day		24^{th} day	
	Aloe gel	Papaya leaf extract incorporated AG	Aloe gel	Papaya leaf extract incorporated AG	Aloe gel	Papaya leaf extract incorporated AG
	Score	Score	Score	Score	Score	Score
B. FINGERFEEL CHARACTERS						
1. Fruit Firmness	3.00	3.00	2.26	2.46	2.12	2.13
2. Skin Tightness	3.00	3.00	3.00	3.00	2.80	2.90
3. Nature of coating material	3.00	3.00	3.00	3.00	2.90	2.96
4. Skin Roughness	2.26	2.28	2.13	2.15	2.00	2.02
B. MOUTHFEEL CHARACTERS						
1. Oral Texture	2.00	2.00	1.80	1.80	1.78	1.79
2. Tomato Juiciness	2.00	2.00	2.00	2.00	1.90	1.90
C. TEXTURAL CHARACTERS						
2. Glossiness	2.00	2.00	2.00	2.00	2.00	2.00
KW value	.580		.232		.180	
X^2 value	**NS**					

4.4.2.2.3. Alcohol insoluble solids

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the alcohol insoluble solids of firm ripe tomatoes under ambient storage condition is shown inTable85.

Alcohol insoluble solids were same for both aloe gel and papaya leaf extract incorporated aloe gel treated fruits during the entire storage period.

4.4.2.2.4. Activity of texture affecting enzymes

Effect of aloe gel and papaya leaf extract incorporated aloe gel treatments on the activity of texture affecting enzymes viz., pectin methyl esterase and poly galacturonase were recorded at 12 days interval till it had lost its shelf life and is shown below.

4.4.2.2.4.1. Pectin Methyl Esterase

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the pectin methyl esterase activity of firm ripe tomatoes under ambient storage condition is shown in Table 86.

No significant difference was found between the pectin methyl esterase activity of fruits treated with aloe gel and papaya leaf extract incorporated aloe gel on the initial day of storage. The low enzyme activity (78.61 and 61.61 respectively) was recorded by the papaya leaf extract incorporated aloe gel treated fruits on the 12^{th} and 24^{th} day of storage.

4.4.2.2.4.2. Poly Galacturonase

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the poly galacturonase activity of firm ripe tomatoes under ambient storage condition is shown in Table 87.

Polygalacturonase activities were same in both aloe gel and papaya leaf extract incorporated aloe gel treated fruits on the initial day. Firm ripe fruits treated with papaya leaf extract incorporated aloe gel recorded a lower poly galacturonase activity of 17.66 and 13.46 on the 12^{th} and 24^{th} day of storage respectively compared to the aloe gel treated fruits.

4.4.2.2.5. Total pectin

Effect of aloe gel and papaya leaf extract incorporated aloe gel coatings on the total pectin content of firm ripe tomato under ambient storage condition is shown in Table 88.

On the initial day the pectin content remained same for both aloe gel and papaya leaf extract incorporated aloe gel treated fruits. The total pectin content was higher for the papaya leaf extract incorporated aloe gel treated fruits on the 12^{th} and 24^{th} day of storage (7.89 and 7.43 respectively).

4.4.2.3. Microbial parameters

Effect of aloe gel and papaya leaf extract incorporated aloe gel on the microbial parameters viz., antimicrobial activity of extracts against pathogens and disease index were recorded for two weeks.

4.4.2.3.1. Invitro antimicrobial activity of extracts against Erwinia and Rhizopus

When the antimicrobial activity of aloe gel and papaya leaf extract incorporated aloe gel against the pathogens Erwinia and Rhizopus was assessed by the in vitro antimicrobial assay, no inhibition zone was formed by the extracts. (Plate 7).

4.4.2.3.2. Artificial inoculation studies or in vivo antimicrobial assay of aloe based extracts

4.4.2.3.2.1. Disease index for bacterial soft rot and Rhizopus rot

When aloe gel and papaya leaf extract incorporated aloe gel coated firm ripe fruits were tested for disease index by inoculating suspension of Erwinia and Rhizopus, no disease symptoms of bacterial soft rot and Rhizopus rot were developed by the coated fruits for a storage period of 14 days.

Table 83. Effect of edible coatings on the total solids of firm ripe tomatoes

Treatments @ 1% for 1minute	Total solids (mg/L)		
	0th day	12th day	24th day
Aloe gel	87.86	87.00	83.14
papaya leaf extract incorporated aloe gel	87.86	87.29	83.86
CD (0.05)	**NS**	**NS**	**NS**

Table 84. Effect of edible coatings on the total insoluble solids of firm ripe tomatoes

Treatments @ 1% for 1 minute	Total Insoluble Solids (mg/L)		
	0th day	12th day	24th day
Aloe gel	75.20	62.40	43.17
papaya leaf extract incorporated aloe gel	75.39	62.49	43.64
CD (0.05)	**NS**	**NS**	**NS**

Table 85. Effect of edible coatings on the alcohol insoluble solids of firm ripe tomatoes

Treatments @ 1% for1 minute	Alcohol insoluble solids (mg/L)		
	0th day	12th day	24th day
Aloe gel	72.47	61.57	52.43
papaya leaf extract incorporated aloe gel	72.47	61.88	53.00
CD (0.05)	**NS**	**NS**	**NS**

Table 86. Effect of edible coatings on the pectin methyl esterase activity of firm ripe tomatoes

Treatments @ 1% for 1min	Pectin methyl esterase (U/ml)		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel	88.14	80.28	62.46
papaya leaf extract incorporated aloe gel	88.07	78.61	61.61
CD (0.05)	**NS**	**0.71**	**0.46**

Table 87. Effect of edible coatings on the poly galacturonase activity of firm ripe tomatoes

Treatments @ 1% for 1min	Polygalacturonase		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel	33.64	18.40	14.06
papaya leaf extract incorporated aloe gel	33.39	17.66	13.46
CD (0.05)	**NS**	**0.32**	**0.40**

Table 88. Effect of edible coatings on the total pectin of firm ripe tomatoes

Treatments @ 1% for 1min	Total pectin		
	0^{th} day	12^{th} day	24^{th} day
Aloe gel	7.76	7.53	7.35
papaya leaf extract incorporated aloe gel	7.76	7.89	7.43
CD (0.05)	**NS**	**0.03**	**0.01**

Aloe gel

Papaya leaf extract incorporated aloe gel

Control

Plate 7. Antimicrobial activity of *Rhizopus*

Based on comparative quality evaluation studies of tomato fruits coated with aloe gel based and papaya leaf extract incorporated aloe gel based edible films, papaya leaf extract incorporated aloe gels at the following specific concentration and duration were selected as the best edible film coating for shelf life extension.

1. Mature Green tomato - Dipping in 2% papaya leaf extract incorporated aloe gel (1:2) + INS 402 for two minutes
2. Firm ripe tomato - Dipping in 1% papaya leaf extract incorporated aloe gel (1:2) + INS 402 for one minute

4.5. EFFICIENCY OF EDIBLE FILM IN REDUCING POST HARVEST LOSS DURING STORAGE AND TRANSPORTATION

Tomato fruits were coated with the above mentioned papaya leaf extract incorporated aloe gel based edible film and were compared with fruits coated with a commercial bee wax formulation and untreated fruits in reducing post harvest loss during storage and transportation.

4.5.1. Efficiency in extending storage life

Tomato fruits of two different maturity stages were coated with the above mentioned papaya leaf extract incorporated aloe gel based edible film and were compared with commercial bee wax coated fruits and untreated fruits in reducing post harvest loss during storage.

4.5.1.1 MATURE GREEN TOMATO

Mature green tomato fruits were dipped in 2% of papaya leaf extract incorporated aloe gel (1:2) + INS 402 and compared with fruits coated with a commercial bee wax formulation for two minutes and packaged in 5% Corrugated Fibre Board (CFB) boxes with and without moulded tray and stored under the ambient and optimum low temperature condition along with untreated fruits. The following physiological, chemical, microbial and physical parameters of fruits were analyzed at 15 days interval till they had lost its shelf life.

All the tomato fruits kept under ambient storage conditions were decayed after the 30th day of storage and comparison could only be made between the fruits stored under optimum low temperature condition. By 45th day of storage, all the uncoated/control fruits got decayed and all observations were taken only for the coated tomato fruits.

4.5.1.1.1. Physiological parameters

The following physiological parameters of coated and packaged mature green tomato fruits were analyzed at 15 days interval till they had lost their shelf life and are shown in Table 89 to Table 91.

4.5.1.1.1.1. Physiological Loss in Weight (PLW)

Physiological loss in weight (PLW) of coated and packaged mature green tomatoes recorded at 15 days interval during storage is shown in Table 89.

Mature green tomato fruits stored under low temperature recorded the least PLW (6.11% and 7.58%) compared to those stored ambient storage condition (15.15 and 16.27 respectively) on the 15th and 30th day of storage respectively.

On the 15th and 30th day of storage, packaging in 5% ventilated CFB box with moulded tray recorded the least PLW (8.67% and 6.66% respectively) compared to fruits packaged in 5% ventilated CFB box. There was no significant difference between the PLW of mature green fruits packaged in 5% ventilated CFB box with and without trays on the 45th and 60th day of storage.

Mature green fruits treated with commercial bee wax formulation recorded the least PLW (5.09% and 5.68%) on the 15th and 30th day of storage, which was followed by papaya leaf extract incorporated aloe gel treated fruits (5.92%. 7.38%).

On the 45th day of storage least PLW (8.52%) was for the fruits treated with commercial wax. On the 60th day of storage there was no significant difference between the PLW of commercial wax (7.42%) and papaya leaf incorporated aloe gel (7.50%) treated mature green fruits. The untreated/control fruits recorded the highest PLW (10.97%, 9.68% and 15.97%) on the 15th, 30th and 45th days of storage respectively.

The interaction effects were significant till 45th day of storage. On the 15th day of storage, the least PLW (3.97%) was recorded by the mature green fruits coated with commercial wax packaged in 5% ventilated CFB with moulded tray and stored under low temperature. The treatment was on par with fruits treated with papaya leaf

Table 89. Effect of edible film coatings and packaging on the PLW of mature green tomatoes during storage

Physiological Loss in Weight (%)					
15th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	13.61	12.83	7.34	4.50
	Commercial wax (T2)	11.87	11.62	6.22	3.97
	Control (T3)	23.11	20.77	12.06	9.88
Mean values	T1- 5.92: T2- 5.09: T3- 10.97	P1- 10.47 P2- 8.67		S1 – 15.15 S2 – 6.11	
CD(0.05)	**T=0.78**	**P = 0.64**		**S = 0.64**	
	TxPxS = 1.56				
30th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	15.25	13.50	8.26	6.52
	Commercial wax (T2)	15.66	12.50	7.00	4.36
	Control (T3)	21.28	19.34	10.25	9.11
Mean values	T1- 7.38: T2- 5.68: T3- 9.68	P1- 8.50 P2- 6.66		S1 – 16.27 S2 - 7.58	
CD(0.05)	**T=0.61**	**P = 0. 50**		**S = 0.50**	
	TxPxS = 1.22				
45th day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	9.84		9.33	
	Commercial wax (T2)	8.67		7.71	
	Control (T3)	16.72		15.23	
Mean values	T1- 9.25: T2- 8.52: T3- 15.97	P1- 11.96 P2- 10.53		TxP = 2.64	
CD(0.05)	**T=0.61**	**P = NS**			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	7.66		7.45	
	Commercial wax (T2)	7.55		7.25	
Mean values	T1- 7.50: T2- 7.42	P1- 7.58 P2- 7.35		TxP - NS	
CD(0.05)	**T = NS**	**P = NS**			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

extract incorporated aloe gel and packaged with 5% ventilated CFB with moulded tray (4.50%) under low temperature storage. Highest PLW (23.11%) was for the uncoated fruits packaged in 5% ventilated CFB box under ambient storage condition.

On the 30th day of storage, the least PLW (4.36%) was recorded by the fruits treated with commercial wax and packaged in 5% CFB box with moulded tray under low temperature storage and highest PLW was for the untreated fruits (21.28%) packaged in 5% CFB box under ambient storage.

When comparisons were made on the 45th day of storage, least PLW was for the fruits coated with commercial wax and packaged in 5% CFB with tray (7.71%) under low temperature storage which was on par with fruits subjected to all the other treatments except the uncoated fruits. Highest PLW (16.72) was for the uncoated fruits packaged in 5% CFB box.

On the 60th day of storage, fruits coated with papaya leaf extract incorporated aloe gel (7.50%) was found equally effective as commercial wax formulation coated fruits (7.42%).

4.5.1.1.1.2. Respiration rate

The respiration rate of coated and packaged mature green tomatoes recorded at 15 days interval during storage is shown in Table 90.

On the initial day of storage there was no significant difference in the respiration rate of mature green fruits stored under different storage temperature. On the 15th and 30th day of storage the fruits stored under low temperature recorded the least respiration rate (6.77% and 7.22% respectively) compared with the fruits under ambient temperature (7.65% and 8.44 respectively).

Influence of different packaging materials were non significant in influencing the respiration rate of mature green fruits on the initial, 15th and 60th day of storage. On the 30th and 45th day of storage fruits packaged in 5% CFB box with molded trays recorded a lower respiration rate (7.72% and 7.43% respectively) compared to fruits packaged in 5% CFB box (7.93% and 7.60% respectively).

Edible coatings had significant influence over the untreated fruits in respiration rate of mature green fruits till 45th day and there was no significant difference between the respiration rate of fruits treated with commercial wax and papaya leaf extract incorporated aloe gel during the entire storage period of 60 days. Highest respiration rate was recorded by the untreated fruits for the entire period of 45 days.

Comparing the interaction effects, on the initial day, respiration rate (5.80%) was least for commercial wax coated fruits packaged in 5% CFB box under low temperature which was on par with all the treated fruits under both storage condition. Highest respiration rate (7.80%) was recorded by the untreated fruits packaged in 5% CFB box without tray under ambient temperature.

On the 15th and 30th day of storage, least respiration rates (6.35% and 6.85% respectively) were for the fruits treated with commercial wax packaged in 5% CFB boxes with moulded tray under low temperature storage which were on par with all the coated fruits stored under low temperature in 5% CFB boxes with and without moulded tray. Highest respiration rate was for the untreated fruits packaged in 5% CFB box under ambient storage with 8.20% and 8.95% respectively.

Commercial wax coated mature green fruits packaged in 5% CFB boxes under low temperature recorded the least respiration rate (7.05%) which was on par with all other treated fruits packaged in 5% CFB boxes with and without trays under low temperature except the control fruits with 7.95% respiration rate on the 45th day of storage.

There was no significant difference between the respiration rate of mature green tomatoes packaged in 5% CFB boxes with and without moulded trays under low temperature storage on the 60th day of storage.

Table 90. Effect of edible film coatings and packaging on the respiration rate of mature green tomatoes during storage

Respiration rate (%)					
0^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	6.60	6.00	6.20	6.15
	Commercial wax (T2)	6.60	6.50	5.80	6.00
	Control (T3)	7.80	7.15	6.90	7.20
Mean values	T1- 6.38: T2- 6.22: T3- 7.11	P1- 6.46 P2- 6.45		S1 – 6.75 S2 – 6.75	
CD(0.05)	**T=0.43**	**P = NS**		**S = NS**	
	TxPxS = 0.85				
15^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	7.65	7.35	6.80	6.55
	Commercial wax (T2)	7.45	7.45	6.70	6.35
	Control (T3)	8.20	7.85	7.85	7.05
Mean values	T1- 7.08: T2- 6.98: T3- 7.57	P1- 7.23 : P2- 7.20		S1 – 7.65: S2 – 6.77	
CD(0.05)	**T=0.26**	**P = NS**		**S = 0.21**	
	TxPxS = 0.51				
30^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	8.45	7.85	7.25	7.05
	Commercial wax (T2)	8.45	8.20	6.90	6.85
	Control (T3)	8.95	8.75	7.65	7.60
Mean values	T1- 7.73: T2- 7.53: T3- 8.23	P1- 7.93 : P2- 7.72		S1 – 8.44: S2 – 7.22	
CD(0.05)	**T=0.21**	**P = 0. 17**		**S = 0.17**	
	TxPxS = 0.41				
45^{th} day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	7.31		7.33	
	Commercial wax (T2)	7.05		7.30	
	Control (T3)	7.95		7.95	
Mean values	T1- 7.35: T2- 7.25: T3- 7.95	P1- 7.60 P2- 7.43		TxP = 0.28	
CD(0.05)	**T=0.19**	**P = 0.16**			
60^{th} day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	7.60		7.25	
	Commercial wax (T2)	7.55		7.45	
Mean values	T1- 7.42: T2- 7.50	P1- 7.57 P2- 7.35		TxP – NS	
CD(0.05)	**T = NS**	**P = NS**			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

4.5.1.1.1.3. Membrane integrity

The percent leakage of mature green fruits packaged in CFB boxes during storage were recorded at 15 days interval and is shown in Table 91.

Percent leakage was same for the fruits stored under different storage conditions on the initial and 15th day of storage. On the 30th day least percent leakage (65.38%) was recorded by the fruits stored under low temperature compared to those under ambient temperature (77.44%).

There was no significant difference among the percent leakage of fruits subjected to different packaging materials, during the entire storage period of 60 days irrespective of edible coatings.

There was significant difference between the percent leakage of fruits subjected to different edible coatings. On the initial day least percent leakage (55.00%) was for the fruits coated with commercial wax which was on par with the fruits treated with papaya leaf extract incorporated aloe gel (55.48%). Uncoated fruits had highest percent leakage (56.35%).

On the 15th day of storage, least percent leakage was recorded for commercial wax coated fruits (57.44%) which was significantly different from the fruits coated with papaya leaf extract incorporated aloe gel (60.14%) and the untreated fruits (61.40%).

Least percent leakage (69.69%) was noticed in the commercial wax treated fruits which was on par with the papaya leaf extract incorporated aloe gel treated fruits (70.16%).Uncoated fruits had highest percent leakage (74.38%) on the 30th day of storage.

Percent leakage was similar for both papaya leaf extract incorporated aloe gel (65.50%) and commercial wax (65.10%) treated fruits on the 45th day of storage. Control fruits had highest percent leakage (72.60).

On the 60th day of storage there was no significant difference between the percent leakage papaya leaf extract incorporated aloe gel and commercial wax coated mature green fruits.

When interaction effects were compared, on the initial day the least percent leakage was recorded by the commercial wax coated fruits (54.22%) packaged in 5%

Table 91. Effect of edible film coatings and packaging on the percent leakage of mature green tomatoes during storage

Percent Leakage (%)					
0th day of storage	Treatments	S1P1	S1P2	S2P1	S2P2
	Papaya leaf incorporated AG (T1)	55.07	54.61	55.82	56.42
	Commercial wax (T2)	55.82	54.77	55.17	54.22
	Control (T3)	56.67	56.42	57.11	55.21
Mean values	T1- 55.48: T2 – 55.00 : T3- 56.35	P1- 55.27 P2 - 55.25		S1 – 55.56 S2 – 55.56	
CD(0.05)	**T=1.12**	**P = NS**		**S = NS**	
	TxPxS = 2.24				
15th day of storage	Treatments	S1P1	S1P2	S2P1	S2P2
	Papaya leaf incorporated AG (T1)	60.34	58.73	60.22	59.17
	Commercial wax (T2)	58.71	57.17	57.12	56.77
	Control (T3)	62.45	61.62	61.18	62.45
Mean values	T1 – 60.14 : T2 – 57.44 : T3-61.40	P1- 60.35 P2 - 58.97		S1 – 60.19 S2 – 59.13	
CD(0.05)	**T=1.89**	**P = NS**		**S = NS**	
	TxPxS = 3.79				
30th day of storage	Treatments	S1P1	S1P2	S2P1	S2P2
	Papaya leaf incorporated AG (T1)	75.47	74.44	66.48	63.41
	Commercial wax (T2)	75.61	75.33	64.61	63.19
	Control (T3)	83.06	80.42	67.55	67.02
Mean values	T1- 70.16: T2- 69.69 : T3- 74.38	P1- 72.00 P2- 70.81		S1 – 77.44 S2 – 65.38	
CD(0.05)	**T=1.68**	**P = NS**		**S = 1.37**	
	TxPxS = 3.38				
45th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	65.83		65.83	
	Commercial wax (T2)	65.61		64.50	
	Control (T3)	72.56		72.56	
Mean values	T1- 7.35: T2- 7.25: T3- 7.95	P1- 68.00 P2- 67.43		TxP = 2.68	
CD(0.05)	**T=1.85**	**P = NS**			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	72.39		69.22	
	Commercial wax (T2)	70.27		69.38	
Mean values	T1- 70.80 : T2- 69.80	P1- 70.89 P2- 69.75		TxP – 4.32	
CD(0.05)	**T = NS**	**P = NS**			

*S1 – Ambient temperature : *S2 – Optimum low temperature

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

ventilated CFB box with moulded tray and stored under low temperature. This was on par with all the fruits except untreated fruits packaged in CFB box and stored under ambient conditions, which had highest percent leakage (56.67%).

Mature green fruits treated with commercial wax and packaged in 5% CFB with moulded tray (56.77%) recorded the least percent leakage on the 15th day of storage. This was on par with all other treated fruits. The untreated fruits had high and similar percent leakage when packaged in 5% ventilated CFB box with and without trays under both storage conditions.

On the 30th day of storage, percent leakage was least (63.19%) for the mature green fruits coated with commercial wax and packaged in 5% CFB box with moulded tray. The treatment was on par with all the treated fruits stored under low temperature whether packaged in 5% ventilated CFB with or without moulded tray. Highest percent leakage (83.06%) was recorded by the untreated fruits packaged in 5% CFB box without tray under ambient temperature.

The percent leakage of both papaya leaf extract incorporated aloe gel and commercial wax treated fruits were similar on 45th day when packaged in 5% ventilated CFB box with moulded tray (64.50% and 65.61% respectively) and without tray (65.83% and 65.83% respectively) under low temperature. The untreated fruits had highest (72.56%) percent leakage irrespective of packaging conditions.

Percent leakage was similar for all mature green fruits treated with papaya leaf extract incorporated aloe gel and commercial wax whether packaged in 5% CFB box with or without moulded tray under low temperature storage on the 60th day of storage.

4.5.1.1.2. Chemical parameters

The following chemical parameters of coated mature green tomato fruits subjected to two different packaging systems and storage conditions were analyzed at 15 days interval till they had lost their shelf life and are shown in Table 92 to 96.

4.5.1.1.2.1. Total Soluble Solids (TSS)

Total Soluble Solids (TSS) of coated mature green tomato fruits subjected to two different packaging systems and storage conditions recorded at 15 days interval are shown in Table 92.

On the initial day, 15th and 30th day of storage there was no significant difference between the TSS of fruits under ambient and low temperature condition. However on the 30th day of storage, higher TSS was recorded by the fruits stored under low temperature (4.85^{0}B) compared to fruits under ambient storage (4.70^{0}B).

Both the packaging conditions were equally effective in maintaining the TSS of stored fruits during the entire period.

The treatments had no significant influence on TSS content of fruits during the initial day. When comparison was made among the treatments on the 15th day of storage, the highest TSS (4.65^{0}B) was recorded by the mature green fruits coated with papaya leaf extract incorporated aloe gel which was on par with the untreated fruits (4.58^{0}B) and least TSS was recorded by the commercial wax treated fruits (4.56^{0}B). TSS was highin the fruits treated with papaya leaf extract incorporated aloe gel (4.87^{0}B) compared with commercial wax treated fruits (4.82^{0}B) on the 30th day of storage. On the 45th day of storage, papaya leaf extract incorporated aloe gel treated fruits recorded highest TSS (4.95^{0}B) which was on par with commercial wax treated fruits (4.82^{0}B) , where as untreated fruits had least (3.90^{0}B) TSS content. On the final day (60th day) the untreated fruits were rotten and the TSS content was same for fruits treated with both papaya leaf extract incorporated aloe gel and commercial wax.

When the interaction effects were considered, there was no significant difference between the TSS content of treated and untreated fruits packaged in 5% ventilated CFB box with and without moulded tray irrespective of storage temperatures till the 30th day of storage. On the 45th day of storage, highest TSS (5.05^{0}B) was recorded by the papaya leaf extract incorporated aloe gel treated mature green fruits stored under low temperature after packaging in 5% ventilated CFB box

Table 92. Effect of edible film coatings and packaging on the TSS of mature green tomatoes during storage

TSS (^{0}Brix)					
0th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	4.30	4.30	4.35	4.35
	Commercial wax (T2)	4.35	4.35	4.35	4.35
	Control (T3)	4.35	4.35	4.35	4.35
Mean values	T1- 4.37 : T2 – 4.38: T3- 4.38	P1 - 4.39 P2 – 4.37		S1 -4.37 S2 -4.39	
CD(0.05)	**T=NS**	**P = NS**		**S = NS**	
	TxPxS = NS				
15th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	4.60	4.60	4.55	4.60
	Commercial wax (T2)	4.55	4.60	4.55	4.55
	Control (T3)	4.55	4.60	4.60	4.45
Mean values	T1 – 4.65: T2 – 4.56: T3-4.58	P1- 4.59 P2 - 4.60		S1 – 4.56 S2 – 4.63	
CD(0.05)	**T= 0.08**	**P = NS**		S = NS	
	TxPxS = NS				
30th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	4.65	4.65	4.80	4.80
	Commercial wax (T2)	4.60	4.70	4.75	4.80
	Control (T3)	4.75	4.75	4.75	4.75
Mean values	T1- 4.87 : T2- 4.82: T3- 4.73	P1- 4.79 P2- 4.83		S1 – 4.70 S2 – 4.85	
CD(0.05)	**T= 0.13**	**P = NS**		S = NS	
	TxPxS = NS				
45th day of storage	Treatments	S2P$_1$		S2P$_2$	
	Papaya leaf incorporated AG (T1)	5.05		4.85	
	Commercial wax (T2)	4.85		4.80	
	Control (T3)	3.90		3.90	
Mean values	T1- 4.95: T2- 4.82: T3- 3.90	P1- 4.60 P2- 4.51		TxP = 0.67	
CD(0.05)	**T=0.47**	**P = NS**			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	5.05		5.15	
	Commercial wax (T2)	4.95		4.85	
Mean values	T1- 5.05 T2 - 4.95	P1- 5.00 P2- 5.00		TxP – NS	
CD(0.05)	**T = NS**	**P = NS**			

*S1 – Ambient temperature : *S2 – Optimum low temperature

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

which was on par with all the other coated fruits. TSS was similar for both the papaya leaf extract incorporated aloe gel and commercial wax treated fruits irrespective of packaging and storage on the 60th day of storage.

4.5.1.1.2.2. pH

pH of coated and packaged mature green tomatoes stored under two conditions recorded at 15 days interval is shown in Table 93.

Both the storage and packaging conditions did not have significant influence in the pH of coated mature green fruits during the entire storage period.

The effect of treatments on the pH of mature green tomato was non-significant on the initial and 15th day of storage. When treatments were compared on the 30th and 45th day of storage, least pH was recorded by fruits treated with papaya leaf extract incorporated aloe gel (4.55and 4.70 respectively) which were on par with the fruits treated with commercial formulations (4.63and 4.85). The highest pH was for the untreated fruits (4.70 and 4.95 respectively). The treatments were non-significant in influencing the pH of mature green tomatoes on the 60th day of storage.

There was no significant difference between the pH of mature green fruits treated with papaya leaf extract incorporated aloe gel and commercial wax and packaged in 5% CFB with and without moulded tray and stored under ambient and optimum low temperature conditions till 15th day of storage. On the 30th day of storage least pH was recorded by all the papaya leaf extract incorporated aloe gel treated fruits, all commercial wax treated fruits except the one packaged in 5% ventilated CFB box with tray under ambient temperature (S_1P_2) and untreated fruits packaged in box with tray and stored under low temperature. The interaction effect was non significant on the pH content on 45thand 60th day of storage.

4.5.1.1.2.3. Vitamin C content

The vitamin C content of mature green tomatoes as influenced by edible coating and packaging under different storage conditions recorded at 15 days interval is shown in Table 94.

Table 93. Effect of edible film coatings and packaging on the pH of mature green during storage

pH					
0th day of storage	Treatments	S1P_1	S1P_2	S2P_1	S2P_2
	Papaya leaf incorporated AG (T1)	4.35	4.25	4.25	4.30
	Commercial wax (T2)	4.30	4.40	4.55	4.25
	Control (T3)	4.55	4.55	4.55	4.55
Mean values	T1- 4.36 : T2 – 4.45: T3- 4.40	P1- 4.38 P2 – 4.42		S1 – 4.40 S2 – 4.40	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
15th day of storage	Treatments	S1P_1	S1P_2	S2P_1	S2P_2
	Papaya leaf incorporated AG (T1)	4.70	4.60	4.60	4.65
	Commercial wax (T2)	4.65	4.80	4.60	4.70
	Control (T3)	4.85	4.85	4.85	4.70
Mean values	T1 – 4.71: T2 – 4.68: T3- 4.73	P1- 4.71 P2 - 4.71		S1 – 4.74 S2 – 4.68	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
30th day of storage	Treatments	S1P_1	S1P_2	S2P_1	S2P_2
	Papaya leaf incorporated AG (T1)	4.60	4.50	4.50	4.50
	Commercial wax (T2)	4.55	4.70	4.60	4.60
	Control (T3)	4.70	4.70	4.70	4.60
Mean values	T1- 4.55: T2- 4.63: T3- 4.70	P1- 4.73 P2- 4.62		S1 – 4.67 S2 – 4.68	
CD(0.05)	T=0.11	P = NS		S = NS	
	TxPxS = 0.13				
45th day of storage	Treatments	S2P_1		S2P_2	
	Papaya leaf incorporated AG (T1)	4.75		4.81	
	Commercial wax (T2)	4.85		4.85	
	Control (T3)	4.95		4.95	
Mean values	T1- 4.70: T2- 4.85: T3- 4.95	P1- 4.85 P2- 4.81		TxP = NS	
CD(0.05)	T=0.23	P = NS			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	5.05		5.10	
	Commercial wax (T2)	5.00		5.30	
Mean values	T1- 5.05: T2- 5.18	P1- 5.20 P2- 5.03		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

Table 94. Effect of edible film coatings and packaging on the vitamin C content of mature green tomatoes during storage

Vitamin C content (mg $100g^{-1}$)					
0th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	15.62	12.50	14.06	14.06
	Commercial wax (T2)	12.50	14.06	14.06	12.50
	Control (T3)	15.62	12.50	14.06	12.50
Mean values	T1- 14.06: T2 – 13.67 : T3- 13.28	P1- 14.32 P2 - 14.02		S1 – 13.80 S2 – 13.54	
CD(0.05)	T=NS	P = NS		S = NS	
	TxPxS = NS				
15th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	10.93	12.50	14.06	14.00
	Commercial wax (T2)	14.06	14.06	14.06	14.06
	Control (T3)	12.50	14.06	12.50	14.06
Mean values	T1 –12.88: T2 – 14.06 : T3 – 13.28	P1- 13.02 P2 - 13.79		S1 – 13.02 S2 – 13.79	
CD(0.05)	T=NS	P = NS		S =NS	
	TxPxS = NS				
30th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	9.23	9.37	15.64	15.13
	Commercial wax (T2)	9.23	9.08	14.70	14.53
	Control (T3)	8.77	9.32	10.94	13.59
Mean values	T1- 12.72: T2- 11.88 : T3- 10.66	P1- 11.67 P2- 11.83		S1 – 9.42 S2 – 14.09	
CD(0.05)	T=NS	P = NS		S = 2.08	
	TxPxS = 5.09				
45th day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	14.59		14.61	
	Commercial wax (T2)	10.94		13.64	
	Control (T3)	9.28		9.27	
Mean values	T1- 14.60: T2- 12.29: T3- 9.28	P1-: 12.00 P2- 12.51		TxP = 5.23	
CD(0.05)	T=3.70	P = NS			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	10.91		12.50	
	Commercial wax (T2)	10.91		12.50	
Mean values	T1- 11.70 : T2- 11.72	P1- 11.70 P2- 11.71		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

Storage conditions were non- significant in influencing the vitamin C content of mature green fruits during the initial and 15th day of storage. On the 30th day of storage, fruits stored under optimum low temperature recorded a high (14.09 mg100g^{-1}) vitamin C content compared to the fruits stored under ambient temperature (9.42 mg100g^{-1}).

The vitamin C content of mature green fruits packaged in 5% ventilated CFB box with and without moulded tray were same throughout the storage period of 60 days. When comparison was made among the treatments there was no significant difference between the vitamin C content of mature green fruits on the initial, 15th and 30th day of storage. On the 45th day of storage, highest vitamin C was recorded in the papaya leaf extract incorporated aloe gel coated fruits (14.60mg100g^{-1}) which was on par with the commercial wax treated fruits (12.29mg100g^{-1}). The untreated fruits had lowest vitamin C content (9.28mg100g^{-1}). On the 60th day there was no significant difference between the vitamin C content of mature green fruits coated with papaya leaf extract incorporated aloe gel and commercial wax formulation.

The interaction effect was also non-significant during the initial and 15th day of storage. On the 30th day of storage, highest vitamin C content (15.64mg100g^{-1}) was recorded by the papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box and stored under low temperature which was on par with all the fruits stored under the low temperature conditions irrespective of packaging systems. The least vitamin C content (8.77mg100g-1) was recorded by untreated fruits packaged in 5% ventilated CFB box stored under ambient condition.

On the 45th day of storage, highest vitamin C content (14.61mg100g^{-1}) was recorded in the papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box with tray and stored under low temperature, which was on par with all the other coated fruits. The untreated fruits had low pH when packaged in 5% ventilated CFB box with tray (9.27mg100g^{-1}) and without tray (9.28mg100g^{-1}) under low temperature storage. The interaction effect was non-significant during the final day of storage.

4.5.1.1.2.4. Titratable acidity

The titratable acidity of coated mature green tomatoes subjected to different packaging and storage was recorded at 15days interval till it had lost its shelf life and is shown in Table 95.

Titratable acidity remained similar for fruits stored in both conditions till the 15th day of storage. On the 30th day of storage, fruits stored under low temperature recorded a high titratable acidity (0.692%) compared to those stored at ambient storage condition (0.650%).

Packaging conditions were not effective in influencing the titratable acidity of mature green fruits during the entire storage period.

When comparison was made among different treatments, there was no significant difference between the titratable acidity of treated and untreated fruits during the entire storage period.

The interaction effect was not significant in influencing the titratable acidity during the initial day of storage. On the 15th day of storage, titratable acidity was highest (0.692%) recorded by the papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box with tray and stored under ambient and low temperature. This was on par with all the other treatments except the untreated fruits stored under ambient temperature. On the 30th day of storage, titratable acidity was highest for the commercial wax coated fruits stored under low temperature after packaging in 5% ventilated CFB box (0.722%), which was on par with all the other treated fruits. There was no interactive effect of edible coatings, packaging systems and storage condition on the titratable acidity of mature green tomatoes on the 45th and 60th day of storage.

4.5.1.1.2.5. Lycopene content

The lycopene content of edible film coated mature green tomatoes subjected to different packaging systems and storage conditions was recorded at 15 days interval till it had lost its shelf life and is shown in Table 96.

There was no significant difference between the lycopene content of mature green tomatoes stored in both conditions during the initial and 15th day of storage. On the 30th day of storage fruits stored under low temperature recorded the least lycopene content (17.84μgg^{-1}) compared to the fruits under ambient storage (23.24μgg^{-1}).

The effect of packaging was non significant in influencing the lycopene content of mature green fruits during the entire storage period.

The comparison of lycopene content between treated and untreated fruits was non significant on the initial day. Fruits treated with commercial wax recorded least lycopene content which was significantly different from the other treatments on the 15th, 30th, 45th and 60th day of storage.

When the interaction effect was compared, it was non significant on the initial day. On the 15th and 30th day of storage, least lycopene content (0.860μgg^{-1}and 8.14μgg^{-1} respectively) was recorded by the commercial wax treated fruits packaged in 5% ventilated CFB box and stored under low temperature. These fruits were on par with all the commercial formulation treated fruits. Highest lycopene content were noticed in all the untreated fruits irrespective of packaging method and storage condition. On the 45th day of storage, fruits coated with commercial wax and packaged in 5% ventilated CFB box with and without tray recorded the least lycopene content (24.67μgg^{-1} and 26.78μgg^{-1} respectively) under low temperature storage. On the 60th day of storage, lycopene content was least (35.77μgg^{-1}) for the commercial wax coated mature green fruits packaged in 5% ventilated CFB box which was on par with similar fruits packaged in 5% ventilated CFB box with tray (36.22μgg^{-1}) both under low temperature storage.

Table 95. Effect of edible film coatings and packaging on the titratable acidity of mature green tomatoes during storage

Titratable acidity (%)					
0th day of storage	Treatments	S1P₁	S1P₂	S2P₁	S2P₂
	Papaya leaf incorporated AG (T1)	0.563	0.589	0.563	0.589
	Commercial wax (T2)	0.538	0.538	0.589	0.589
	Control (T3)	0.589	0.563	0.589	0.563
Mean values	T1- 0.575 : T2 – 0.563: T3- 0.575	P1- 0.571 P2 - 0.571		S1 – 0.563 S2 – 0.580	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
15th day of storage	Treatments	S1P₁	S1P₂	S2P₁	S2P₂
	Papaya leaf incorporated AG (T1)	0.615	0.692	0.640	0.692
	Commercial wax (T2)	0.615	0.589	0.614	0.640
	Control (T3)	0.563	0.565	0.640	0.640
Mean values	T1 – 0.653 : T2 – 0.608 : T3-0.633	P1- 0.643 P2 - 0.644		S1 – 0.614 S2 – 0.648	
CD(0.05)	T=NS	P = NS		S = NS	
	TxPxS = 0.12				
30th day of storage	Treatments	S1P₁	S1P₂	S2P₁	S2P₂
	Papaya leaf incorporated AG (T1)	0.687	0.672	0.692	0.692
	Commercial wax (T2)	0.666	0.666	0.722	0.720
	Control (T3)	0.638	0.641	0.623	0.589
Mean values	T1- 0.655 : T2- 0.684: T3- 0.655	P1- 0.677 P2- 0.664		S1 – 0.650 S2 –0.692	
CD(0.05)	T=NS	P = NS		S = 0.02	
	TxPxS = 0.07				
45th day of storage	Treatments	S2P₁		S2P₂	
	Papaya leaf incorporated AG (T1)	0.709		0.706	
	Commercial wax (T2)	0.670		0.706	
	Control (T3)	0.703		0.713	
Mean values	T1- 0.708: T2- 0.703: T3- 0.708	P1- 0.701 P2- 0.715		TxP = NS	
CD(0.05)	T=NS	P = NS			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	0.738		0.743	
	Commercial wax (T2)	0.712		0.716	
Mean values	T1- 0.741 : T2- 0.714	P1- 0.725 P2- 0.729		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

Table 96. Effect of edible film coatings and packaging on the lycopene content of mature green tomatoes during storage

Lycopene content ($\mu g g^{-1}$)					
0th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	0.675	0.660	0.670	0.650
	Commercial wax (T2)	0.675	0.690	0.655	0.660
	Control (T3)	0.660	0.660	0.670	0.650
Mean values	T1- 0.651 : T2 – 0.662: T3- 0.660	P1- 0.654 P2 – 0.661		S1 – 0.661 S2 – 0.654	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
15th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	8.14	8.17	7.47	7.39
	Commercial wax (T2)	0.880	0.880	0.860	0.880
	Control (T3)	8.55	8.37	8.14	8.17
Mean values	T1 – 7.79: T2 – 0.870: T3- 8.30	P1- 5.67 P2 - 5.64		S1 –5.83 S2 – 5.49	
CD(0.05)	T= 0.50	P = NS		S = NS	
	TxPxS = 1.01				
30th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	27.28	27.22	19.38	17.28
	Commercial wax (T2)	10.14	10.14	8.14	8.17
	Control (T3)	34.72	33.92	25.77	28.32
Mean values	T1- 22.79 : T2- 9.06: T3- 30.69	P1- 20.44 P2- 20.65		S1 – 23.24 S2 – 17.84	
CD(0.05)	T= 6.89	P = NS		S = 1.29	
	TxPxS = 3.17				
45th day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	35.77		34.22	
	Commercial wax (T2)	26.78		24.67	
	Control (T3)	47.21		45.17	
Mean values	T1- 35.00: T2- 25.72: T3- 46.19	P1- 35.37 P2- 35.91		TxP = 2.87	
CD(0.05)	T= 2.01	P = NS			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	48.39		48.94	
	Commercial wax (T2)	35.77		36.22	
Mean values	T1- 48.66: T2- 36.00	P1- 42.08 P2- 42.58		TxP – 4.25	
CD(0.05)	T = 3.09	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

4.5.1.1.3. Microbial parameters

The effect of edible skin coatings and packaging on bacterial count on the surface of mature green tomatoes was recorded at 15 days interval and are shown in Table 97.

Initially the bacterial count recorded on the surface of both papaya leaf extract incorporated aloe gel and commercial formulation treated fruits packaged in 5% ventilated CFB box with and without tray under ambient and low temperature storage was too less to count.

The bacterial count was too numerous on the untreated fruits irrespective of packaging and storage conditions during the entire storage period.

On the 15th and 30th day of storage, the bacterial count was low on fruits stored under low temperature (2.45x10^{2}cfu/g, 2.38 x10^{2}cfu/g respectively) compared to fruits under ambient storage condition (3.71 x10^{2}cfu/g, 2.38 x10^{2}cfu/g).

The effect of two different packaging conditions was non-significant in influencing the bacterial load recorded on the coated fruits throughout the storage period.

When comparison was made among treatments, all the treatments were equally effective in maintaining the bacterial population on the surface of the coated fruits throughout the storage period.

The interaction effects had significant influence on the microbial count during 15th and 30th day of storage. On the 15th day of storage, least bacterial count was observed on the fruits treated with commercial wax (1.25 x10^{2}cfu/g) and packaged in 5% ventilated CFB box with tray stored under low temperature, which was on par with all the treated fruits stored under low temperature. On the 30th day of storage, least bacterial count (2.20 x10^{2}cfu/g) was noticed in commercial wax treated fruits packaged in 5% ventilated CFB box which was on par with the fruits treated with papaya leaf extract incorporated aloe gel packaged in 5% ventilated CFB box. On the 45th and 60th day of storage, the bacterial count were same on the surface of all treated mature green fruits irrespective of packaging systems under low temperature storage condition.

Table 97. Effect of edible film coatings and packaging on the microbial load of mature green tomatoes during storage

	Bacterial population x 10^2cfu/g				
0th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	TLTC	TLTC	TLTC	TLTC
	Commercial wax (T2)	TLTC	TLTC	TLTC	TLTC
	Control (T3)	TNTC	TNTC	TNTC	TNTC
15th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	3.50	4.25	1.40	1.35
	Commercial wax (T2)	3.55	3.55	1.45	1.25
	Control (T3)	TNTC	TNTC	TNTC	TNTC
Mean values	T1 – 2.62: T2 – 2.45	P1- 2.60 P2 – 2.45		S1 – 3.71 S2 – 2.45	
CD(0.05)	T= NS	P = NS		S = 0.31	
	TxPxS = 0.63				
30th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	4.80	5.00	2.30	2.60
	Commercial wax (T2)	4.30	4.15	2.20	2.45
	Control (T3)	TNTC	TNTC	TNTC	TNTC
Mean values	T1- 3.67 : T2- 3.27	P1- 3.40 P2- 3.55		S1 – 4.56 S2 – 2.38	
CD(0.05)	T= NS	P = NS		S = 0.62	
	TxPxS = 0.12				
45th day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	3.55		3.25	
	Commercial wax (T2)	3.40		3.20	
	Control (T3)	TNTC		TNTC	
Mean values	T1- 3.40: T2- 3.30	P1- 3.37 P2- 3.32		TxP = NS	
CD(0.05)	T= NS	P = NS			
60th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	3.60		3.45	
	Commercial wax (T2)	3.50		3.35	
Mean values	T1- 3.47: T2- 3.47	P1- 3.40 P2- 3.55		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

4.5.1.1.4. Physical parameters

Effects of different edible film coatings and packaging on physical quality parameters of mature green tomatoes during storage were judged by the sensory panel at 15 days interval and are shown in Table 98 to 103.

4.5.1.1.4.1. Appearance

The effects of coatings and packaging on the appearance of mature green fruits stored under ambient and low temperature are shown in Table 98. When the treatments were compared, significant difference was found between the appearance of fruits subjected to different treatments during the entire storage period.

On the initial day of storage highest rank with mean score for appearance (8.60) was recorded by papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box with and without trays under ambient temperature. The fruits kept under the same conditions had highest mean score and rank for appearance (8.40) during 15th day of storage. Least mean score (8.00) and rank for appearance were recorded for commercial wax treated fruits, packaged in 5% ventilated CFB box and stored under ambient condition during initial and 15th day of storage. Commercial wax treated fruits subjected to low temperature storage after packaging in CFB box with tray had least rank and mean score (8.00) during the initial day.

On the 30th day of storage, highest mean score and rank for appearance (8.27) were recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and stored under low temperature. The least mean score (5.93) was for the commercial wax treated fruits packaged in 5% ventilated CFB box with tray and stored under ambient temperature.

On the 45th day of storage comparison was made only between the treated and untreated fruits under low temperature and highest rank with mean score for appearance (8.00) was recorded by the papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box with and without tray. The least rank with mean score (6.50) was for the commercial wax treated fruits, packaged in CFB box with tray.

On the 60th day of storage, the high rank with mean score for appearance (7.90) was for the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and low mean score (5.73) was for the commercial wax treated fruits packaged in box without tray.

4.5.1.1.4.2. Colour

The effects of edible coatings and packaging on the colour of mature green tomato fruits stored under ambient and low temperature are shown in Table 99. Significant differences were found between the colour of treated and untreated mature green tomato fruits packaged and stored in two different conditions during the entire storage period.

On the initial day of storage, the highest rank with mean score (8.73) for colour was for the commercial wax coated fruits packaged in 5% ventilated CFB box with tray under ambient storage. On 15th day, highest mean score of 8.13 was observed by the papaya leaf extract incorporated aloe gel treated fruits kept under ambient storage, irrespective of packaging systems. Least rank with mean scores on initial and 15th day were obtained for the untreated fruits (7.93and 6.33 respectively) packaged in 5% ventilated CFB box with tray under low temperature storage.

On the 30th day of storage the highest rank with mean score (8.00) for colour was for the mature green fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box without tray under low temperature and least mean score (5.67) was for the fruits treated with commercial wax and packaged in 5% ventilated CFB box without tray under ambient storage.

On the 45th and 60th day of storage highest rank with mean scores for colour (7.67 and 7.60 respectively) were for the papaya leaf extract incorporated aloe gel coated fruits packaged in 5% ventilated CFB box with tray. The least ranks and mean scores (5.53 and 5.00 respectively) were for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray under low temperature storage.

Table 98. Effect of edible film coatings and packaging on the appearance of mature green tomatoes during storage

Treatments	0th day		15th day		30th day		45th day		60th day	
	Ambient temperature (S1)									
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.60	8.60	8.40	8.40	7.00	7.07	-	-	-	-
Commercial wax	8.00	8.40	7.13	7.27	6.00	5.93	-	-	-	-
Control	8.20	8.27	7.27	7.40	6.71	6.74			-	-
	Optimum low temperature (S2)									
Papaya leaf incorporated AG	8.30	8.53	8.25	8.30	8.20	8.27	8.00	8.00	7.86	7.90
Commercial wax	8.07	8.00	7.20	7.60	6.80	7.00	6.50	6.80	5.73	6.07
Control	8.47	8.20	7.20	7.33	6.93	7.27	6.67	7.00	-	-
X^2 value	26.35		117.13		128.27		23.45		22.56	
Kw value	**19.68**				**20.78**		**20.67**		**19.99**	

Table 99. Effect of edible film coatings and packaging on the colour of mature green tomatoes during storage

Treatments	0th day		15th day		30th day		45th day		60th day	
	Ambient temperature (S1)									
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.33	8.33	8.13	8.13	7.71	7.00	-	-	-	-
Commercial wax	8.07	8.73	7.00	7.00	5.67	6.00	-	-	-	-
Control	8.40	8.20	7.47	6.93	6.00	5.93	-	-	-	-
	Optimum low temperature (S2)									
Papaya leaf incorporated AG	8.10	8.20	8.05	8.07	8.00	7.93	7.53	7.67	7.50	7.60
Commercial wax	8.27	8.13	6.87	7.27	5.93	7.17	5.53	7.07	5.00	6.00
Control	8.07	7.93	7.13	6.33	6.80	6.30	6.60	6.17	-	-
X^2 value	22.24		101.38			133.78	25.67		21.88	
Kw value	**19.68**					**20.78**	**20.67**		**19.99**	

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

4.5.1.1.4.3. Flavour

The effects of coatings and packaging on the flavour of fruits stored under ambient and low temperature are shown in Table 100. All the treatments were significantly different from each other influencing the flavour of tomato fruits during the entire storage period.

On the initial day of storage highest rank with mean score for flavour (8.33) was recorded by fruits treated with papaya leaf extract incorporated aloe gel packaged in 5% ventilated CFB box with and without trays under ambient temperature. Least rank with sensory mean score (6.40) was recorded by commercial wax treated fruits packaged in 5% ventilated CFB box without tray and stored under low temperature.

On the 15th day of storage, the highest rank with mean score for flavour was recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray under ambient temperature (8.13) and least mean score (5.53) was for the fruits treated with commercial wax and packaged in 5% ventilated CFB box with tray under low temperature storage condition.

On the 30th day of storage, highest rank with mean score (7.93) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with and without tray stored under low temperature and least mean score (5.13) was for the commercial wax treated fruits packaged in 5% ventilated CFB box with tray under ambient temperature.

On the 45th day of storage the highest rank with mean score (7.73) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and least mean score (4.93) was for the fruits treated with commercial wax, both packaged in 5% ventilated CFB box with tray.

On the 60th day of storage highest rank as well as mean score for flavour was for the papaya leaf extract incorporated aloe gel treated fruits (7.70) and least mean score (4.20) was for the commercial wax treated fruits, both packaged in 5% ventilated CFB box with tray under low temperature storage.

4.5.1.1.4.4. Taste

The effects of coatings and packaging on the taste of mature green fruits stored under ambient and low temperature are shown in Table 101. Significant differences were found between the taste of treated and untreated mature green fruits packaged in two different packaging and storage conditions during the entire storage period.

Papaya leaf extract incorporated aloe gel coated fruits packaged in 5% ventilated CFB box with tray and subjected to low temperature storage had highest sensory rank and scores for taste throughout the storage period. The scores recorded were 8.47, 8.33, 8.00, 7.80 and 7.80 during 0, 15, 30, 45 and 60 days of storage respectively.

Least rank with mean scores (6.53 and 6.00 respectively) were for the commercial wax treated fruits packaged in 5% ventilated CFB box with tray under ambient temperature storage during initial and 15th day of storage.

On the 30th day of storage the rank and mean score were least (5.87) for the fruits treated with commercial wax and packaged in 5% ventilated CFB box with and without tray under ambient storage.

On the 45th and 60th day of storage highest ranks and mean scores for taste (7.80) were for the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray under low temperature conditions. The least mean score (6.33) was for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray under low temperature storage.

4.5.1.1.4.5. Texture

The effects of coatings and packaging on the texture of fruits stored under ambient and low temperature are shown in Table 102. All the treatments were significantly different from one another in influencing the texture of fruits during the entire storage period.On the initial day of storage highest rank with mean score (8.67) for texture was recorded by mature green fruits treated with papaya leaf extract incorporated aloe gel

Table 100. Effect of edible film coatings and packaging on the flavour of mature green tomatoes during storage

Treatments	0th day		15th day		30th day		45th day		60th day	
	Ambient temperature (S1)									
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.33	8.33	8.07	8.13	7.65	7.40	-	-	-	-
Commercial wax	7.40	7.13	5.60	5.53	5.33	5.13	-	-	-	-
Control	8.20	8.27	7.13	7.07	6.07	6.20	-	-	-	-
	Optimum low temperature (S2)									
Papaya leaf incorporated AG	8.10	8.27	8.05	8.07	7.93	7.93	7.60	7.73	7.60	7.70
Commercial wax	6.40	7.00	5.67	5.40	5.33	5.35	5.20	4.93	4.93	4.20
Control	7.93	7.47	6.33	7.23	6.13	7.00	6.03	6.60	-	-
X^2 value	47.78		133.34		128.67		23.78		23.56	
Kw value	**19.68**				**20.78**		**20.67**		**19.99**	

Table 101. Effect of edible film coatings and packaging on the taste of mature green tomatoes during storage

Treatments	0th day		15th day		30th day		45th day		60th day	
	Ambient temperature (S1)									
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.20	8.13	7.93	7.93	7.22	7.60	-	-	-	-
Commercial wax	7.00	6.53	6.53	6.00	5.87	5.87	-	-	-	-
Control	8.10	8.17	6.93	7.13	6.89	6.00	-	-	-	-
	Optimum low temperature (S2)									
Papaya leaf incorporated AG	8.23	8.47	8.10	8.33	8.00	8.00	7.73	7.80	7.73	7.80
Commercial wax	7.20	7.07	6.73	6.87	6.67	6.80	6.33	6.40	6.33	6.40
Control	8.20	8.07	7.60	7.47	7.17	7.27	7.13	7.07	-	-
X^2 value	75.37		119.66		138.78		27.68		24.34	
Kw value	**19.68**				**20.78**		**20.67**		**19.99**	

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

and packaged in 5% ventilated CFB box with trays under low temperature storage. Least mean scores (8.00) were recorded by commercial wax treated and untreated fruits packaged in 5% ventilated CFB box without tray under low temperature.

On the 15th day of storage the highest mean score (8.27) was recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray under ambient temperature and lowest mean score (6.13) was for the untreated fruits packaged in 5% ventilated CFB box under low temperature storage condition.

On the 30th day of storage, highest mean score (7.73) was recorded by mature green tomato fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray stored under low temperature and least mean score (5.47) was for the untreated fruits packaged in 5% ventilated CFB box without tray and stored under ambient temperature.

On the 45th day of storage the comparison was made only between the treated and untreated fruits under low temperature. The highest rank with mean score for texture (7.53) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with and without tray and least mean score (5.40) was for the untreated fruits packaged in 5% ventilated CFB box without tray.

On the 60th day of storage highest rank with mean score for texture (7.53) was obtained for fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and least mean score (5.67) was for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray, both stored under low temperature.

4.5.1.1.4.6. Overall acceptability

The effects of coatings and packaging on the overall acceptability of mature green fruits stored under ambient and low temperature condition are shown in Table 103. Significant difference was found between the treatments on the overall acceptability during the storage period of 60 days.

On the initial day of storage highest rank with mean score for overall acceptability (8.53) was recorded by fruits treated with papaya leaf extract incorporated aloe gel, packaged in 5% ventilated CFB box without trays under ambient temperature. Least rank with mean score (7.20) was recorded by commercial wax treated fruits packaged in 5% ventilated CFB box with tray under low temperature.

On the 15th day of storage the highest mean score (8.40) was recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and lowest mean score (6.73) was for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray, both under ambient temperature storage condition.

On the 30th day of storage, highest mean score (8.10) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and stored under low temperature and least mean score (5.80) was for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray under ambient temperature.

On the 45th day of storage the highest mean score (7.80) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and least mean score (6.20) was for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray, all kept under low temperature.

On the 60th day of storage highest rank with mean score for overall acceptability (7.70) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with and without tray and least mean score (6.00) was for the commercial wax treated fruits packaged in 5% ventilated CFB box without tray under low temperature.

Table 102. Effect of edible film coatings and packaging on the texture of mature green tomatoes during storage

Treatments	0th day		15th day		30th day		45th day		60th day	
	Ambient temperature (S1)									
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.47	8.47	8.13	8.27	7.50	7.53	-	-	-	-
Commercial wax	8.13	8.53	7.93	8.07	6.87	6.93	-	-	-	-
Control	8.10	8.07	7.80	7.00	5.47	5.93	-	-	-	-
	Optimum low temperature (S2)									
Papaya leaf incorporated AG	8.13	8.67	7.80	8.22	7.70	7.73	7.53	7.53	7.47	7.53
Commercial wax	8.00	8.27	7.20	7.20	7.13	7.27	5.67	6.07	5.67	6.07
Control	8.00	8.05	6.13	6.93	5.87	6.40	5.40	6.00	-	-
X^2 value	21.06		103.47		139.89		29.67		23.49	
Kw value	**19.68**				**20.78**		**20.67**		**19.99**	

Table 103. Effect of edible film coatings and packaging on the overall acceptability of mature green tomatoes during storage

Treatments	0th day		15th day		30th day		45th day		60th day	
	Ambient temperature (S1)									
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.53	8.50	8.33	8.40	7.90	8.00	-	-	-	-
Commercial wax	7.33	7.67	6.73	6.87	5.80	5.93	-	-	-	-
Control	8.30	8.20	7.07	7.13	6.00	6.27	-	-	-	-
	Optimum low temperature (S2)									
Papaya leaf incorporated AG	8.47	8.47	8.07	8.13	8.00	8.10	7.73	7.80	7.70	7.70
Commercial wax	7.40	7.20	6.90	6.87	6.53	6.67	6.20	6.47	6.00	6.17
Control	8.20	8.13	7.40	7.53	6.87	6.93	6.47	6.40	-	-
X^2 value	57.50		110.62		132.78		31.78		24.90	
Kw value	**19.68**				**20.78**		**20.67**		**19.99**	

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray.

4.5.1.2 FIRM RIPE TOMATO

Firm ripe tomato fruits were dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 and were compared with fruits coated with a commercial bee wax formulation each at 1% concentration for one minute and packaged in 5% ventilated Corrugated Fibre Board (CFB) boxes with and without moulded tray and stored under the ambient and optimum low temperature condition along with untreated fruits. The following physiological, chemical, microbial and physical parameters of fruits were analyzed at 12 days interval till they had lost their shelf life.

Both the packaged tomato fruits stored under ambient conditions were decayed after the 12th day of storage and comparison could be made only between the fruits stored under optimum low temperature condition on 24th day of storage. By 36thday of storage, all the uncoated/control fruits were decayed and all observations were taken only for the coated tomato fruits kept under low temperature condition.

4.5.1.2.1. Physiological parameters

The following physiological parameters were analyzed at 12 days interval till they had lost their shelf life and are shown in Table 104 to 106.

4.5.1.2.1.1. Physiological Loss in Weight (PLW)

Physiological loss in weight (PLW) of coated and packaged firm ripe tomatoes recorded at 12 days interval during storage is shown in Table 104. Firm ripe tomato fruits stored under low temperature recorded the least PLW (8.78%) compared to those stored ambient storage condition (12.83%) on the 12th day of storage. Packaging in 5% ventilated CFB box with and without moulded tray was found equally effective in reducing the weight loss of firm ripe fruits over the entire storage period of 36 days.

Firm ripe fruits treated with papaya leaf extract incorporated aloe gel recorded the least PLW on the 12th and 24th day of storage (7.53% and 7.33% respectively). PLW of papaya leaf extract incorporated aloe gel treated fruits was on par with commercial wax treated fruits (7.58%) on the 24th day of storage. On the 36th day of storage there was no significant difference between the PLW of commercial wax (7.70%) and papaya leaf extract incorporated aloe gel (7.77%) treated firm ripe fruits.

Table 104. Effect of edible film coatings and packaging on the PLW of firm ripe tomatoes during storage

Physiological Loss in Weight (PLW) (%)					
12th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	9.78	9.06	6.43	4.87
	Commercial wax (T2)	8.16	9.60	6.73	8.32
	Control (T3)	21.11	19.27	14.11	12.22
Mean values	T1- 7.53: T2- 8.20: T3-16.68	P1-10.56 P2-11.05		S1 –12.83 S2 –8.78	
CD(0.05)	T=0.62	P = NS		S = 0.50	
	TxPxS = 1.24				
24th day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	7.29		7.37	
	Commercial wax (T2)	7.43		7.71	
	Control (T3)	18.28		16.78	
Mean values	T1-7.33: T2-7.58 : T3-17.53	P1-11.00 P2-10.62		TxP = 3.25	
CD(0.05)	T=2.30	P =NS			
36th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	7.94		7.46	
	Commercial wax (T2)	7.71		7.82	
Mean values	T1- 7.77: T2-7.70	P1-7.82 P2- 7.64		TxP = NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

The untreated/control fruits recorded the highest PLW on the 12th and 24th day of storage (16.68% and 17.53% respectively).

The interaction effects were significant till 24th day of storage. On the 12th day of storage, the least PLW (4.87%) was recorded by the papaya leaf extract incorporated aloe gel coated firm ripe fruits packaged in 5% ventilated CFB box with moulded tray and stored under low temperature which was significantly different from all the other treated fruits. Highest PLW (21.11%) was for the uncoated fruits packaged in 5% ventilated CFB box and stored under ambient condition.

On the 24th day of storage least PLW (7.29%) was recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% CFB box under low temperature storage and highest PLW was for the untreated fruits (18.28%) packaged in 5% CFB box under low temperature storage.

Interactive effects were non- significant in influencing the PLW of firm ripe tomatoes on the 36th day of storage.

4.5.1.2.1.2. Respiration rate

The respiration rate of coated and packaged firm ripe tomatoes recorded at 12 days interval during storage is shown in Table 105.

On the initial day of storage there was no significant difference between the respiration rates of firm ripe fruits under different storage temperatures. On the 12th day of storage the fruits stored under low temperature recorded the least respiration rate (6.65%) compared with to the fruits under ambient storage temperature (8.29%).

The effect of different packaging materials was non-significant in influencing the respiration rate of firm ripe fruits on the initial, 12th, 24th and 36th day of storage.

There was no significant difference between the respiration rate of fruits treated with commercial wax and papaya leaf extract incorporated aloe gel during the initial day of storage. On the 12thday of storage least respiration rate was recorded by the

Table 105. Effect of edible film coatings and packaging on the respiration rate of firm ripe tomatoes during storage

Respiration Rate (% CO_2 evolved)					
0^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	4.40	4.55	4.40	4.40
	Commercial wax (T2)	4.25	4.45	4.00	4.45
	Control (T3)	4.55	4.50	4.40	4.45
Mean values	T1-4.43: T2- 4.28: T3- 4.47	P1-4.46 P2-4.33		S1 –4.45 S2 – 4.35	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = 0.44				
12^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	8.34	8.01	6.25	6.05
	Commercial wax (T2)	7.94	7.39	5.55	5.65
	Control (T3)	9.06	8.99	8.60	7.80
Mean values	T1-7.16: T2-6.63: T3- 8.61	P1-7.62 P2- 7.31		S1 –8.29 S2 –6.65	
CD(0.05)	T=0.47	P = NS		S = 0.38	
	TxPxS = NS				
24^{th} day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	7.05		6.95	
	Commercial wax (T2)	7.10		6.15	
	Control (T3)	10.39		10.80	
Mean values	T1- 7: T2-6.63: T3-10.60	P1-8.18 P2- 7.96		TxP = NS	
CD(0.05)	T= 1.10	P = NS			
36^{th} day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	7.00		6.95	
	Commercial wax (T2)	7.00		7.05	
Mean values	T1-7.23: T2-7.02	P1-7.25 P2-7.00		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

fruits treated with commercial wax (6.63%). On 24th day, papaya leaf extract incorporated aloe gel and commercial wax treated fruits had similar respiration rate (7.00% and 6.63% respectively). On the 36th day both papaya leaf extract incorporated aloe gel and commercial wax coatings were equally effective in influencing the respiration rate of firm ripe tomatoes. Highest respiration rate was recorded by the untreated fruits (8.61% and 10.60% respectively) during 12th and 24th day of storage.

On comparing the interaction effects, respiration rate was least (4.00%) for commercial wax coated fruits packaged in 5% CFB box and stored under low temperature on the initial day. The interaction effect was non significant on the 12th, 24th and 36th days of storage.

4.5.1.2.1.3. Membrane integrity

The percent leakage of edible film coated firm ripe fruits packaged in two types of CFB boxes during storage was recorded at 12 days interval for measuring membrane integrity and is shown in Table 106.

Percent leakage was same for the coated and packaged firm ripe fruits under different storage condition on the initial day. On the 12th day, the least percent leakage (74.60%) was recorded by the fruits stored under low temperature compared to the fruits under ambient temperature (84.60%).

There was no significant difference between the percent leakage of fruits subjected to two different packaging materials, during the entire storage period of 36 days irrespective of edible coatings.

There was significant difference among the percent leakage of fruits coated with different edible coatings till 24th day of storage. On the initial and 12th day the least percent leakage was for the fruits coated with commercial wax formulation (70.28% and 75.77% respectively). Least percent leakage was for the commercial wax treated fruits (77.10%) which was on par with the papaya leaf extract incorporated aloe gel treated fruits (77.60%) on 24th day of storage. Uncoated fruits

Table 106. Effect of edible film coatings and packaging on the percent leakage of firm ripe tomatoes during storage

Percent Leakage (%)					
0^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	70.80	72.61	71.05	71.43
	Commercial wax (T2)	70.80	70.27	70.84	69.21
	Control (T3)	75.88	73.61	75.21	74.83
Mean values	T1-71.48: T2-70.28 : T3- 74.89	P1- 72.43 P2-72.00		S1 –72.30 S2 –72.10	
CD(0.05)	T= 0.79	P = NS		S = NS	
	TxPxS = 1.58				
12^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	82.89	83.22	73.17	72.09
	Commercial wax (T2)	80.60	80.43	71.67	70.35
	Control (T3)	91.37	89.32	81.09	79.45
Mean values	T1-77.85: T2-75.77: T3-85.31	P1-80.13 P2- 79.15		S1 –84.60 S2 – 74.60	
CD(0.05)	T=1.34	P = NS		S = 1.09	
	TxPxS = 2.68				
24^{th} day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	78.90		76.27	
	Commercial wax (T2)	76.37		77.85	
	Control (T3)	91.74		90.83	
Mean values	T1- 77.60: T2-77.10: T3- 91.30	P1-82.34 P2-81.65		TxP = NS	
CD(0.05)	T=3.23	P = NS			
36^{th} day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	81.37		79.28	
	Commercial wax (T2)	77.71		79.38	
Mean values	T1-80.30: T2- 78.50	P1-79.54 P2- 79.32		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

had highest percent leakage till the 24th day of storage. On the 36th day of storage there was no significant difference between the percent leakage of papaya leaf extract incorporated aloe gel and commercial wax coated firm ripe fruits.

When interaction effects (edible coating x packaging systems x storage temperature) were compared on the initial day, the least percent leakage was recorded by the commercial wax coated fruits (69.21%) packaged in 5% ventilated CFB box with moulded tray stored under low temperature. This was on par with the fruits treated with commercial wax and packaged in 5% CFB box with tray and stored under ambient storage temperature. On the 12th day of storage firm ripe fruits treated with commercial wax and packaged in 5% ventilated CFB box with moulded tray recorded the least percent leakage (70.35%) which was on par with the fruits treated with commercial wax and packaged in 5% ventilated CFB box (71.67%) and papaya leaf extract incorporated aloe gel treated fruits packaged in 5% CFB box (72.09%) with tray under low temperature storage. The percent leakage of firm ripe fruits remained same for both papaya leaf extract incorporated aloe gel and commercial wax coated fruits on the 24th and 36th day of storage.

4.5.1.2.2. Chemical parameters

The following chemical parameters of coated firm ripe tomato fruits subjected to two different packaging systems and storage conditions were analyzed at 12 days interval till they had lost their shelf life and are shown in Table 107 to 111.

4.5.1.2.2.1. Total Soluble Solids (TSS)

Total Soluble Solids (TSS) of coated firm ripe tomato fruits subjected to two different packaging systems and storage conditions, recorded at 12 days interval is shown in Table 107.

During the entire storage period, there was no significant difference between the TSS content of fruits stored under ambient and low temperature condition. Both the packaging conditions were equally effective in influencing the TSS content of coated and packaged fruits during the entire storage period.

Table 107. Effect of edible film coatings and packaging on the TSS of firm ripe tomatoes during storage

TSS (^{0} Brix)					
0^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	4.65	4.40	4.65	4.15
	Commercial wax (T2)	4.65	4.45	4.55	4.50
	Control (T3)	4.65	4.45	4.50	4.55
Mean values	T1-4.46: T2-4.48 : T3-4.53	P1- 4.45 P2-4.54		S1 –4.45 S2 –4.54	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
12^{th} day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	4.40	4.15	4.55	4.20
	Commercial wax (T2)	4.30	4.35	4.05	4.55
	Control (T3)	4.45	4.55	4.50	4.75
Mean values	T1-4.53: T2-4.31: T3-4.33	P1-4.42 P2- 4.42		S1 –4.39 S2 –4.45	
CD(0.05)	T=0.19	P = NS		S = NS	
	TxPxS = NS				
24^{th} day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	4.25		4.30	
	Commercial wax (T2)	4.10		3.90	
	Control (T3)	4.05		4.15	
Mean values	T1-4.27 : T2-4.00: T3- 4.10	P1-4.11 P2-4.13		TxP = NS	
CD(0.05)	T= NS	P = NS			
36^{th} day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	4.05		4.15	
	Commercial wax (T2)	3.85		3.90	
Mean values	T1- 4.10: T2- 3.87	P1-3.97P2- 4.00		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

The treatments had no significant influence on TSS content of fruits during the initial day, 24th and 36th day of storage and when comparison was made among the treatments on the 12th day of storage, the highest TSS (4.53^{0}B) was recorded by the firm ripe fruits coated with papaya leaf extract incorporated aloe gel which was significantly different from untreated fruits (4.33^{0}B) and least TSS was recorded by the commercial wax coated fruits (4.31^{0}B).

When the interaction effects were considered, there was no significant difference between the TSS content of both treated and untreated fruits subjected to different packaging and storage systems during the entire storage period.

4.5.1.2.2.2. pH

pH of coated firm ripe tomatoes subjected to two different packaging systems and storage conditions recorded at 12 days interval is shown in Table 108. Both the storage and packaging conditions did not have significant influence in the pH of coated firm ripe fruits during the entire storage period. The effect of treatments on the pH of firm ripe tomato was non-significant during the entire storage period of 36 days. There was no significant difference between the pH of firm ripe fruits treated with papaya leaf extract incorporated aloe gel and commercial wax and packaged in 5% ventilated CFB with and without moulded tray and stored under ambient and optimum low temperature conditions during the entire storage period.

4.5.1.2.2.3. Vitamin C content

The vitamin C content of firm ripe tomatoes as influenced by edible coating and packaging under different storage conditions were recorded at 12 days interval and is shown in Table 109.

Storage conditions were non- significant in influencing the vitamin C content of firm ripe fruits during the initial day. On the 12th day of storage, fruits stored under optimum low temperature recorded a high (16.21mg100g^{-1}) vitamin C content compared to the fruits stored under ambient temperature (12.21 mg100g^{-1}).

Table 108. Effect of edible film coatings and packaging on the pH of firm ripe tomatoes during storage

pH					
0th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	5.05	5.00	4.90	5.00
	Commercial wax (T2)	4.80	5.05	4.85	4.90
	Control (T3)	5.00	5.00	4.85	5.05
Mean values	T1-4.98: T2-4.88 : T3-5.01	P1-5.02 P2- 4.88		S1 –5.00 S2 – 4.91	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
12th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	5.20	5.25	5.10	5.20
	Commercial wax (T2)	5.25	5.25	5.20	5.20
	Control (T3)	5.20	5.20	5.25	5.25
Mean values	T1-5.18: T2-5.22: T3-5.22	P1-5.25 P2-5.17		S1 –5.22 S2 – 5.20	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
24th day of storage	Treatments			$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)			5.40	5.25
	Commercial wax (T2)			5.45	5.35
	Control (T3)			5.25	5.45
Mean values	T1-5.20 : T2-5.32: T3- 5.40			P1-5.33 P2- 5.28	TxP = NS
CD(0.05)	T= NS			P = NS	
36th day of storage	Treatments			S2P1	S2P2
	Papaya leaf incorporated AG (T1)			5.45	5.40
	Commercial wax (T2)			5.40	5.40
Mean values	T1-5.42: T2-5.45			P1-5.47: P2- 5.40	TxP – NS
CD(0.05)	T = NS			P = NS	

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

Table 109. Effect of edible film coatings and packaging on vitamin C content of firm ripe tomatoes during storage

Vitamin C content ($mg100g^{-1}$)					
0th day of storage	Treatments	S1P1	S1P2	S2P1	S2P2
	Papaya leaf incorporated AG (T1)	18.18	16.36	16.36	18.18
	Commercial wax (T2)	18.18	16.36	16.36	16.36
	Control (T3)	16.36	18.18	16.36	18.18
Mean values	T1-17.27: T2-16.82 : T3- 17.27	P1-17.27 : P2- 17.27		S1 –17.27: S2 – 17.27	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
12th day of storage	Treatments	S1P1	S1P2	S2P1	S2P2
	Papaya leaf incorporated AG (T1)	13.77	14.72	17.93	17.86
	Commercial wax (T2)	13.74	14.44	16.36	16.61
	Control (T3)	9.79	10.13	12.73	12.73
Mean values	T1-15.22: T2-15.32: T3- 12.11	P1-14.42: P2-14.00		S1 –12.21: S2 – 16.21	
CD(0.05)	T=2.14	P = NS		S = 1.75	
	TxPxS = 4.29				
24th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	14.55		14.55	
	Commercial wax (T2)	13.61		16.76	
	Control (T3)	8.50		9.35	
Mean values	T1- 14.55: T2-15.19: T3-8.93	P1-12.22: P2- 13.55		TxP = NS	
CD(0.05)	T=2.54	P = NS			
36th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	9.90		10.13	
	Commercial wax (T2)	9.35		9.95	
Mean values	T1-10.02: T2- 9.65	P1-9.62: P2- 10.04		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

The vitamin C content of firm ripe fruits packaged in 5% ventilated CFB box with and without moulded tray were similar throughout the storage period of 36 days.

When comparison was made among the treatments there was no significant difference between the vitamin C content of edible film coated firm ripe fruits on the initial day of storage. On the 12th and 24th day of storage, highest vitamin C content was recorded in the commercial wax coated fruits (15.32mg100g^{-1} and 15.19mg100g^{-1} respectively) which was on par with the papaya leaf extract incorporated aloe gel treated fruits (15.22mg100g^{-1} and 14.55mg100g^{-1}respectively). The untreated fruits had lowest vitamin C content on 12th and 24th day of storage (112.11mg100g^{-1} and 8.93mg100g^{-1}). On the 36th day there was no significant difference between the vitamin C content of firm ripe fruits coated with different skin coatings.

The interaction (edible coating × packaging × storage temperature) effect was non-significant during the initial day of storage. On the 12th day of storage, highest vitamin C content (17.93mg100g^{-1}) was recorded by the papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box and stored under low temperature which was on par with all the treated fruits stored under both the temperature conditions irrespective of packaging systems. The least vitamin C content was recorded by untreated fruits packaged in 5% ventilated CFB box and stored under ambient temperature condition. The interaction effect was non-significant during 24th and the final day of storage.

4.5.1.2.2.4. Titratable acidity

The titratable acidity of coated firm ripe tomatoes subjected to different packaging and storage was recorded at 12 days interval till it had lost its shelf life and is shown in Table 110.

Titratable acidity was similar for fruits stored under both the conditions on the initial day of storage. On the 12th day of storage, fruits stored under low temperature recorded a high titratable acidity (0.759%) compared to those stored at ambient storage condition (0.553%).

Table 110. Effect of edible film coatings and packaging on the titratable acidity of firm ripe tomatoes during storage

Titratable acidity (%)					
0th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	0.655	0.655	0.655	0650
	Commercial wax (T2)	0.655	0.660	0.650	0.655
	Control (T3)	0.655	0.650	0.655	0.660
Mean values	T1-0.653: T2-0.655 : T3- 0.655	P1- 0.654: P2- 0.655		S1 –0.654: S2 – 0.655	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = NS				
12th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	0.555	0.585	0.750	0.750
	Commercial wax (T2)	0.550	0.545	0.775	0.755
	Control (T3)	0.540	0.545	0.745	0.760
Mean values	T1-0.655: T2-0.660: T3- 0.648	P1-0.649: P2- 0.649		S1 –0.553: S2 – 0.759	
CD(0.05)	T=0.01	P = NS		S = 0.01	
	TxPxS = 0.03				
24th day of storage	Treatments	S2P$_1$		S2P$_2$	
	Papaya leaf incorporated AG (T1)	0.540		0.545	
	Commercial wax (T2)	0.555		0.555	
	Control (T3)	0.460		0.500	
Mean values	T1-0.543 : T2-0.555: T3-0.480	P1-0.520: P2- 0.531		TxP = NS	
CD(0.05)	T=0.03	P = NS			
36th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	0.550		0.555	
	Commercial wax (T2)	0.530		0.565	
Mean values	T1-0.553: T2- 0.547	P1-0.542: P2-0.557		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

Packaging conditions were not effective in influencing the titratable acidity of firm ripe fruits during the entire storage period.

When comparison was made among different treatments, there was no significant difference between the titratable acidity of treated and untreated fruits on the initial day. On the 12th and 24th day of storage, highest titratable acidity was recorded by the commercial wax coated fruits (0.660% and 0.555% respectively), which was on par with the papaya leaf extract incorporated aloe gel treated firm ripe fruits (0.655% and0.543% respectively). On the 36th day of storage both the coatings were equally effective in influencing the titratable acidity of firm ripe fruits.

The interaction (edible coating × packaging × storage temperature) effect was significant only during the 12thday of storage. The highest titratable acidity (0.775%) was recorded by commercial wax coated fruits packaged in CFB box and stored under optimum low temperature. This was on par with all the fruits kept under low temperature irrespective of packaging systems and edible coatings.

4.5.1.2.2.5. Lycopene content

The lycopene content of edible film coated firm ripe tomatoes subjected to different packaging systems and storage conditions was recorded at 12 days interval till it had lost its shelf life and is shown in Table 111.

There was no significant difference between the lycopene content of firm ripe tomatoes stored in both conditions on the initial day of storage. On the 12th day of storage, fruits stored under low temperature recorded a lower lycopene content (37.02$\mu g g^{-1}$) compared to the fruits under ambient storage (45.45$\mu g g^{-1}$).

The effect of packaging was found non significant in influencing the lycopene content of firm ripe fruits during the entire storage period.

The comparison of lycopene content between treated and untreated fruits was non significant on the initial day. Fruits treated with commercial wax recorded least lycopene content (40.06$\mu g g^{-1}$) on 12th day, which was on par with papaya leaf extract

Table 111. Effect of edible film coatings and packaging on lycopene content of firm ripe tomatoes during storage

Lycopene content (μgg^{-1})					
0th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	36.26	36.71	34.81	37.37
	Commercial wax (T2)	36.81	33.93	34.87	34.32
	Control (T3)	36.87	34.27	34.33	35.20
Mean values	T1-36.29: T2-35.17 : T3- 36.99	P1-36.33 P2- 35.97		S1 –36.49 S2 –35.81	
CD(0.05)	T= NS	P = NS		S = NS	
	TxPxS = 4.63				
12th day of storage	Treatments	S1P$_1$	S1P$_2$	S2P$_1$	S2P$_2$
	Papaya leaf incorporated AG (T1)	45.15	43.37	37.21	35.67
	Commercial wax (T2)	43.61	43.72	35.67	35.22
	Control (T3)	47.97	48.89	39.98	38.67
Mean values	T1-40.53: T2-40.06: T3- 43.13	P1-41.55 P2- 40.93		S1 –45.45 S2 – 37.02	
CD(0.05)	T=1.65	P = NS		S = 1.34	
	TxPxS = 3.03				
24th day of storage	Treatments	S2P$_1$	S2P$_2$		
	Papaya leaf incorporated AG (T1)	46.80	44.22		
	Commercial wax (T2)	40.92	39.88		
	Control (T3)	47.73	45.72		
Mean values	T1-45.51 : T2-40.40: T3-48.72	P1-45.15: P2- 43.28	TxP = 4.30		
CD(0.05)	T=3.04	P = NS			
36th day of storage	Treatments	S2P1	S2P2		
	Papaya leaf incorporated AG (T1)	47.82	44.33		
	Commercial wax (T2)	41.40	41.08		
Mean values	T1-46.08: T2-41.24	P1-44.45 : P2- 42.87	TxP – 3.17		
CD(0.05)	T = 2.24	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

incorporated aloe gel treated fruits (40.53µgg^{-1}). Commercial wax treated fruits had least lycopene content (40.40µgg^{-1}) during the 24th and 36th days of storage.

When the interaction effect was compared, it was non significant on the initial day. On the 12th day of storage, least lycopene content (35.22µgg^{-1}) was recorded by the commercial wax treated fruits packaged in 5% ventilated CFB box with tray and stored under low temperature.

On the 24thday of storage, commercial wax coated firm ripe fruits packaged in 5% ventilated CFB box with tray recorded the least lycopene content (39.88µgg^{-1}) which was on par with the fruits packaged in 5% ventilated CFB box without tray under low temperature storage. On 36th day, commercial wax coated fruits packed in CFB box with tray had least lycopene (41.08µgg^{-1}), which was on par with those packaged under CFB boxes without tray (41.40µgg^{-1}).

4.5.1.2.3. Microbial parameters

The effect of edible skin coatings and packaging on bacterial count observed on the surface of firm ripe tomatoes was recorded at 12 days interval and is shown in Table 112.

Initially the bacteria on the surface of both papaya leaf extract incorporated aloe gel and commercial wax treated fruits packaged in 5% ventilated box CFB with and without tray under ambient and low temperature storage was too less to count.

The bacterial count was too numerous for untreated fruits irrespective of packaging and storage conditions during the entire storage period.

On the 12th day of storage the lower bacterial count was recorded in fruits stored under low temperature (4.4x10^{2}cfu/g) compared to fruits under ambient storage condition (5.6 x10^{2}cfu/g).

The effect of two different packaging conditions were non-significant in influencing the bacterial load recorded on the fruits throughout the storage period.

Table 112. Effect of edible film coatings and packaging on the microbial load of firm ripe tomatoes during storage

(Bacterial population x10²cfu/g)					
0th day of storage	Treatments	$S1P_1$	$S1P_2$	$S2P_1$	$S2P_2$
	Papaya leaf incorporated AG (T1)	TLTC	TLTC	TLTC	TLTC
	Commercial wax (T2)	TLTC	TLTC	TLTC	TLTC
	Control (T3)	TNTC	TNTC	TNTC	TNTC
12th day of storage	Treatments				
	Papaya leaf incorporated AG (T1)	6.8	6.3	3.6	3.5
	Commercial wax (T2)	6.3	6.2	3.4	3.2
	Control (T3)	TNTC	TNTC	TNTC	TNTC
Mean values	T1- 4.8: T2- 4.3: T3- tntc	P1- 4.6: P2- 4.4		S1 – 5.6: S2 – 4.4	
CD(0.05)	T=NS	P = NS		S = 0.60	
	TxPxS = 1.4				
24th day of storage	Treatments	$S2P_1$		$S2P_2$	
	Papaya leaf incorporated AG (T1)	4.6		4.3	
	Commercial wax (T2)	4.3		4.2	
	Control (T3)	TNTC		TNTC	
Mean values	T1- 4.4: T2- 4.3: T3- TNTC	P1- 4.4: P2- 4.3		TxP = NS	
CD(0.05)	T= NS	P = NS			
36th day of storage	Treatments	S2P1		S2P2	
	Papaya leaf incorporated AG (T1)	4.6		4.4	
	Commercial wax (T2)	4.5		4.5	
Mean values	T1- 4.5: T2- 4.4	P1- 4.5: P2- 4.4		TxP – NS	
CD(0.05)	T = NS	P = NS			

*S1 – Ambient temperature : *S2 – Optimum low temperature
*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

When comparison was made among treatments, all the treatments were equally effective in maintaining the bacterial population on the fruit surface throughout the storage period.

The interaction effects had significant influence on the microbial count during 12^{th} day of storage. On the 12^{th} day of storage, least bacterial count was observed on the commercial wax coated fruits packaged in 5% ventilated CFB box with tray stored under low temperature(3.2×10^2cfu/g), which was on par with all the treated fruits stored under low temperature. Highest bacterial load (6.8×10^2cfu/g) was on the fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box under ambient storage condition.

On the 24^{th} and 36^{th} day of storage, the bacterial count was similar on the surface of all treated firm ripe fruits irrespective of packaging systems under low temperature storage condition.

4.5.1.2.4. Physical parameters

Effects of different edible film coatings and packaging systems on the physical quality parameters of firm ripe tomato were judged by the sensory panel at 12 days interval and the mean scores and ranks are shown in Table 113 to 118.

4.5.1.2.4.1. Appearance

The effects of coatings and packaging on the appearance of firm ripe fruits stored under ambient and low temperature are shown in Table 113. When the treatments were compared, significant differences were found between the appearance of fruits during the entire storage period.

On the initial day of storage highest rank with mean score for appearance (8.73) was recorded by fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with and without trays under low temperature storage. Least rank with mean score (7.93) was recorded by commercial wax coated fruits packaged in 5% ventilated CFB box under ambient temperature.

On the 12th, 24th and 36th day of storage the highest rank and scores (8.53, 8.40 and 8.20 respectively) were recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box under optimum low temperature. The lowest scores (7.68, 7.33 and 6.80) were for the fruits coated with commercial wax and packaged in 5% ventilated CFB box under low temperature storage condition. Commercial wax coated fruits packaged in CFB box and stored under ambient condition also had least rank and score during 12th day of storage.

4.5.1.2.4.2. Colour

The effects of coatings and packaging on the colour of firm ripe tomato fruits stored under ambient and low temperature are shown in Table 114.

On the initial day of storage, there was no significant difference between the colour of firm ripe tomato fruits, however highest mean sensory score (8.46) was recorded by fruits coated with papaya leaf extract incorporated aloe gel packaged in 5% ventilated CFB box under low temperature storage and least score was for the untreated fruits packaged in 5% ventilated CFB box (8.05) with tray under low temperature storage.

Significant difference was noticed between colour of coated and uncoated firm ripe tomato fruits subjected to two different packaging and storage conditions from the 12th day of storage onwards. On the 12th and 24th day of storage, fruits coated with papaya leaf extract incorporated aloe gel, packaged in 5% ventilated CFB box and stored under low temperature scored highest ranks with mean scores (8.40 and 8.23 respectively) for colour.

On the 36th day of storage highest rank with mean score (7.87) was for the fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and least rank with score (6.53) was for the commercial wax treated fruits packaged in 5% ventilated CFB box both under low temperature storage.

Table 113. Effect of edible film coatings and packaging on the appearance of firm ripe tomatoes during storage

Treatments	Appearance							
	0th day		12th day		24th day		36th day	
	Ambient temperature (S1)							
	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.66 (2)	8.33 (3)	8.30 (3)	8.33 (2)	-	-	-	-
Commercial wax	7.93 (9)	8.20 (6)	7.68 (7)	7.73 (6)	-	-	-	-
Control	8.21 (5)	8.06 (8)	7.89 (5)	8.00 (4)	-	-		
	Optimum low temperature (S2)							
Papaya leaf incorporated AG	8.73 (1)	8.73 (1)	8.53 (1)	8.33 (2)	8.40 (1)	8.30 (2)	8.20 (1)	8.00 (2)
Commercial wax	8.26 (4)	8.26 (4)	7.68 (7)	7.73 (6)	7.33 (6)	7.40 (5)	6.80 (4)	7.00 (3)
Control	8.13 (7)	8.26 (4)	7.89 (5)	8.00 (4)	7.53 (4)	7.87 (3)	-	-
X^2 value	26.05		21.65		29.14		29.76	
Kw value	**20.78**				**20.67**		**20.67**	

Table114. Effect of edible film coatings and packaging on the colour of firm ripe tomatoes during storage

Treatments	Colour							
	0th day		12th day		24th day		36th day	
	Ambient temperature (S1)							
	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.23	8.20	8.05 (5)	8.15 (3)	-	-	-	-
Commercial wax	8.20	8.13	7.70 (10)	7.78 (9)	-	-	-	-
Control	8.07	8.13	7.68 (11)	7.79 (8)	-	-		
	Optimum low temperature (S2)							
Papaya leaf incorporated AG	8.46	8.30	8.40 (1)	8.20 (2)	8.23 (1)	8.13 (2)	7.83 (2)	7.87 (1)
Commercial wax	8.26	8.13	7.87 (7)	7.65 (12)	7.07 (6)	7.33 (5)	6.53 (4)	7.07 (3)
Control	8.10	8.05	8.10 (4)	8.00 (6)	7.53 (4)	7.73 (3)	-	-
X^2 value	12.81		23.13		26.57		50.45	
Kw value	**20.78**				**20.67**		**20.67**	

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

4.5.1.2.4.3. Flavour

The effects of coatings and packaging on the flavour of firm ripe tomato fruits stored under ambient and low temperature are shown in Table 115. All the treatments were significantly different from one another influencing the flavour of tomato fruits during the entire storage period.

Highest rank with mean scores for flavour were obtained for firm ripe fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box under low temperature storage till 24^{th} day of storage.

On the 36^{th} day of storage, papaya leaf extract incorporated aloe gel coated fruits packaged in 5% ventilated CFB box with moulded tray and stored under low temperature had highest rank with mean score of 7.73 for flavour. Least rank with score was for the fruits coated with commercial wax packaged in 5% ventilated CFB box (4.93) on the final day of storage.

4.5.1.2.4.4. Taste

The effects of different coatings and packaging on the taste of firm ripe fruits stored under ambient and low temperature are shown as mean scores and ranks in Table 116.

Significant differences were found between the taste of treated and untreated firm ripe fruits subjected to two different packaging and storage conditions during the entire storage period.

Highest rank and mean scores for taste were for the fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and stored under low temperature and least scores were for the commercial wax treated fruits packaged in 5% ventilated CFB box under low temperature storage during the entire storage period of 36 days.

4.5.1.2.4.5. Texture

The effects of edible film coatings and packaging on the texture of firm ripe fruits stored under ambient and low temperature are shown in Table 117. All the

Table 115. Effect of edible film coatings and packaging on the flavour of firm ripe tomatoes during storage

Treatments	Flavour							
	0th day		12th day		24th day		36th day	
	Ambient temperature (S1)							
	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.46 (2)	8.40 (3)	8.27 (3)	8.27 (3)	-	-	-	-
Commercial wax	6.86 (9)	6.73 (10)	6.47 (11)	6.73 (9)	-	-	-	-
Control	8.14 (5)	8.00 (6)	7.80 (6)	7.71 (7)	-	-		
	Optimum low temperature (S2)							
Papaya leaf incorporated AG	8.53 (1)	8.40 (3)	8.40 (1)	8.30 (2)	8.33 (1)	8.23 (2)	7.60 (2)	7.73 (1)
Commercial wax	7.13 (7)	7.00 (8)	7.07 (8)	6.65 (10)	7.00 (5)	6.13 (6)	4.93 (4)	5.20 (3)
Control	8.30 (4)	8.26 (5)	8.10 (4)	8.00 (5)	7.20 (4)	7.83 (3)	-	-
X^2 value	66.10		76.16		40.88		50.45	
Kw value	**20.78**				**20.67**		**20.67**	

Table 116. Effect of edible film coatings and packaging on the taste of firm ripe tomatoes during storage

Treatments	Taste							
	0th day		12th day		24th day		36th day	
	Ambient temperature (S1)							
	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.30 (3)	8.23 (4)	8.00 (6)	8.07 (4)	-	-	-	-
Commercial wax	6.86 (8)	6.73 (9)	5.87 (12)	6.00 (11)	-	-	-	-
Control	8.18 (5)	8.16 (6)	7.80 (8)	7.93 (7)	-	-		
	Optimum low temperature (S2)							
Papaya leaf incorporated AG	8.33 (2)	8.46 (1)	8.27 (2)	8.43 (1)	8.13 (2)	8.20 (1)	7.73 (2)	7.80 (1)
Commercial wax	6.26 (10)	6.73 (9)	6.07 (10)	6.47 (9)	6.00 (6)	6.33 (5)	5.40 (4)	6.00 (3)
Control	8.06 (7)	8.23 (4)	8.03 (5)	8.13 (3)	8.00 (3)	7.87 (4)	-	-
X^2 value	94.93		92.72		43.39		32.79	
Kw value	**20.78**				**20.67**		**20.67**	

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

treatments were significantly different from one another in influencing the texture of fruits during the entire storage period.

On the initial day of storage, highest rank with mean scores (8.50) for texture were recorded by firm ripe fruits treated with papaya leaf extract incorporated aloe gel packaged in 5% ventilated CFB box with trays and stored under ambient and low temperature. Least score (8.13) with rank was recorded by untreated fruits packaged in 5% ventilated CFB box stored under low temperature.

On the 12th and 24th day of storage, the highest rank and mean scores (8.47 and 8.40 respectively) were recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray under low temperature.

The highest and lowest mean scores (8.07 and 7.67) were obtained for the commercial wax coated fruits packaged in CFB box with and without tray respectively on the final day of storage.

4.5.1.2.4.6. Overall acceptability

The effects of coatings and packaging on the overall acceptability of firm ripe fruits stored under ambient and low temperature are shown in Table 118. Significant difference was noticed among the treatments on the overall acceptability during the storage period of 36 days.

On the initial day of storage highest rank with mean score for overall acceptability (8.66) was recorded by papaya leaf extract incorporated aloe gel treated fruits packaged in 5% ventilated CFB box stored under low temperature and least rank with score (7.20) was recorded by commercial wax treated fruits packaged in 5% ventilated CFB box under ambient temperature.

On the 12th day of storage the highest rank and score (8.53) were recorded by the fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with and without tray under low temperature storage and least

Table 117. Effect of edible film coatings and packaging on the texture of firm ripe tomatoes during storage

Texture								
Treatments	0th day		12th day		24th day		36th day	
	Ambient temperature (S1)							
	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.46 (2)	8.50 (1)	8.00 (7)	8.13 (6)	-	-	-	-
Commercial wax	8.26 (5)	8.26 (5)	8.23 (3)	8.19 (5)	-	-	-	-
Control	8.25 (5)	8.26 (5)	8.00 (7)	8.13 (6)	-	-		
	Optimum low temperature (S2)							
Papaya leaf incorporated AG	8.46 (2)	8.50 (1)	8.40 (2)	8.47 (1)	8.37 (2)	8.40 (1)	7.97 (3)	8.00 (2)
Commercial wax	8.30 (4)	8.35 (3)	8.20 (4)	8.20 (4)	8.13 (3)	8.03 (4)	7.67 (4)	8.07 (1)
Control	8.13 (7)	8.16 (6)	8.00 (7)	8.13 (6)	7.40 (6)	7.80 (5)	-	-
X^2 value	27.93		21.68		21.87		32.79	
Kw value	**20.78**				**20.67**		**20.67**	

Table 118. Effect of edible film coatings and packaging on the overall acceptability of firm ripe tomatoes during storage

Overall Acceptability								
Treatments	0th day		12th day		24th day		36th day	
	Ambient temperature (S1)							
	P1	P2	P1	P2	P1	P2	P1	P2
Papaya leaf incorporated AG	8.53 (4)	8.40 (6)	8.33 (3)	8.38 (2)	-	-	-	-
Commercial wax	7.20 (12)	7.53 (10)	7.02 (11)	7.13 (10)	-	-	-	-
Control	8.28 (7)	8.16 (8)	8.00 (6)	7.80 (7)	-	-		
	Optimum low temperature (S2)							
Papaya leaf incorporated AG	8.66 (1)	8.60 (2)	8.53 (1)	8.53 (1)	8.50 (1)	8.50 (1)	7.73 (2)	7.80 (1)
Commercial wax	7.40 (11)	7.60 (9)	7.27 (9)	7.40 (8)	7.23 (5)	7.37 (4)	6.20 (4)	6.47 (3)
Control	8.46 (5)	8.56 (3)	8.13 (4)	8.10 (5)	7.67 (3)	7.87 (2)	-	-
X^2 value	81.98		72.50		32.97		29.82	
Kw value	**20.78**				**20.67**		**20.67**	

*P1 – 5% ventilated CFB : *P2 - 5% ventilated CFB with tray

score (7.02) was for the commercial wax treated fruits packaged in 5% ventilated CFB box under ambient temperature storage condition.

On the 24th day of storage, highest score (8.50) for overall acceptability was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with and without tray stored under low temperature and least score (7.23) as well as rank was for the commercial wax treated fruits packaged in 5% ventilated CFB box under low temperature.

On the 36th day of storage, comparison was made between the two different treated fruits under low temperature. The highest rank with mean score (7.80) was recorded by fruits treated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with tray and least rank with score (6.20) was for the commercial wax treated fruits packaged in 5% ventilated CFB box.

4.5.2. Efficiency in withstanding transportation hazards

4.5.2.1 MATURE GREEN TOMATO

Mature green tomato fruits were dipped in 2% of papaya leaf extract incorporated aloe gel(1:2) + INS 402 and commercial bee wax formulation for two minutes and packaged in 5% ventilated Corrugated Fibre Board (CFB) boxes with and without moulded tray and transported to distant market to analyze the efficiency of edible coatings in withstanding transportation hazards. Tomato fruits without any coating were set as control for comparison. The harvest maturity for tomatoes meant for distant market is mature green stage and hence they were transported to 512 km distance in a reefer cargo van maintained at a temperature of 18^0C.

The following physiological, chemical, microbial and physical parameters of fruits were analyzed before and after subjecting to transportation and are shown below.

4.5.2.1.1. Physiological parameters

The following physiological parameters of coated and uncoated mature green fruits after packaging were analyzed before and after subjecting to transportation and are shown in Table 119 to 121.

4.5.2.1.1.1. Physiological Loss in Weight (PLW)

Physiological loss in weight (PLW) of coated and packaged mature green tomatoes analyzed before and after transportation is shown in Table 119.

The mature green fruits packaged in 5% ventilated CFB box with moulded tray recorded the low PLW (2.05%) compared to fruits packaged in 5% ventilated CFB box (2.38%) after transportation to the distant market.

When comparison was made among the treatments, fruits coated with commercial wax recorded the least PLW (1.95%) which was on par with the papaya leaf extract incorporated aloe gel coated fruits (2.03%).

The interaction effect on PLW of fruits was non significant in mature green tomato fruits.

4.5.2.1.1.2. Respiration rate

Respiration rate recorded before and after transportation of coated and packaged mature green tomatoes is shown in Table 120.

Respiration rate was less for the mature green fruits packaged in 5% ventilated CFB box with tray (6.46%) compared to packaging in 5% ventilated CFB box (6.96%).

The treatments were found significant in withstanding the transportation hazards of mature green fruits. The commercial wax coated fruits recorded the least respiration rate (6.53%) which was on par with the fruits coated with papaya leaf extract incorporated aloe gel (6.60%). Highest respiration rate was recorded in untreated fruits (7.00%).

The interaction effect on respiration rate of fruits after transportation was non significant.

Table 119.Effect of edible film coatings and packaging on the PLW of mature green tomatoes during transportation

Physiological loss in weight (%)							
	Before transportation			After transportation			CD (0.05)
Treatment	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	0	0	0	2.24	2.07	2.84	TxP- NS
5% CFB box (tray) (P2)	0	0	0	1.83	1.83	2.49	
Mean T	T1 – 2.03 : T2 – 1.95 : T3 – 2.66						T1xT2xT3 – 0.26
Mean P	P1- 2.38 : P2 – 2.05						P1xP2 – 0.21

Table 120.Effect of edible film coatings and packaging on the respiration rate of mature green tomatoes during transportation

Respiration rate (% CO_2 evolved)							
	Before transportation			After transportation			CD (0.05)
Treatment	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	6.65	6.55	6.60	7.15	7.15	7.65	TxP- NS
5% CFB box (tray) (P2)	6.15	6.00	6.60	6.45	6.40	7.15	
Mean T	T1 – 6.60 : T2 – 6.53 :T3 – 7.00						T1xT2xT3- 0.30
Mean P	P1- 6.96 : P2 – 6.46						P1xP2 – 0.25

4.5.2.1.1.3. Membrane integrity

Percent leakage of coated and packaged mature green tomatoes recorded before and after transportation is shown in Table 121.

The mature green fruits packaged in 5% ventilated CFB box with tray recorded a lower percent leakage (58.28%) compared to fruits packaged in 5% ventilated CFB box (60.05%).

Among the treatments, fruits coated with commercial wax recorded the least percent leakage (58.13%) which was on par with papaya leaf extract incorporated aloe gel coated fruits (58.50%). Highest percent leakage was for the uncoated fruits (60.82%).

There was no influence on interaction (coating × packaging) on percent leakage of mature green fruits after transportation.

4.5.2.1.2. Chemical parameters

The following chemical parameters of coated and packaged mature green tomato fruits were analyzed before and after transportation and are shown in Table 122 to 126.

4.5.2.1.2.1. Total Soluble Solids (TSS)

Total Soluble Solids (TSS) of coated mature green tomato fruits subjected to two different packaging systems were recorded before and after transportation and are shown in Table 122. TSS remained same in coated and uncoated fruits before and after transportation irrespective of the two packaging conditions. The interaction effect was also not significant.

4.5.2.1.2.2. pH

pH of coated mature green tomato fruits subjected to two different packaging systems recorded before and after transportation is shown in Table 123. pH of mature green fruits was not influenced by edible coatings, packaging systems and their interaction.

Table 121.Effect of edible film coatings and packaging on the percent leakage of mature green tomatoes during transportation

Percent leakage (%)							
	Before transportation			After transportation			CD (0.05)
Treatment	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	57.78	57.23	58.38	61.72	59.39	65.78	TxP- NS
5% CFB box (tray) (P2)	55.22	56.27	55.66	59.27	59.83	63.44	
Mean T	T1 – 58.50 : T2 – 58.13 : T3 – 60.82						T1xT2xT3 – 1.40
Mean P	P1- 60.05 : P2 – 58.28						P1xP2 – 1.14

Table 122. Effect of edible film coatings and packaging on the TSS of mature green tomatoes during transportation

TSS (^{0}Brix)							
	Before transportation			After transportation			
Treatment	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	4.35	4.45	4.25	4.75	4.55	4.60	TxP-NS
5% CFB box (tray) (P2)	4.35	4.30	4.30	4.60	4.60	4.75	
Mean T	T1 – 4.47 : T2 – 4.48 : T3 – 4.51						T1xT2xT3 – NS
Mean P	P1- 4.49 : P2 – 4.48						P1xP2 – NS

4.5.2.1.2.3. Vitamin C content

When vitamin C content of coated mature green tomato fruits subjected to two different packaging systems were recorded before and after transportation (Table 124), it was similar for coated and uncoated mature green fruits packaged in both 5% ventilated CFB box with and without tray before and after distant market transportation.

4.5.2.1.2.4. Titratable acidity

Titratable acidity of coated mature green tomato fruits subjected to two different packaging systems were recorded before and after transportation and is shown in Table 125. There was no significant difference between the titratable acidity of coated and uncoated mature green fruits irrespective of packaging systems, when transported to distant market.

4.5.2.1.2.5. Lycopene content

Lycopene content of coated mature green tomato fruits subjected to two different packaging systems were recorded before and after transportation and is shown in Table 126. The packaging systems were not significant in influencing the lycopene content of mature green fruits before and after transportation.

When the treatments were compared, mature green fruits coated with commercial wax recorded the least lycopene content ($0.631 \mu g g^{-1}$) which was on par with the papaya leaf extract incorporated aloe gel coated fruits ($0.646 \mu g g^{-1}$). Uncoated fruits showed the highest lycopene content ($0.678 \mu g g^{-1}$).

4.5.2.1.3. Microbial parameters

The effect of edible skin coatings and packaging on the bacterial count on the mature green fruit surface was recorded before and after transportation.

The bacteria on the surface of both papaya leaf extract incorporated aloe gel and commercial wax treated fruits packaged in 5% ventilated CFB box with and

Table 123. Effect of edible film coatings and packaging on the pH of mature green tomatoes during transportation

pH							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	TxP- NS
5% CFB box (P1)	4.25	4.55	4.40	4.85	4.70	4.70	
5% CFB box (tray) (P2)	4.30	4.55	4.35	4.60	4.80	4.80	
Mean T	T1 – 4.50 : T2 – 4.65 : T3 – 4.56						T1xT2xT3 –NS
Mean P	P1- 4.57 : P2 – 4.56						P1xP2 – NS

Table 124.Effect of edible film coatings and packaging on the vitamin C content of mature green tomatoes during transportation

Vitamin C content (mg $100g^{-1}$)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	TxP-NS
5% CFB box (P1)	14.06	12.50	14.06	14.06	12.50	14.06	
5% CFB box (tray) (P2)	12.50	15.62	12.50	12.50	15.62	12.50	
Mean T	T1 – 13.28 : T2 – 14.06 : T3 –13.28						T1xT2xT3 –NS
Mean P	P1- 13.54 : P2 – 13.54						P1xP2 – NS

Table 125.Effect of edible film coatings and packaging on the titratable acidity of mature green tomatoes duringtransportation

Titratable acidity (%)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	TxP- NS
5% CFB box (P1)	0.686	0.687	0.685	0.688	0.686	0.686	
5% CFB box (tray) (P2)	0.688	0.680	0.687	0.685	0.686	0.688	
Mean T	T1 – 0.686 : T2 – 0.686 : T3 – 0.685						T1xT2xT3 -NS
Mean P	P1- 0.686 : P2 – 0.686						P1xP2 – NS

Table 126.Effect of edible film coatings and packaging on the lycopene content of mature green tomatoes during transportation

Lycopene content ($\mu g g^{-1}$)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	TxP- NS
5% CFB box (P1)	0.650	0.630	0.685	0.665	0.630		
5% CFB box (tray) (P2)	0.625	0.630	0.670	0.645	0.635	0.670	
Mean T	T1 – 0.646 : T2 – 0.631 T3 – 0.678						T1xT2xT3 -0.02
Mean P	P1-0.658 : P2 – 0.646						P1xP2 – NS

tray was too less to count (TLTC) before and after transportation. The bacterial count was too numerous (TNTC) for all untreated fruits irrespective of packaging system.

4.5.2.1.4. Physical parameters

The effect of edible skin coatings and packaging on the physical parameters viz., appearance, colour, flavour, texture, taste and overall acceptability of the mature green fruits were recorded before and after transportation and are shown in Table 127.

There was no significant difference noticed in any of the physical parameters of mature green fruits irrespective of edible coating and packaging. However the highest mean sensory scores were recorded by the fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with moulded tray when subjected to distant market transportation.

4.5.2.2. FIRM RIPE TOMATO

Firm ripe tomatoes were coated with the selected papaya leaf extract incorporated aloe gel(1:2) + INS 402 and were compared with fruits coated with a commercial bee wax formulation each at 1% for one minute and packaged in 5% ventilated Corrugated Fibre Board (CFB) boxes with and without moulded tray and transported to local market to analyze the efficiency of edible coatings and packaging in withstanding transportation hazards. Tomato fruits without any coating were set as control for comparison. The harvest maturity for local market tomato is “firm ripe” and hence the coated firm ripe tomato fruits after packaging were transported to 128 km distance in a cargo van to represent the local market transport.

The following physiological, chemical, microbial and physical parameters of the coated firm ripe fruits were analyzed before and after subjecting to transportation and are shown below.

Table 127. Effect of edible film coatings and packaging on the physical parameters of mature green tomatoes during transportation

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability
Before Transportation						
Papaya leaf incorporated AG + 5% CFB box	8.07	8.00	8.00	8.03	8.13	8.20
Papaya leaf incorporated AG+ 5% CFB with tray	8.00	8.00	8.00	8.13	8.13	8.20
Commercial wax +5% CFB box	8.07	8.00	7.47	8.00	8.13	7.45
Commercial wax +5% CFB box with tray	8.00	8.00	7.47	8.05	8.13	7.40
Control +5% CFB box	8.00	8.00	8.07	8.13	8.00	8.13
Commercial wax +5% CFB box with tray	8.00	8.00	8.07	8.13	8.00	8.13
After Transportation						
Papaya leaf incorporated AG + 5% CFB box	7.50	7.65	7.57	7.87	7.60	7.63
Papaya leaf incorporated aloe gel + 5% CFB with tray	7.53	7.67	7.63	7.93	7.67	7.66
Commercial wax +5% CFB box	7.43	7.55	7.45	7.80	7.47	7.35
Commercial wax +5% CFB box with tray	7.45	7.56	7.16	7.80	7.52	7.40
Control +5% CFB box	7.45	7.40	7.57	7.70	7.25	7.34
Commercial wax +5% CFB box with tray	7.47	7.48	7.57	7.78	7.22	7.35
X^2 value	11.33	16.78	19.76	14.45	16.06	16.16
Kw value	**20.78**					

4.5.2.2.1. Physiological parameters

The following physiological parameters of coated and uncoated firm ripe fruits after subjecting to different packaging systems were analyzed before and after subjecting to transportation and are shown in Table 128 to 130.

4.5.2.2.1.1. Physiological Loss in Weight (PLW)

Physiological loss in weight (PLW) of coated and packaged firm ripe tomatoes analyzed before and after transportation is shown in Table 128. The PLW of firm ripe fruits packaged in 5% ventilated CFB box with and without moulded tray remained similar after transportation to local market. When comparison was made among the treatments, fruits coated with commercial wax recorded the least PLW (2.04%) which was on par with the papaya leaf extract incorporated aloe gel coated fruits (2.11%). The interaction effect of packaging and coating on PLW of the fruits subjected to local market was non significant.

4.5.2.2.1.2. Respiration rate

Respiration rate recorded before and after transportation of coated and uncoated packaged firm ripe tomato is shown in Table 129. Respiration rate was similar for the firm ripe fruits packaged in 5% ventilated CFB box with and without tray. The treatments were found non significant in influencing the respiration rate of firm ripe fruits. The interaction effect on respiration rate was non significant in fruits subjected to local market transport.

4.5.2.2.1.3. Membrane integrity

Percent leakage of coated and packaged firm ripe tomatoes recorded before and after transportation is shown in Table 130.

The firm ripe fruits packaged in 5% ventilated CFB box with tray recorded a low percent leakage (71.88%) compared to fruits packaged in 5% ventilated CFB box (73.46%).

Table 128. Effect of edible film coatings and packaging on the PLW of firm ripe tomatoes during transportation

Physiological loss in weight (%)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commer cial wax (T2)	Control (T3)	TxP-NS
5% CFB box (P1)	0	0	0	2.17	2.12	3.08	
5% CFB box (tray) (P2)	0	0	0	2.06	1.94	3.05	
Mean T	T1 – 2.11 : T2 – 2.04 : T3 –3.06						T1xT2xT3 – 0.16
Mean P	P1- 2.45 : P2 – 2.35						P1xP2 – NS

Table 129. Effect of edible film coatings and packaging on the respiration rate of firm ripe tomatoes during transportation

Respiration Rate (%)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commer cial wax (T2)	Control (T3)	
5% CFB box (P1)	4.00	4.50	4.85	4.40	4.45	5.00	TxP-NS
5% CFB box (tray) (P2)	4.45	4.60	4.60	4.75	4.85	4.90	
Mean T	T1 – 4.40 : T2 – 4.60 : T3 – 4.83						T1xT2xT3 – NS
Mean P	P1- 4.53 : P2 – 4.69						P1XP2 - NS

Table 130. Effect of edible film coatings and packaging on the percent leakage of firm ripe tomato during transportation

Percent Leakage (%)							
	Before transportation			After transportation			CD (0.05)
Treatment	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	70.27	72.11	76.11	71.84	73.21	78.34	TxP- NS
5% CFB box (tray) (P2)	71.05	70.80	71.88	72.15	71.50	73.89	
Mean T	T1 – 71.63 : T2 – 71.33 : T3 –75.06						T1xT2 xT3 – 1.11
Mean P	P1-73.46 : P2 – 71.88						P1xP2 - 0.90

Among the treatments, fruits coated with commercial wax recorded the least percent leakage (71.33%) which was on par with those treated with papaya leaf extract incorporated aloe gel (71.63%). The highest percent leakage was for the uncoated fruits (75.06%). There was no significance in the interaction effect on the percent leakage of firm ripe fruits subjected to transportation.

4.5.2.2.2. Chemical parameters

The following chemical parameters of coated and packaged firm ripe tomato fruits were analyzed before and after transportation and are shown in Table 131 to 134.

4.5.2.2.2.1. Total Soluble Solids (TSS)

Total Soluble Solids (TSS) of coated firm ripe tomato fruits subjected to two different packaging systems recorded before and after transportation is shown in Table 131. Edible coatings, packaging systems and their interactions were non-significant in influencing the TSS of firm ripe tomatoes during transportation.

4.5.2.2.2.2. pH

pH of coated firm ripe tomato fruits subjected to two different packaging systems recorded before and after transportation is shown in Table 132. Low pH (4.85) was recorded by firm ripe fruits packaged in 5% ventilated CFB box with tray compared to 5% ventilated CFB box without tray. The treatments as well as the interactions were non significant in influencing the pH of firm ripe fruits during local market transportation.

4.5.2.2.2.3. Vitamin C content

Vitamin C content of coated and uncoated firm ripe tomato fruits subjected to two different packaging systems, recorded before and after transportation is shown in Table 133. Vitamin C content was not influenced by edible coatings, packaging systems and their interactions when subjected to local market transportation.

4.5.2.2.2.4.Titratable Acidity

Titratable acidity of coated and uncoated firm ripe tomato fruits recorded before and after transportation after subjecting to two different packaging systems is

Table 131. Effect of edible film coatings and packaging on the TSS of firm ripe tomatoes during transportation

TSS (⁰Brix)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	4.40	4.45	4.35	4.70	4.55	4.40	TxP-NS
5% CFB box (tray) (P2)	4.50	4.65	4.65	4.65	4.15	4.50	
Mean T	T1 – 4.56 : T2 – 4.45 : T3 – 4.47						T1xT2xT3 – NS
Mean P	P1- 4.52 : P2 – 4.48						P1xP2 – NS

Table 132. Effect of edible film coatings and packaging on the pH of firm ripe tomatoes during transportation

pH							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	4.85	5.00	4.80	4.90	4.75	4.85	TxP-NS
5% CFB box (tray) (P2)	5.05	5.15	5.05	5.00	4.90	5.05	
Mean T	T1 – 4.95 : T2 – 4.95 : T3 – 4.94						T1xT2xT3 – NS
Mean P	P1-5.03 : P2 – 4.85						P1xP2 – 0.12

Table 133. Effect of edible film coatings and packaging on the vitamin C content of firm ripe tomato during transportation

Vitamin C content (mg $100g^{-1}$)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	18.18	18.31	18.18	16.37	18.32	18.18	TxP-NS
5% CFB box (tray) (P2)	18.37	18.18	18.180	16.37	16.37	16.37	
Mean T	T1 – 17.73		T2 – 17.79		T3 –17.32		T1xT2xT3 – NS
Mean P	P1-17.30 : P2 – 17.92						P1xP2 – NS

Table 134. Effect of edible film coatings and packaging on the titratable acidity of firm ripe tomatoes during transportation

Titratable acidity (%)							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	
5% CFB box (P1)	0.655	0.655	0.655	0.655	0.660	0.655	TxP-NS
5% CFB box (tray) (P2)	0.660	0.655	0.660	0.655	0.650	0.655	
Mean T	T1 – 0.656 : T2 – 0.655 : T3 – 0.656						T1xT2xT3 – NS
Mean P	P1-0.656 : P2 – 0.656						P1xP2 – NS

shown inTable 134. Packaging systems, edible coatings and their interactions had not influenced the titratable acidity of firm ripe fruits transported to local market.

4.5.2.2.2.5. Lycopene content

Lycopene content of coated and uncoated firm ripe tomato fruits subjected to two different packaging systems recorded before and after transportation is shown in Table 135. The effects of packaging systems, edible coatings and their interactions were not significant in influencing the lycopene content of firm ripe fruits before and after transportation.

4.5.2.2.3. Microbial parameters

The effect of edible skin coatings and packaging on bacterial count recorded on the surface of firm ripe tomatoes before and after transportation.

The bacteria recorded on the surface of both papaya leaf extract incorporated aloe gel and commercial wax treated fruits packaged in 5% ventilated box CFB with and without tray were too less to count (TLTC) before and after transportation. The bacterial count was too numerous on untreated fruit surface irrespective of packaging systems during the transportation.

4.5.2.2.4. Physical parameters

The effect of edible skin coatings and packaging on the physical parameters viz., appearance, colour, flavour, texture, taste and overall acceptability of the firm ripe fruits were recorded before and after transportation and are shown in Table 136.

There was no significant difference between the physical parameters of coated and uncoated firm ripe fruits after transportation irrespective of packaging; however the highest mean sensory scores were recorded by the fruits coated with papaya leaf extract incorporated aloe gel and packaged in 5% ventilated CFB box with moulded tray when subjected to distant market transportation.

Table 135. Effect of edible film coatings and packaging on the lycopene content of firm ripe tomatoes during transportation

Lycopene content (μgg^{-1})							
	Before transportation			After transportation			CD (0.05)
Treatments	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	Papaya leaf incorporated AG (T1)	Commercial wax (T2)	Control (T3)	TxP- NS
5% CFB box (P1)	36.83	35.21	36.72	37.88	35.77	37.89	
5% CFB box (tray) (P2)	34.82	34.55	35.89	36.26	35.21	36.72	
Mean T	T1 – 36.44 : T2 – 35.18 : T3 – 36.80						T1xT2xT3 – NS
Mean P	P1-35.57 : P2 – 36.71						P1xP2 – NS

Table 136. Effect of edible film coatings and packaging on the physical parameters of firm ripe tomatoes during transportation

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability
Before Transportation						
Papaya leaf incorporated AG + 5% ventilated CFB box	8.07	8.00	8.00	8.03	8.13	8.20
Papaya leaf incorporated AG+5% ventilated CFB with tray	8.00	8.00	8.00	8.13	8.13	8.20
Commercial wax +5% ventilated CFB box	8.07	8.00	7.47	8.07	8.13	8.00
Commercial wax +5% ventilated CFB box with tray	8.00	8.00	7.47	8.17	8.13	8.00
Control +5% ventilated CFB box	8.00	8.00	8.07	8.13	8.00	8.13
Commercial wax +5% ventilated CFB box with tray	8.00	8.00	8.07	8.13	8.00	8.13
After Transportation						
Papaya leaf incorporated AG + 5% ventilated CFB box	7.50	7.57	7.64	7.80	7.52	7.66
Papaya leaf incorporated AG + 5% ventilated CFB with tray	7.54	7.60	7.67	7.87	7.57	7.75
Commercial wax +5% ventilated CFB box	7.39	7.46	6.56	7.54	7.45	7.00
Commercial wax +5% ventilated CFB box with tray	7.40	7.50	6.55	7.55	7.47	7.00
Control +5% ventilated CFB box	7.47	7.48	7.50	7.40	7.25	7.34
Control +5% ventilated CFB box with tray	7.45	7.40	7.58	7.45	7.22	7.35
X^2 value	11.33	16.78	34.56	12.34	16.56	24.58
Kw value	**NS**					

4.5.5. Cost of production

Cost of preparation for 1 litre commercial bee wax formulation was Rs.210/-when prepared @ 2%, which could be utilized for dipping 1.5 kg mature green tomatoes fruits, thus costing Rs. 14000/- for dipping 100Kg fruits. For firm ripe fruits, cost of preparation of wax formulation was Rs. 186.50/- when prepared @ 1% concentration and the total cost for dipping 100 Kg firm ripe fruits was calculated to be Rs. 12.433/ (Table 137).

Table 137.Cost of production of commercial wax formulation

Commercial Formulation		Mature green	Firm ripe
		Bee wax + Rice bran oil	
Concentration of formulation		2%	1%
Item	*Quantity*	*Cost (Rs)*	*Cost (Rs)*
Bee wax	Rs. 2.5/g	50.00	25.00
Rice bran oil	Rs. 155/litre	155.00	155.00
Labour cost		5.00	6.50
Total cost for preparation of 1l. formulation		210.00	186.50
Quantity of fruits that can be treated		1.5 kg	1.5 kg
Cost for treating 100 kg fruit		Rs.14,000/-	Rs.12,433/-

When cost of production of the papaya leaf extract incorporated aloe gel formulation and commercial wax formulation was compared, it is evident that the papaya leaf extract incorporated aloe gel formulation could be prepared at a very cheap rate compared to commercial formulation.

Combining all the five steps of the experiment, a viable and efficient post harvest management schedule has been formulated for extending shelf life of tomatoes of two different maturities as shown below.

Harvest Maturity	Surface sanitization	Skin treatment	Packaging	Storage	Transportation	Shelf life
Mature Green	Dipping in 2ppm ozonized water for 10 minutes	Dipping in 2% papaya leaf extract incorporated aloe gel for two minutes	5% ventilated CFB box with moulded tray	Storing under optimum low temperature of $12^0 - 20^0$C	Distant market transportation in reefer cargo van at 18^0C	60 days
Firm Ripe		Dipping in 1% papaya leaf extract incorporated aloe gel for one minute		Storing under optimum low temperature of 10^0-15^0C	Transportation to local market in cargo van	36 days

DISCUSSION

5. DISCUSSION

Tomatoes deteriorate rapidly after harvest either during or after transport, storage or marketing. Due to the consumer's concerns over the safety of foods containing synthetic chemicals and economic impacts of spoiled foods, a lot of attention has been given to naturally derived compounds or natural products for preserving fruits and vegetables. In recent years, the use of *Aloe vera* gel has gained much attention for use as a safe and environment-friendly postharvest treatment and it has been identified as a novel coating agent with good antimicrobial properties.

The results of the investigation on "*Aloe vera* gel based edible film coating for shelf life extension in tomato" were analyzed statistically and are discussed in this chapter under following five headings.

1. Preliminary trial for preparation and standardization of aloe extract
2. Standardization of aloe gel as edible film for extension of shelf life
3. Evaluation of plant leaf extract incorporated aloe gel for extension of shelf life
4. Quality evaluation of film coated tomato
5. Efficiency of aloe based edible film in reducing postharvest loss during storage and transportation

5.1. PRELIMINARY TRIAL FOR PREPARATION AND STANDARDIZATION OF ALOE EXTRACT

New technological advances in antimicrobial edible coatings for food may hold promise in extending shelf life, reducing packaging layers, meeting food safety and quality requirements. Recently, research interest has increased in using aloe vera gel-based edible coating material for fruits and vegetables. *Aloe vera* gel has been proven as one of the best edible and biologically safe preservative coatings for different types of foods because of its film-forming properties, antimicrobial actions, bio-degradability and biochemical properties.

Edible coatings are thin layers of edible material applied to the product surface in addition to or as a replacement for natural protective waxy coatings and provide a barrier to moisture, oxygen and solute movement for the food (Ergun and Satici, 2012). They are applied directly on the food surface by dipping, spraying or brushing (Mchugh and Senesi, 2000).

As the present study is the first to assess the efficiency of *Aloe vera* gel based edible film in extending shelf life of any tropical vegetable in Kerala, a preliminary trial was conducted for standardization of aloe extract. The extracted aloe was mixed with four different gelling agents and tomato fruits were dipped in seven different concentrations of these mixtures for five different durations to form 140 treatment combinations and observations like shelf life and physiological loss in weight (PLW) were recorded to select the 12 superior treatment combinations.

The extracted aloe gel has considerably thin and liquid consistency and it required addition of a suitable gelling agent to form a mixture of necessary thick consistency so as to act as an edible film coating. Gelling agent is a substance which can increase the viscosity of a liquid without substantially changing its other properties.

Fruits coated with different combinations of aloe based extracts had similar shelf life. The success of edible coatings for fresh products totally depends on the control of internal gas composition after coating. Quality criteria for fruits and vegetables coated with edible films must be determined carefully and the quality parameters must be monitored throughout the storage period. One of the major quality parameters which determines the success of edible coating is weight loss of edible film coated fruits (Dhall, 2010); and hence the effects of different gelling agents, concentrations and duration of treatment on the PLW of tomato fruits were analyzed.

The PLW of fruits coated with aloe gel added with the four gelling agents were significantly different from one another. Least PLW (16.13%) was recorded by the fruits dipped in aloe gel + potassium alginate (INS 402), which was followed by fruits coated with aloe gel + sodium alginate (INS 401) (18.01%). INS 440 and INS 508 had less efficiency in maintenance of optimum physiological properties. Least PLW in fruits treated with aloe gel mixed with gelling agents, INS 401 and INS 402 might be due to their better and uniform thickening property. Alginates are polysaccharide extracted from marine brown algae (Phaeophyceae), a common type of gelling agent employed in the food industry (Mancini and McHugh, 2000; Yang and Paulson, 2000).

According to Rhim (2004) alginates can act as a potential film or coating component because of its unique colloidal properties which include thickening, stabilizing, suspending, film forming, gel producing, and emulsion stabilizing properties. Zapata *et al*., (2009) found that alginate edible coating in a mixture of essential oils (thymol, menthol, eugenol, carvacrol) had a better effect in reducing ripening processes in tomato, only at 1% level. An edible coating comprising of sodium alginate along with several additives viz., antimicrobials, flavoring agents and antioxidants was patented by Girard (2011) for covering fruit and vegetables.

Evaluation of seven different concentrations used for coating tomato fruits revealed that all of them were equally effective in reducing the weight loss during storage. This was supported by the findings of Tzortzakis (2016) who had reported that aloe coating on tomatoes at 5%, 10%, 15% and 20% concentrations had non-significant effect on weight loss during 14^{th} day of storage.

When five different durations were compared, the superiority of one minute dipping was proved with least PLW(17.58%) which was on par with the fruits dipped for two (18.01%) and five minutes (18.07%).

Considering all the parameters sodium alginate (INS 401) and potassium alginate (INS 402) were selected as the best two gelling agents to modify or improve the consistency of pure aloe gel. Among the seven different concentrations tried, as all the concentrations were equally effective, the least two concentrations viz., 1% and 2% were selected considering the economics of application. The three equally effective durations viz., one, two and five minutes were selected thus forming the12 superior treatments combinations were selected for the further study. Dipping in 1 and 2% of (aloe gel mixed with INS 401or 402) each for 1, 2 and 5 minutes were the 12 superior treatment combinations selected from the preliminary trial.

5.2. STANDARDIZATION OF ALOE GEL AS EDIBLE FILM FOR EXTENSION OF SHELF LIFE

Postharvest life of tomato (*Solanum lycopersicum),* a climacteric fruit is very short due to loss of quality and storability that occurs mainly due to higher respiration, transpiration, postharvest diseases and enhanced ripening and senescence. Edible coatings using natural biomaterials are being explored as a safer alternative to extend the shelf life of perishable food crops and improve food appearance (Mahfoudhi *et al.,* 2015).

The aim of this research programme was to study the effect of aloe vera based skin coatings on the changes in physiochemical and microbial parameters of tomato fruits during post harvest life. As harvest maturity of tomato depends mainly on distance to market, any recommendation on post harvest management of tomato should be formulated separately for both mature green and firm ripe tomato fruits. Hence the present work was conducted as two independent experiments separately for fruits of two different maturity stages, viz., mature green and firm ripe meant for distant and local markets respectively.

5.2.1. Physiological parameters

Harvested fruits and vegetables are living, respiring and are metabolically very active resulting in increased physiological loss in weight. Physiological loss in weight is a phenomenon related with shelf life of vegetables, accelerated weight loss being directly related with respiration of whole vegetables. A vegetable with least respiration rate, percent leakage and physiological loss in weight maintains its turgidity, freshness and quality. Hence these parameters were recorded at 12 days interval for the tomato fruits harvested at two different maturity stages viz., mature green and firm ripe.

All the mature green coated/treated fruits had a shelf life of 36 days, whereas untreated fruits were damaged after 24th day of storage.

During the 24th day of storage, mature green fruits treated with 2% (aloe gel +INS 402) for two minutes had least PLW (3.85%) compared to uncoated fruits which had 14.23% PLW. As the untreated mature green fruits were decayed after

24th day of storage, comparison could be made among the treated/coated fruits alone on the final *ie.,* 36th day of storage. Fruits dipped in 2% (aloe gel + INS 402) for two minutes recorded the least weight loss (5.92%) on the final day also when the different aloe gel based formulations are compared.

In firm ripe tomatoes, almost all the aloe gel based formulations were equally effective in reducing the PLW when compared with untreated fruits on the 12th day of storage. After 12th day of storage and before 24th day of storage all the untreated fruits were decayed and comparison could be made only among the different aloe gel formulations on the 24th day of storage. Results revealed that fruits dipped in 1% (aloe gel +INS 402) for one minute recorded the least weight loss (5.84%) at the end of storage (24th day). Weight loss mainly occurs due to water loss by transpiration and loss of carbon reserves due to respiration (Vogler and Ernst, 1999). The reduced weight loss in aloe gel coated fruits are due to the barrier property of aloe gel based edible coating that restricts water transfer and thereby protects the fruits from other mechanical injuries.

Similar weight suppressions were found in nectarines treated with 2.5% aloe gel (Ahmed *et al*., 2009), in cherries (Martinez-Romero *et al*., 2006) and in table grapes (Castillo *et al.,* 2010) treated with 33% aloe gel and in 'Granny Smith' apples treated up to 10% aloe gel (Ergun and Satici, 2012). According to Misir *et al.,* (2014), the positive effect in terms of reduction of moisture loss may be due to the hygroscopic properties of aloe gel that allow the formation of water barrier between the fruit and the surrounding environment. *Aloe vera* gel is mostly composed of polysaccharide which is highly effective as a barrier against moisture loss without incorporation of lipid (Ni *et al*., 2004). According to John (2008), application of edible coatings on fresh fruits and vegetables has been found to be helpful in reducing their postharvest moisture and weight loss.

Mature green and firm ripe fruits coated with 1% and 2% of (aloe gel + INS 402) for one and five minutes were also equally effective in reducing the weight loss at the end of storage on the 36th and 24th day of storage respectively.

The coatings had significant effect on the respiration of mature green fruits with least respiration (4.00%) recorded by 2% (aloe gel+ INS 402) for five minutes compared with the control samples (6.90%) on the 24th day of storage. While comparing different concentrations and durations of aloe gel coatings alone, it had no significant influence on respiration rate at the end of storage. The significance of aloe gel coated fruits is because of the ability of aloe gel film to decrease the gas permeability through the fruit surface. According to Serrano *et al.*, (2006), the aloe gel operates through a combination of mechanisms forming a protective layer against the oxygen and moisture of the air. According to Chrysargyris *et al.*, (2016) the respiration rate of tomato fruits coated with aloe gel at 5%, 10%, 15% and 20% concentrations for ten minutes was non significant during the entire storage period of 14 days.

Edible coatings using gelling agents INS 402 at all concentrations and duration had similar effect in reducing the respiration rate. Coating with 2% aloe gel +INS 401 for two and five minutes also had same effect on the 12th day of storage. Fruits coated with formulations of INS 402 except 1% (aloe gel +INS 402) for two minutes exhibited reduced respiration rate on 24th day of storage. The result was supported by Serrano *et al.*, (2006) who had proved that aloe gel partially clogs the stomatal pores of the samples, forming a protective layer against the surrounding oxygen while limiting CO_2 evolution. This is in line with the findings of Castillo *et al.*, (2010) also. Paladines *et al.*, (2014) reported that the respiration rate decreased in aloe treated stone fruits like cherries, nectarines and plums.

Percent leakage is the phenomenon related with the membrane integrity of the fruit tissues. Biophysical changes in membrane lipids and enzymatic and non-enzymatic lipid peroxidation lead to altered membrane properties and resulted in defects such as ion leakage and cellular de-compartmentation (Marangoni *et al.*, 1996). According to Palma *et al.*, (1995) a physiological pattern for ripening and senescence of tomato fruit was established based on weight loss patterns, colour development, ion leakage, lipid fatty acid profiles of microsomal membrane lipids, microsomal K^+ stimulated ATPase activity and electrophoretically separated protein patterns of microsomal membranes. Fruits having less weight loss, respiration and transpiration maintain the structural integrity of the membranes and thereby give better firmness for the fruits. The rate and extension of firmness loss during storage are the main factors determining fruit quality and postharvest shelf life (Padmaja and Bosco, 2014).

On the 24th day of storage the least percent leakage (74.35%) in mature green tomato was those treated with 2% (aloe gel + INS 402) for five minutes, which revealed the superiority of aloe gel over the untreated fruits (86.84%). On the final day of storage, while comparing aloe gel formulations alone, all the different concentrations and durations of (aloe gel + INS 402) were equally effective in reducing the percent leakage compared with (aloe gel + INS 401) in case of mature green and firm tomato fruits. The reduced percent leakage in fruits coated with aloe gel could be due to reduced breakdown of cell wall components due to slower respiration. This is in line with the findings of Castillo *et al*., (2010), Ahmed *et al*., (2009) and Martinez-Romero *et al*., (2006) in table grapes, sweet cherries and nectarines respectively with reduced firmness. In both mature green and firm ripe fruits percent leakage was highest recorded by the untreated fruits due to the higher rate of respiration and ripening. Hongmei *et al*., (2009) reported a significantly higher firmness level on jujube fruits coated with aloe vera gel than the control samples.

5.2.2. Chemical Parameters

When the effect of aloe gel based formulations on the chemical quality parameters viz., TSS, pH, vitamin C, titratable acidity and lycopene content of mature green and firm ripe tomato fruits were evaluated, the aloe gel based formulations had significant influence on the chemical parameters when compared with that of the fruits without any coatings.

In mature green fruits, on the 24th day of storage, TSS was highest (5.25^{0}B) for the fruits dipped in 2% (aloe + INS 402) for five minutes which was on par with other concentrations and durations of (aloe gel + INS 402). In firm ripe fruits also all the different concentrations and durations of (aloe gel +INS 402) were found equally effective in maintaining the TSS on the 12th day of storage.

When comparison was made among the different aloe gel formulations alone at the end of storage of mature green (36th day) and firm ripe fruits (24th day), the TSS remained similar for fruits coated with all the aloe gel based edible coatings.

This was supported by the findings of Chrysargyris, (2016) that the tomato fruits dipped in 10% and 15% aloe gel increased the TSS on 14 days after storage.

On the 24th day of storage, all the different concentrations and durations of (aloe gel + INS 402) was equally effective in maintaining the pH of mature green tomatoes, however the least pH was recorded by the fruits treated with 2% (aloe gel + INS 402) for two and five minutes and 1% (aloe gel +INS 402) for two minutes. In firm ripe fruits almost all the different concentrations of (aloe gel + INS 402) and (aloe gel + INS 401) were equally effective in maintaining the pH of firm ripe fruits on the 12th day of storage compared to control. Here the pH values were least for the aloe gel treated mature green and firm ripe fruits when compared with uncoated fruits.

The increased pH in untreated fruits may be due to the breakdown of acids that occurs during respiration. Athmaselvi *et al.,* (2013) reported an increased pH in control fruits compared with aloe gel coated tomato fruits at 20 days after storage. All the different concentrations and durations of aloe gel based edible films were equally effective in influencing the pH of mature green and firm ripe fruits on the final day of storage (36th and 24th day respectively). According to Ajeethan and Mikuntha (2016) the variation in pH may be due to the difference in the micro environment created by gel coatings coupled with less oxidative reactions and lesser decline in degradation of acids, thus maintaining the integrity of cells compared with the untreated fruits.

On the 24th day of storage of mature green fruits, highest vitamin C content (15.01 mg $100g^{-1}$) was recorded by fruits coated with 2% (aloe gel +INS 402) for two minutes compared with the uncoated fruits (14.79 mg $100g^{-1}$). On the 36thday, no significant difference was found between the vitamin C content of fruits coated with different aloe based coatings. The retention of ascorbic acid in aloe gel coated tomato fruits compared with the control fruits were supported by many research findings. According to Arowora *et al.*, (2013) ascorbic acid content for coated oranges was found to be higher than that of uncoated fruits. Brishti *et al.*, (2013) found that ascorbic acid content was higher in aloe coated papaya fruits than the control fruits during the storage period at temperatures 25°C-29°C and 82-84% RH.

In firm ripe fruits, all the aloe gel based formulations were equally effective in maintaining the vitamin C content on the 12th and 24th day of storage.

The higher vitamin C content in the treated fruits resulted to an increase in the antioxidants which increased the structural integrity of the membranes and hence the coated fruits recorded least percent leakage also. Lower vitamin C content was noticed in untreated fruits (10.91 mg $100g^{-1}$) compared to the coated fruits. This was due to low oxygen permeability of coating which delayed the deteriorative oxidation reaction of ascorbic acid content (Ayranci and Tunc, 2003). Similar result was found in aloe gel coated nectarines also (Ahmed *et al.*, 2009). Srinu *et al.,* (2012) reported that coating reduces respiration of the fruits and retains the ascorbic acid in the fruits.

In mature green tomatoes titratable acidity was influenced only on 24th day of storage. Fruits coated with 2% aloe +INS 402 for one, two and five minutes and 1% for one minute had highest titratable acidity content. Untreated mature green fruits had least (0.657%) titratable acidity. Tripathi and Dubey (2004) reported a greater titratable acidity content retention in aloe coated berries, which indicates that control (uncoated fruits) fruits presented a more pronounced maturation development than coated berries during storage periods. This increased titratable acidity content of coated fruits was due to the protective effect of aloe gel coating as a barrier to O_2 from the surrounding atmosphere (Valverde *et al.*, 2005). Similar result was reported for aloe gel treated table grape (Castillo *et al.*, 2010) and aloe gel coated `star king' cherries (Martinez-Romero *et al.*, 2006).

Lycopene content is an important quality parameter associated with ripening of fruits. As the lycopene content is inversely related to ripening, the fruit with decreased lycopene content indicates a delay in ripening. In mature green tomato lycopene content was least (32.88 μgg^{-1}) in mature green fruits dipped in 2% (aloe gel +INS 402) for two minutes compared with control fruits (51.17μgg^{-1}) on the 24th day of storage. Fruits dipped in 2% (aloe gel +INS 402) for one and five minutes and 1% (aloe gel + INS 402) for one minute were also equally effective in reducing the lycopene content in mature green tomatoes (Fig.1).

In firm ripe tomato all the aloe gel formulations were equally effective in reducing the lycopene content compared to uncoated fruits on the 12th day of storage.

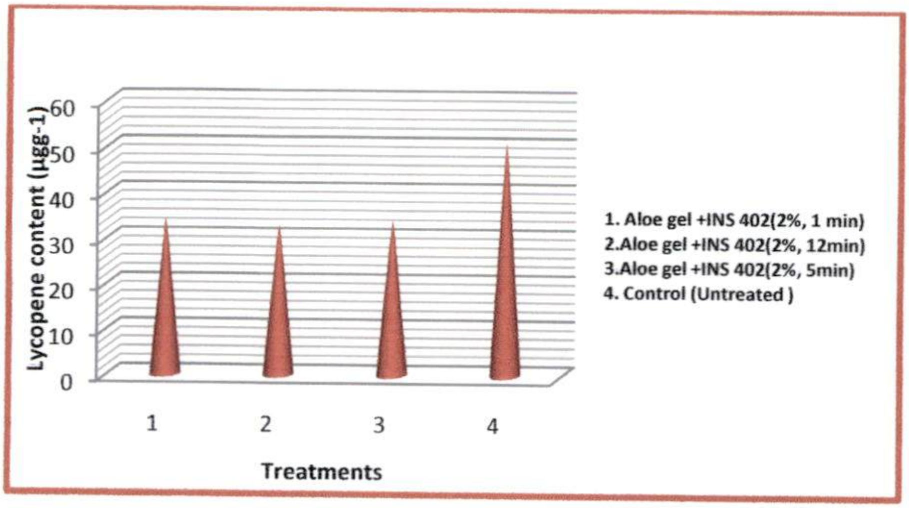


Fig 1. Effect of aloe based coatings on the lycopene content of mature green tomato

Though there was no significant difference, the least lycopene content was recorded by the fruits treated with 1% (aloe gel +INS 402) for one minute (57.42 $\mu g g^{-1}$) on the final day of storage (24th day).

The increased lycopene content in uncoated fruits is due to the decrease in chlorophyll content and increased synthesis of the red pigment lycopene. The result is supported by the findings of Tripathi and Dubey (2004) who had reported a darker colored untreated (control) table grapes compared to aloe treated ones, indicating characters of overripe fruit, which is detrimental to color quality. The modified atmosphere created by the aloe gel coating retarded the ethylene production rate, therefore delaying ripening, chlorophyll degradation, anthocyanin accumulation and carotenoid synthesis thus ultimately delaying fruit color change (Carrillo-Lopez, 2000). Chrysargyris *et al*., (2016) reported that the decreased lycopene content in 10% and 15% aloe coated tomato fruits are related to the reduced ethylene emission rates and it slows down the ripening process.

5.2.3 Microbial parameters

All the aloe gel based formulations were equally effective in reducing the bacterial population on the surface of both mature green and firm ripe tomatoes compared with the control fruits during the entire storage period. The bacterial population was too numerous to count on the surface of uncoated fruits from the initial day onwards, which shows the ability of aloe gel coating to act as a protective barrier against many microbes. Similar findings revealed that, aloe gel coating itself was effective in controlling microbial growth of 'Starking' cherry and 'Crimson' table grape without incorporation of other antimicrobial compounds such as garlic oil, potassium sorbate and nisin to increase the activity (Pranato *et al*., 2005a; 2005b). Anthraquinones in aloe gel presented antimicrobial activity against *Staphylococcus aureus* strains and against *Escherichia coli*, through inhibition of solute transport in membranes (Hamman, 2008; Lone, 2009). Cock (2008) reported that the principal constituent of aloe gel emodine, has been effective against several gram positive bacteria.

5.2.4. Physical parameters

Quality parameters of tomato include appearance, colour, flavour, taste and texture, which are related to the fruit compositions at the time of harvest and the compositional changes due to post harvest handling. Hence these parameters were analyzed for both mature green and firm ripe tomatoes.

Physical parameters of fruits were almost uniform during the initial stages of storage irrespective of harvest maturity stages or edible coatings. There was no significant difference between the different physical parameters analyzed and hence the treatments with highest mean sensory score were considered as the efficient aloe gel based edible film coating.

In mature green fruits on the 24th and 36th day of storage when all the physical parameters were analyzed the highest sensory scores were recorded by the fruits dipped in 2% (aloe gel +INS 402) for two minutes except for colour. For firm ripe fruits the sensory scores were highest for the fruits dipped in 1% (aloe gel +INS 402) for one minute on the 12th and 24th day.

Color is an important factor that determines the consumer acceptance. In mature green and firm ripe tomatoes the aloe gel coatings retained the color development due to the delay in ripening. The modified atmosphere created by the aloe based edible coating retarded the ethylene production rate therefore, delayed ripening, chlorophyll degradation and carotenoid synthesis thus ultimately delaying color change of fruits (Hoa *et al.,* 2002). This delay in ripening in aloe coated mature green and firm ripe tomatoes resulted in the retention of colour.

Tomato flavor involves perception of taste and aromas of many chemical constituents. Flavor and taste are another important quality parameter influencing consumer acceptance. Mature green fruits treated with 2% (aloe gel +INS 402) for two minutes and firm ripe tomatoes treated with 1% (aloe gel +INS 402) for one minute scored highest scores for flavour (7.80 and 7.67 respectively) and which might be due to the retained titratable acidity in the coated fruits compared with the untreated fruits on the 24th day of storage.

Based on the sensory parameters highest mean score was recorded by the mature green fruits treated with 2% (aloe gel +INS 402) for two minutes for flavor (7.67) and taste (7.73). Similarly the highest sensory scores for flavor (7.53) and taste (7.54) were recorded by firm ripe fruits treated with 1% (aloe gel + INS 402) for one minute.

Loss of texture is one of the main factors limiting quality and post-harvest shelf life of fruits and vegetables. The rate and extension of texture/firmness loss during storage are the main factors determining the appearance and acceptability of fruits. Fruit softening occurs considerably as a result of degradation of the middle lamella of cell wall (Misir *et al.*, 2014). The highest sensory score for texture was scored by mature green and firm ripe fruits treated with aloe based edible coatings and this higher texture was attributed by the reduced rate in the breakdown of the cell wall components as a result of the decreased respiration rate and weight loss caused by aloe coatings.

On the final day of storage the mature green fruits treated with 2% (aloe gel +INS 402) for two minutes recorded the least weight loss, respiration rate and percent leakage resulting in better fruit texture and hence scored higher sensory score (7.73) for texture and all these parameters resulted in better appearance of the fruits with a higher score of 7.67. Accordingly in firm ripe fruits, the highest sensory score for texture (7.60) was recorded by fruits treated with 1% (aloe gel +INS 402) for one minute, which was due to the least weight loss, respiration rate and percent leakage, and hence scored the highest score for appearance (7.53) also. The least sensory scores for texture (7.89 and7.00) and appearance (7.87 and 7.20) scored by the untreated mature green and firm ripe fruits on the 12th and 24th day of storage were due to the higher weight loss, respiration rate and percent leakage during storage.

On the final day of storage, there was no significant difference in the chemical and microbial parameters of fruits due to different aloe based film coatings. Hence based on the physiological and physical parameters, 2% (aloe gel +INS 402) for two minutes and 1% (aloe gel +INS 402) for one minute were selected as the best aloe vera gel based edible film coatings for shelf life extension in mature green and firm ripe tomatoes respectively.

For mature green tomatoes a higher concentration (2%) of aloe gel +INS 402 was required whereas the same formulation at 1% concentration was effective for firm ripe fruits. The difference in the concentration might be due to the difference in textural parameters related to different maturity stage of tomatoes. According to Sirisomboon *et al.*, (2012) the peel at the mature green stage contributed approximately 70% of the firmness compared to 90% at the red stage. So for maintaining the required texture and firmness a higher concentration of aloe gel formulation might be required for mature green fruits and a lower concentration for firm ripe fruits.

One kilogram aloe leaves produce 850 ml gel, which was mixed with different ingredients including gelling agent, INS 402 to produce 42.5 litre formulation, when prepared at 2% concentration and cost of preparation the formulation was worked out to be Rs 47.16/- which could be utilized for dipping 85 Kg mature green tomatoes. The same 850 ml gel when prepared at 1% concentration could produce 85 litres formulation for Rs 48.66/- which could be utilized for dipping 170 kg firm ripe tomatoes. So cost of dipping 100 Kg mature green tomatoes with the selected aloe based formulation was calculated to be Rs.55.48/- and it was Rs.28.62/- for 100 Kg firm ripe tomatoes.

5.3. EVALUATION OF PLANT LEAF EXTRACT INCORPORATED ALOE GEL FOR EXTENSION OF SHELF LIFE

Application of several semi permeable edible coatings is now being used as an alternate way for achieving the modified atmosphere and the market for edible films and coatings has experienced remarkable growth over the last 5 years. Fruits coated with these edible coatings are reported to extend the shelf life of many fruits and vegetables. *Aloe vera* based edible film coatings which are biodegradable and eco friendly are widely used as an economically viable alternative to increase the shelf life of perishables.

Products derived from plants may potentially control microbial growth in diverse situations and many of the plant leaf extracts are reported to have antimicrobial activities and this property is being used for the preservation of many fruits and vegetables. The aim of this part of the experiment was to find out the possibility of increasing the efficiency of aloe gel based edible film selected from previous part (4.2), by incorporating natural and cheap plant extracts to substitute the quantity of aloe gel with plant leaf extracts so as to reduce the cost of preparation of edible films without affecting the efficiency in increasing the shelf life of tomato. Aloe gel was mixed with leaf extracts of papaya, guava and ocimum in 1:1 and 1:2 ratio and plant leaf extract incorporated aloe gels (PLEAG) formulations were made.

Mature green and firm ripe tomato fruits were coated with different plant leaf extract incorporated aloe gels (PLEAG)prepared in different ratios and were compared to the aloe gel based film coated fruits (aloe gel + INS 402) selected from 4.2 of the experiment. The concentration of the extract and duration of the treatment were also selected from previous part.

5.3.1. Physiological parameters

Mature green tomatoes coated with PLEAG and pure aloe gel based formulation had a shelf life of 36 days and firm ripe tomatoes had 24 days. Hence the physiological parameters viz., physiological loss in weight, respiration rate and percent leakage were recorded at 12 days interval.

Mature green fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 recorded the least physiological loss in weight (PLW) of 1.18% on the final day (36^{th} day) of storage and this was found equally effective with fruits coated with papaya leaf extract incorporated aloe gel (1:1) + INS 402 (1.23%) and pure aloe gel + INS 402 (1.33%). The lower weight loss by coated fruits might be due to the effect of aloe gel coating to prevent the moisture loss from the fruit surface. According to Yogiraj *et al.*, (2014) phytochemical analysis of papaya leaf extract revealed the presence of alkaloids, glycosides, flavanoids, saponins, tannins, phenols and steroids. The least PLW recorded by papaya leaf incorporated aloe gel coated fruits might be due to the antimicrobial property of papaya leaves which had further increased the efficiency of aloe gel coating alone. This was supported by the findings of Brishti *et al.,* (2013) who had reported a lower weight loss percentage in papaya leaf extract incorporated aloe gel coated fruits when compared with aloe gel coated fruits after 8 days of storage.

On the final day of storage (24th day), firm ripe fruits coated with papaya leaf incorporated aloe gel (1:2) + INS 402 recorded the least PLW (1.29%) and this was equally effective as all the other treatments except the ocimum leaf incorporated aloe gel (1:2) + INS 402 (1.90%). According to Misir *et al.,* (2014) aloe gel based edible coating acts as a barrier, and thereby restricting water transfer and protecting fruit skin from mechanical injuries. The efficiency of papaya leaf extract incorporated aloe gel to reduce weight loss was in line with the results of Marpudi *et al*., (2011) who had found that papaya fruits coated with aloe gel and papaya leaf incorporated aloe gel showed a similar weight loss of 33% after 15 days after storage.

Fruits coated with guava leaf incorporated aloe gel were also equally effective as papaya leaf incorporated aloe gel and pure aloe gel based coatings. Research findings of Mohamed (1994) revealed the presence of polyphenolic compounds in guava viz., quercetin, avicularin and guaijaverin as the active antimicrobial components in guava leaf. The presence of these antimicrobial components might be responsible for increasing the efficiency of aloe gel and thus reduced the weight loss in firm ripe fruits.

In mature green and firm ripe tomatoes, all the plant leaf extract incorporated aloe gels (PLEAG) and aloe gel coatings were equally effective in reducing the respiration rate in fruits. According to Banks *et al*., (1993) application of a surface coating has been reported to increase resistance of fruit skin to gas diffusion and the creation of a modified internal atmosphere. This modified internal atmosphere reduced the respiration rate in coated fruits and hence resulted in least weight loss also.

The least weight loss and respiration rate in coated fruits resulted in reduced percent leakage and thereby making the fruits more firm. On the final day of storage, mature green fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 recorded the least percent leakage (55.93%). According to Brishti *et al*., (2013) treatment with aloe gel and papaya leaf incorporated aloe gel significantly reduced the loss of firmness associated with less weight loss in papaya fruits during storage. Similar results were found in coated strawberries (Del Valle *et al.*, 2005) and cherries (Alonso and Alique, 2004). Fruits treated with papaya leaf extract incorporated aloe gel (1:1) +INS 402 (56.93%), aloe gel + INS 402 (57.06) and guava leaf extract incorporated aloe gel (1:2) + INS 402 (58.47%) were also equally effective in reducing the percent leakage in mature green tomatoes.

On the final day of storage (24th day) of firm ripe tomatoes, the least percent leakage (68.84%) was for the fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 which was equally effective as fruits dipped in aloe gel + INS 402 (69.53%). This has clearly indicated that the ripening of coated fruits was delayed by delaying softening and thus proved to maintain the texture of fruit efficiently.

5.3.2. Chemical parameters

The effect of plant leaf extract incorporated aloe gel (PLEAG) on the chemical quality parameters *viz.,* TSS, pH, vitamin C, titratable acidity and lycopene content of mature green and firm ripe tomato fruits were evaluated and compared with that of the fruits coated with pure aloe gel based coatings.

When TSS, pH, vitamin C content and titratable acidity of mature green and firm ripe tomatoes were compared, all the PLEAG and aloe based formulations were equally effective in maintaining the chemical parameters on the final day of storage. The quality maintenance in coated tomatoes might be due to the positive effect of aloe gel coatings and also due to the antimicrobial activities imparted by the different plant extracts used.

Hassanpour (2015) reported the efficiency of aloe gel coating in retention of TSS, titratable acidity and vitamin C content levels in raspberry due to the lower gas permeability inhibiting the respiratory rate and retarding the overall metabolic activity of fruits during storage. According to Pranoto *et al*., (2005b), the ability of edible films to retard moisture, oxygen, aroma and solute transport may be improved by including additives such as antioxidants, antimicrobials, colorants, flavours, fortifying nutrients and spices in film formulation. The addition of natural antioxidants derived from plant extracts as a way of increasing the shelf life of food products has become increasingly popular and it has also improved the stability of lipids and lipid-containing foods, thereby preventing sensorial and nutritional quality loss (Ozcan, 2003; Ponce *et al*., 2004). Morillon *et al.,* (2002) reported that the gas barrier and hydrophobic properties of aloe based edible coatings could be improved with the addition of plant lipids, since the increase of lipid content in the composition of edible coatings leads to higher hydrophobic properties and barrier efficacy. These findings clearly proved the efficiency of PLEAG over aloe based formulations. PLEAG and aloe based coatings were equally effective in reducing the lycopene content in mature green tomatoes on the 36th day of storage. In firm ripe tomatoes the least lycopene content (58.16μgg^{-1}) was observed in fruits dipped in papaya leaf extract incorporated aloe gel (1:1) +INS 402 which was on par with fruits dipped in papaya leaf incorporated aloe gel (1:2) +INS 402 (59.12 μgg^{-1}) and aloe gel +INS 402 (59.44μgg^{-1}) treated tomato fruits.

The pigment content is changed during fruit development and during ripening the chlorophyll content decreases and a prompt synthesis of carotenoids occurs resulting in the synthesis of red pigment lycopene and β-carotene. The least lycopene content in the coated firm ripe fruits reveals the decreased synthesis of carotenoids due to the reduced ethylene emission rates and ripening process.

5.3.3. Microbial parameters

When the bacterial load on the surface of coated mature green and firm ripe tomatoes were analyzed, both plant leaf extract incorporated aloe gel (PLEAG) and pure aloe gel coatings were equally effective in reducing the bacterial population. According to Habeeb *et al.,* (2007) aloe gel is composed of a wide range of constituents which are mainly responsible for the antimicrobial activity against various microorganisms. Suresh *et al.,* (2008) reported that the aqueous extracts of the *Carica papaya* and *Psidium guajava* inhibited the growth of many micro organisms viz., *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus* which shows that the extract contains substances that can inhibit the growth of these microorganisms. Secondary metabolites in ocimum leaves viz., alkaloids, glycosides, tannins and flavanoids are responsible for the inhibition of microorganisms (Balakumar *et al.*, 2011).

5.3.4. Physical parameters

When the effect of different plant leaf extract incorporated aloe gel (PLEAG) + INS 402 and aloe gel +INS 402 on the physical parameters like appearance, colour, flavour, taste, texture and overall acceptability of tomatoes was assessed, the superiority of papaya leaf extract was revealed compared to guava and ocimum leaf extract for incorporating with aloe gel.

Mature green fruits coated with papaya leaf incorporated aloe gel + INS 402 recorded the highest mean sensory scores for all the physical parameters compared to fruits coated with other plant extracts and pure aloe based formulations. In firm ripe fruits both papaya leaf extract incorporated aloe gel and pure aloe gel scored highest mean sensory scores for appearance and colour. For all the other parameters like flavour, taste, texture and overall acceptability highest mean sensory score was for the papaya leaf extract incorporated aloe gel coated fruits.

The mature green and firm ripe fruits coated with papaya leaf extract incorporated aloe gel + INS 402 recorded the least physiological loss in weight and percent leakage and hence resulted in highest sensory score for the physical parameters viz., appearance, texture and overall acceptability. Aloe gel + INS 402 was also equally effective in reducing the PLW and percent leakage in mature green and firm ripe fruits and thereby scored comparatively higher mean sensory scores for the above physical parameters analyzed.

In mature green tomatoes, fruits coated with papaya leaf extract incorporated aloe gel + INS 402 recorded the least lycopene content on the final day of storage and hence resulted in higher sensory score for colour. Firm ripe tomatoes coated with papaya leaf extract incorporated aloe gel + INS 402 and aloe gel + INS 402 had reduced lycopene content and resulted in higher sensory score for colour.

The cost of preparation of pure and plant leaf extract incorporated aloe based edible films were compared to check whether substitution of aloe gel with plant leaf extracts is possible without affecting its efficiency in increasing the shelf life of tomato.

One kilogram aloe leaves produce 850 ml gel, which was mixed with different ingredients including papaya leaf extract and gelling agent, INS 402 to produce 52.5 litre formulation, when prepared at 2% concentration and cost of preparation the formulation was worked out to be Rs 48.16/- which could be utilized for dipping 105 Kg mature green tomatoes. The same 850 ml gel when prepared at 1% concentration could produce 105 litres formulation for Rs 49.66/- which could be utilized for dipping 210 Kg firm ripe tomatoes.

So cost of dipping 100 Kg mature green tomatoes with the selected papaya leaf extract incorporated aloe based formulation was calculated to be Rs.45.87/- and it was Rs.23.65/- for 100 Kg firm ripe tomatoes. When PLEAG was used, an amount of Rs.9.61/- could be saved in treating 100 kg mature green tomatoes. Similarly when the pure aloe based formulation is replaced with PLEAG based aloe gel for skin coating, an amount of Rs.4.97/- could be saved in treating 100 Kg firm ripe fruits. These rates could clearly prove the possibility of substitution of aloe gel with plant leaf extracts without affecting its efficiency in increasing the shelf life of tomatoes.

Considering the efficiency in maintaining the physiological, chemical, microbial and physical parameters, papaya leaf extract incorporated aloe gel (1:2) + INS 402 was selected as the effective plant leaf extract incorporated aloe gel (PLEAG) for increasing the efficiency of the aloe gel for increasing the shelf life of tomatoes.

5.4. QUALITY EVALUATION OF FILM COATED TOMATO

Bioactive products of plants are less persistent in environment and are safe for mammals, other non target organisms (Meepagala, 2002; Fokialakis, 2006) and for the control of postharvest disease than synthetics (Barrera-Necha *et al.,* 2008).

Papaya leaf is a potential antifungal agent that could be used as a bio based additive which contains bioactive compounds having antifungal activity (Banos *et al.,* 2002). Thus, the extracts of papaya leaf could be incorporated into aloe gel to enhance the effectiveness of the anti-fungal activity of aloe gel matrix.

Tomato fruits at two maturity stages *viz.*, mature green and firm ripe, were coated separately with the aloe gel based film coating selected from part 4.2 of the experiment and papaya leaf extract incorporated aloe gel selected from part 4.3 of the experiment. The textural and other quality parameters of both these coated fruits were analysed in detail so as to select the most efficient aloe based edible film coating capable of increasing the shelf life of tomato.

5.4.1. Physical Parameters

Effects of aloe gel and papaya leaf extract incorporated aloe gel treatments on the firmness and bio yield point of mature green and firm ripe tomatoes were analyzed along with sensory perception of textural parameters for a period of 36 and 24 days respectively at 12 days interval.

Firmness of fruits and vegetables influences all the textural parameters associated with the commodity. According to Kader *et al*., (1978a) the textural quality of tomatoes is influenced by flesh firmness, the ratio between pericarp and locular tissue and skin toughness. Mature green and firm ripe fruits treated with papaya leaf extract incorporated aloe gel recorded a higher firmness (49.16N and 32.95N respectively) and bio yield point (137.92N and 86.75N respectively) compared to fruits treated with aloe gel at the end of storage.

The point at which the appropriate probe of a texture analyzer punctures through the fruit skin and begins to penetrate into the fruit flesh, is represented by the sudden change in slope of the graph, called the 'bio yield point' and it causes an irreversible damage. As the fruit becomes firmer the force required to puncture through the fruit skin is more and hence resulted higher bio yield point in papaya leaf extract incorporated aloe gel coated fruits compared to aloe gel coated fruits. The above results revealed the superiority of papaya leaf extract incorporated aloe gel over pure aloe gel in maintaining the fruit firmness. This result was in conformity with the findings of Marpudi *et al.,* (2011) who had observed a firmness of 1N, 2.5N and 4N respectively for control, aloe gel and papaya leaf extract incorporated aloe gel coated papaya fruits when stored for 15 days. According to Brishti *et al.,* (2013) papaya fruits coated with papaya leaf incorporated aloe gel recorded a higher firmness of 3.2N compared to aloe gel coated fruits with 3.00N.

Texture in food products is generally defined as the overall feeling that the food gives in the mouth and therefore comprised of properties that can be evaluated by touch (Abbott, 2004).

The sensory perception of finger feel, mouth feel and textural appearance of mature green and firm ripe fruits revealed that papaya leaf extract incorporated aloe gel and pure aloe gel were equally effective in maintaining the physical parameters of fruits. The higher retention of fruit firmness might be the reason for higher sensory scores obtained when sensory perception of textural parameters analyzed.

5.4.2. Chemical parameters

The textural properties of tomatoes may also be evaluated in terms of their component parts, the most important being total solids, total insoluble solids, alcohol insoluble solids and total pectin. Hence these parameters of treated fruits were assessed on storage. In addition, the activity of texture-affecting enzymes viz., pectin methyl esterase and poly galacturonase enzymes were also evaluated.

Mature green and firm ripe fruits coated with aloe gel and papaya leaf extract incorporated aloe gel were equally effective in maintaining the total solids, total and alcohol insoluble solids during the entire storage period.

The two enzymes involved in the breakdown of pectin are pectin methyl esterase (PME) and poly galcturonase (PG). PME has been implicated in various growth and developmental processes in plants, including textural changes in ripening fruits, formation of abscission zones and cell wall growth, maturation, and extensibility (Northcote, 1986).

Papaya leaf extract incorporated aloe gel recorded the least pectin methyl esterase and poly galacturonase activity in both mature green (61.88 and 9.94U/ml respectively) and firm ripe (61.61 and 13.46 U/ml respectively) fruits on the final day of storage. This reduction in enzyme activity in the papaya leaf incorporated aloe gel coated mature green and firm ripe fruits resulted in increased fruit pectin content also. (8.64 and 7.43 respectively). According to Tieman and Handa, (1994) lowered PME activity has a marked effect on the integrity of tomato fruits stored for extended periods and modifies repartitioning of cations, in particular calcium, between soluble and bound forms in ripening fruits.

According to Perkins-Veazie, (2010), fruit softening occurs considerably during ripening which is mainly as a result of degradation of the middle lamella of the cell wall of cortical parenchyma cells. Brummell and Harpster, (2001) reported that changes in cell wall structure and in their composition are mainly due to the combined action of enzymes including hydrolases, particularly polygalacturonase (PG), pectin methyl estarase (PME), galactosidase (Gal), pectatelyase (PL) and cellulose (Cel). The results of the quality evaluation studies are in line with the findings of Martinez-Romero *et al.*, (2006) who had reported that aloe gel has a role in the reduction of activity of poly galacturonase, pectin methyl esterase and galactosidase enzymes responsible for fruit softening and maintains the pectin content. According to Brishti *et al.,* (2013) the treatment with aloe gel and papaya leaf incorporated aloe gel significantly reduced the loss of firmness and thereby provided a better texture for the coated papaya fruits by reduced enzyme activity.

5.4.3. Microbial parameters

According to Satheesh *et al.,* (2004) a number of plant species have been reported to possess natural substances that are toxic to many fungi causing plant diseases. Ranaware *et al.,* (2010) indicated the efficacy of aqueous plant extracts as potential inhibitors of many pathogens. Similarly Dwivedi and Shukla (2000) reported the effectiveness of aqueous extracts of different species of plants against *Fusarium oxysporum*.

In tomato the bacterial soft rot and rhizopus rot are the two major post harvest diseases and hence this study was conducted with the objective of determining the *in vitro* and *in vivo* antimicrobial assay of papaya leaf extract incorporated aloe gel and pure aloe gel based extracts against these pathogens. *In vitro* antimicrobial assay of these extracts against *Erwinia* and *Rhizopus* showed no formation of inhibition zone. Even though aloe vera and papaya leaf extracts are reported to have many antimicrobial properties, the non formation of inhibition zone in the present study might be due to the usage of lower concentrations of aloe based extracts in the formulations.

Fruit disease index is used as a measure to indicate the effect of selected coatings on the microbial quality of fruits. *In vivo* study revealed that the disease symptoms of bacterial soft rot and Rhizopus rot were not observed on surface of papaya leaf incorporated aloe gel and pure aloe gel coated mature green and firm ripe fruits until two weeks due to the anti-microbial potential of coated materials.

In untreated fruits about 80% surfaces of the mature green and firm ripe fruits were affected by the diseases. The absence of disease symptoms in the coated fruits might be due to the effect of the film coating formed by aloe gel which could act as a protective barrier for the entry of these post harvest pathogens (Fig 2). This was in line with the findings of Habeeb *et al.,* (2007) that aloe gel and papaya leaf extract contain bioactive agents to prevent disease development in coated papaya fruits.

Based on comparative quality evaluation studies of tomato fruits coated with aloe gel and papaya leaf extract incorporated aloe gel based edible films, papaya leaf extract incorporated aloe gels at the following specific concentration and duration were selected as the best edible film coating for shelf life extension.

Dipping in 2% [papaya leaf extract incorporated aloe gel (1:2) + INS 402] for two minutes was selected for extending shelf life of mature green tomatoes, where as in case of firm ripe tomatoes, dipping in 1% [papaya leaf extract incorporated aloe gel (1:2) + INS 402] for one minute was effective.

5.5. EFFICIENCY OF EDIBLE FILM IN REDUCING POST HARVEST LOSS DURING STORAGE AND TRANSPORTATION

Tomato fruits were coated with the papaya leaf extract incorporated aloe gel based edible film selected from part 4.4 of the experiment and were compared with fruits coated with a commercial bee wax formulation and untreated fruits with the objective of assessing the efficiency of edible films in reducing postharvest loss during storage and transportation.

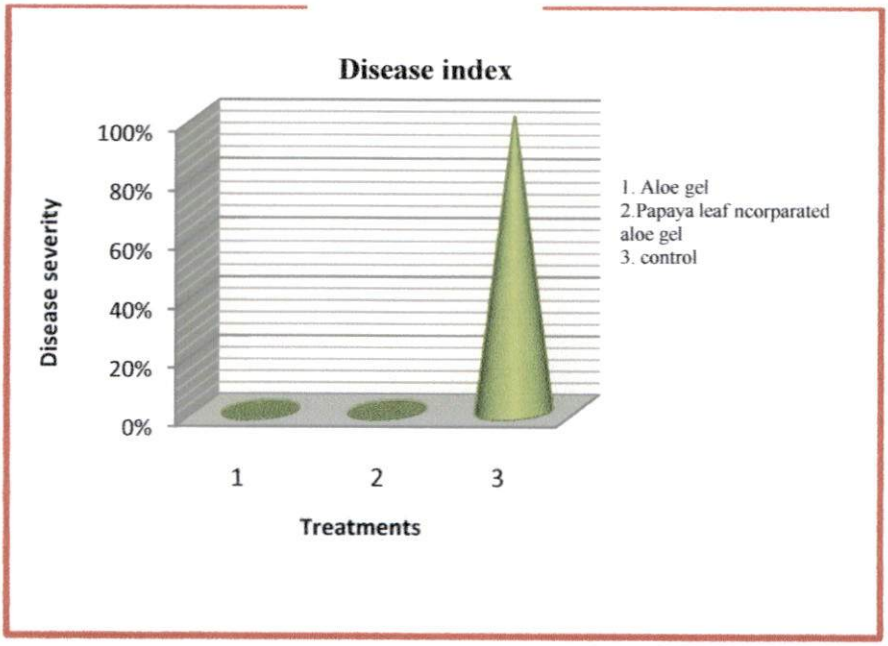


Fig 2. Effect of edible coatings on the disease development by artificial inoculation of tomatoes

5.5.1. Efficiency in extending storage life

Mature green tomato fruits were dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 and a commercial bee wax formulation each at 2% for two minutes and packaged in 5% ventilated Corrugated Fibre Board (CFB) boxes with and without moulded tray and stored under the ambient and optimum low temperature condition along with untreated fruits. Firm ripe fruits were subjected to the same type of packaging and storage except that the fruits were dipped in 1% concentration for one minute.

The following physiological, chemical, microbial and physical parameters of fruits were analyzed till they had lost their shelf life.

The coated and packaged mature green and firm ripe fruits under low temperature storage had a shelf life of 60 and 36 days respectively, and hence observations for mature green fruits were recorded at 15 days interval and firm ripe fruits at 12 days interval.

All the mature green and firm ripe tomato fruits kept under ambient storage conditions were decayed after the 30^{th} and 12^{th} day of storage respectively and therefore comparison could be made only between the fruits stored under optimum low temperature condition. An additional 30 and 24 days of shelf life was reported in mature green and firm ripe fruits respectively for fruits stored under low temperature when compared with ambient storage. This itself proved the necessity of low temperature storage for increasing the shelf life of tomato fruits. Hardenburg *et al.*, (1986) mentioned that storage under low temperature has been considered as the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rot development. According to Maharaj and Sankat (1990) the storage life of breadfruits at 28^0C for 8 days was extended upto 18 days at 16^0C without any characteristic changes. Latifah (2009) reported a longer shelf life of 10 days in rambutan packed inside the sealed and perforated bags stored at 10^0C.

5.5.1.1. Physiological parameters

On the 12th and 30th day of storage of firm ripe and mature green fruits, the physiological parameters were greatly influenced by the effect of storage conditions.

For all the physiological parameters analyzed, low temperature storage was found superior in reducing the physiological loss in weight, respiration rate and percent leakage of tomato fruits compared to fruits stored under ambient storage conditions **(Fig 3).** This was in line with the findings of Rai *et al.,* (2011) that respiration of fruits decreases with the progress of storage under low temperature due to the accumulation of carbon dioxide inside the packages and this protects the fruit from physiological, pathological and physical deterioration in the fruits and thereby retained the freshness.

Wills *et al.*, (1996) reported that the rate of a chemical reaction approximately doubles with each 10^0 C rise in temperature. According to Rajkumar and Mitali (2009) low temperature storage is necessary to increase the shelf-life of fruits and vegetables by means of retarding the natural physiological deterioration and preventing the activity of decay organisms. Prasad (1998) revealed that deterioration of lovi lovi fruits started from the first day of storage and the loss was more under room conditions rather than those kept under low temperature.

When the effect of two different packaging conditions on the shelf life of mature green tomato fruits were analyzed, significant difference was found between the two packaging systems viz., 5% ventilated CFB box with and without moulded tray in reducing the physiological parameters like PLW and respiration rate of mature green fruits **(Fig 4).** Moulded tray acts as an insert which prevents physical damage and abrasion. Lal and Fageria (2004) reported that lining of polythene in gunny bags acted as a water vapour barrier between atmosphere and the fruits, thereby reducing the rate of transpiration. In firm ripe tomatoes both the packaging systems were equally effective in maintaining the physiological parameters.

The findings were also supported by Ryall and Uota (1955) that Yellow Newton apples stored for six months in sealed 150 gauge polyethylene box with

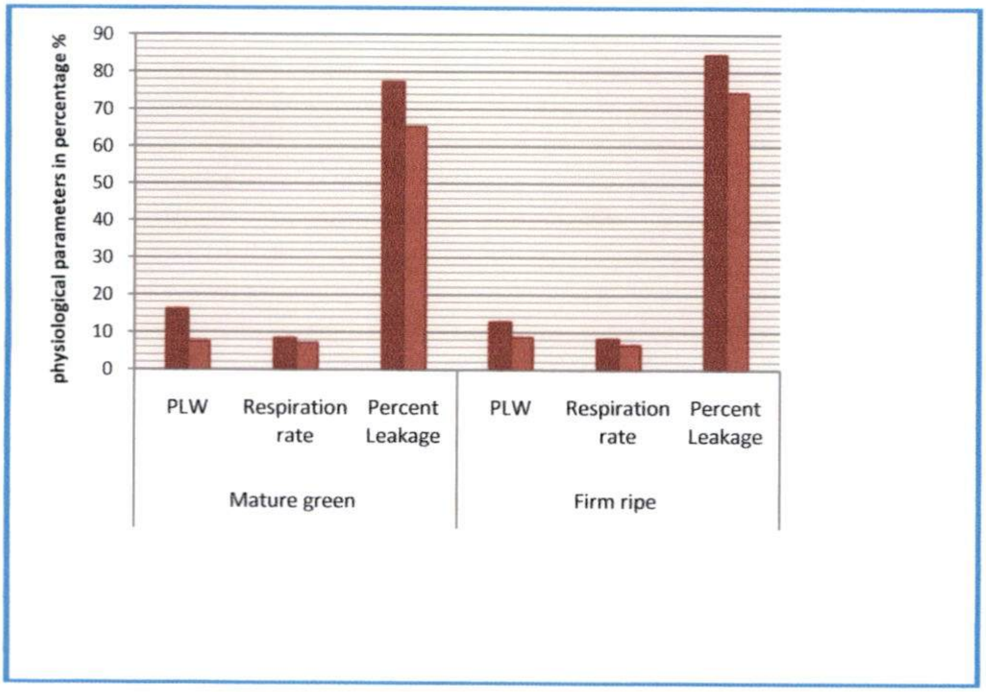


Fig 3. Effect of storage conditions on the physiological parameters of tomatoes

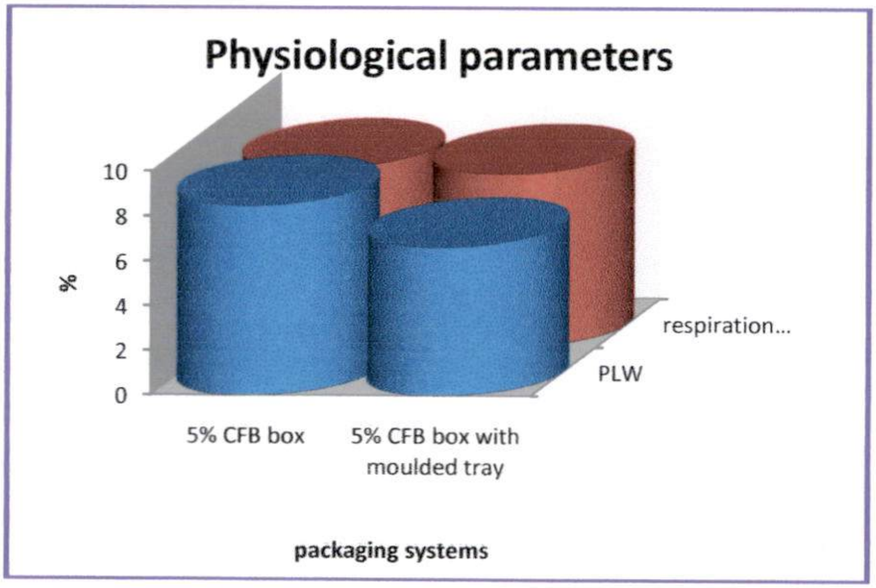


Fig 4. Effect of packaging systems on the physiological parameters of tomatoes

liners at 4.4 °C retained green colour and firm texture, and developed less scald than fruits in check boxes without film liners. Waskar *et al*., (1999) also revealed that the shelf life of sapota was extended to 13 and 15 days by packing in polythene bags in CFB box or in polythene bags respectively and storing in a cool chamber.

When the different treatments *viz.,* papaya leaf incorporated aloe gel and commercial bee wax formulation were compared with uncoated fruits, it was found that the treatments were superior in reducing the physiological parameters analyzed (Fig 5) compared to uncoated fruits. The standardized papaya leaf incorporated aloe gel was equally effective in reducing all the physiological parameters of firm ripe and mature green tomatoes compared to commercial wax coated fruits on the final day of storage.

Martinez-Romero *et al*., (2006) reported that a higher aloe concentration (33% v/v) significantly reduced the firmness losses (more than 50%) during cold storage in cherries. The effectiveness of wax coating was supported by the findings of Banik *et al*., (1998) who had reported that ber fruits coated with paraffin wax when kept at 10-12^{0}C and 85- 90% RH could be stored up to 18 days with minimum spoilage and physiological weight loss in comparison with 100% spoilage in untreated fruits at 28^{0}C and 70% RH on 9thday of storage. Banana cv. Robusta dipped in six percent wax gave shelf life of 13 days in room storage and 24 days in cold storage (Doshi and Sutar, 2010).

5.5.1.2. Chemical parameters

Storage temperature had no influence in the TSS and pH content of the stored fruits; however the vitamin C, titratable acidity and lycopene content were greatly influenced by the storage conditions. The result showed that the mature green and firm ripe fruits stored under low temperature was found superior in maintaining an increased vitamin C and titratable acidity as well as reduced lycopene content in the fruits indicating a delayed ripening process.

The decreased vitamin C content in ambient storage condition might be due to the acidation and degradation of ascorbic acid molecules forming dehydro ascorbic acid by enzyme ascorbinase (Das and Desh, 1967). Shetty (2017) reported a highest

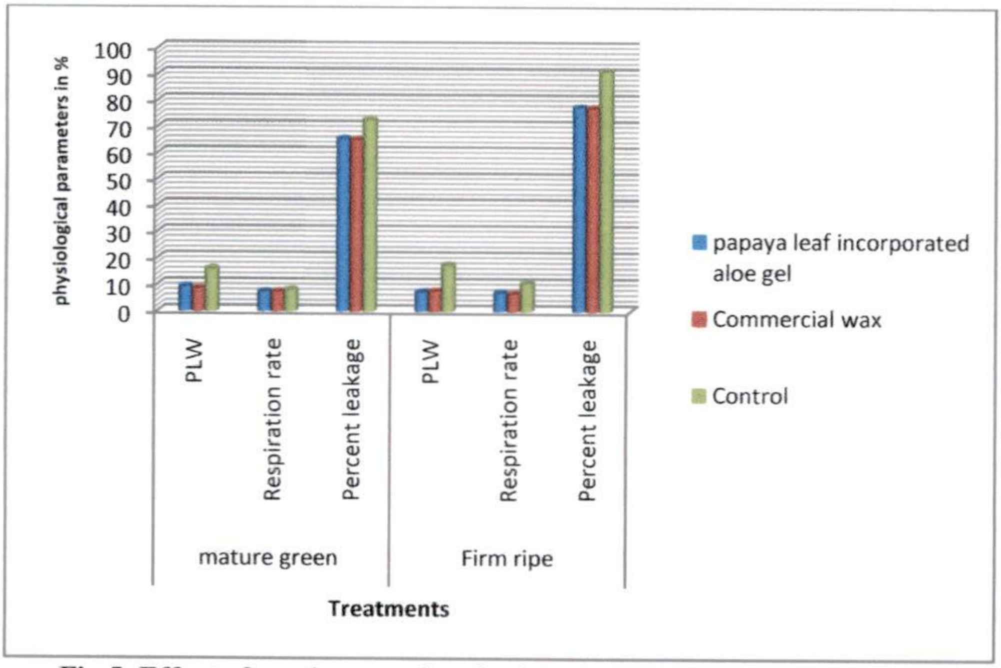


Fig 5. Effect of coatings on the physiological parameters of tomatoes

acidity (0.40%) in rambutan fruits treated with paraffin and bee wax at the end of 4 days of storage. According to Reshma (2014), pineapple fruits stored at 8 ± 2°C had the highest post harvest life of 33 days with better biochemical qualities compared to fruits under ambient condition. According to Worakeeratikul *et al.,* (2007) chitosan retarded browning, total soluble solids, and titratable acidity in rose- apple fruit (4°C) at concentrations of 0.05, 0.1 and 0.2% (v/v), wrapped with PVC film and stored at 5°C for 72 hrs.

Both the packaging systems were equally effective in maintaining the chemical parameters of firm ripe and mature green tomatoes.

The coatings had not influenced the chemical parameters like TSS, pH, vitamin C content and titratable acidity of tomato fruits except lycopene content. Mature green fruits and firm ripe fruits treated with commercial wax recorded least lycopene content (36.00$\mu g g^{-1}$ and 41.24$\mu g g^{-1}$respectively) which was significantly different from papaya leaf incorporated aloe gel on the final day of storage (Fig 6). The least lycopene content recorded in commercial wax coated fruits might be due to the delay in ripening which can be considered as a positive factor for shelf life extension. But the commercial wax coated fruits exhibited a non uniform colour development compared to papaya leaf incorporated aloe gel treated fruits which had developed an attractive uniform colour (Plate 8). Reduced ethylene production has been reported in papaya leaf extract incorporated aloe gel coated papaya fruits (Marpudi *et al.*, 2011) and in peach fruits coated with wax emulsions (Erbil and Muftugil, 1986).

Dipping of banana fruits in 1.5 percent or 2.5 percent Tal-prolong solution delayed yellow colour development by 4-8 days (NHB, 2012). According to Saravanan *et al.*, (2013) six percent wax coating in Dwarf Cavendish increased the green life by 40 days.

5.5.1.3. Microbial parameters

The bacterial load on the surface of coated mature green and firm ripe fruits was least when stored under low temperature condition (2.38 x10^2cfu/g and 4.40 x10^2cfu/g respectively). According to Philips (1996) reducing the respiration rate by

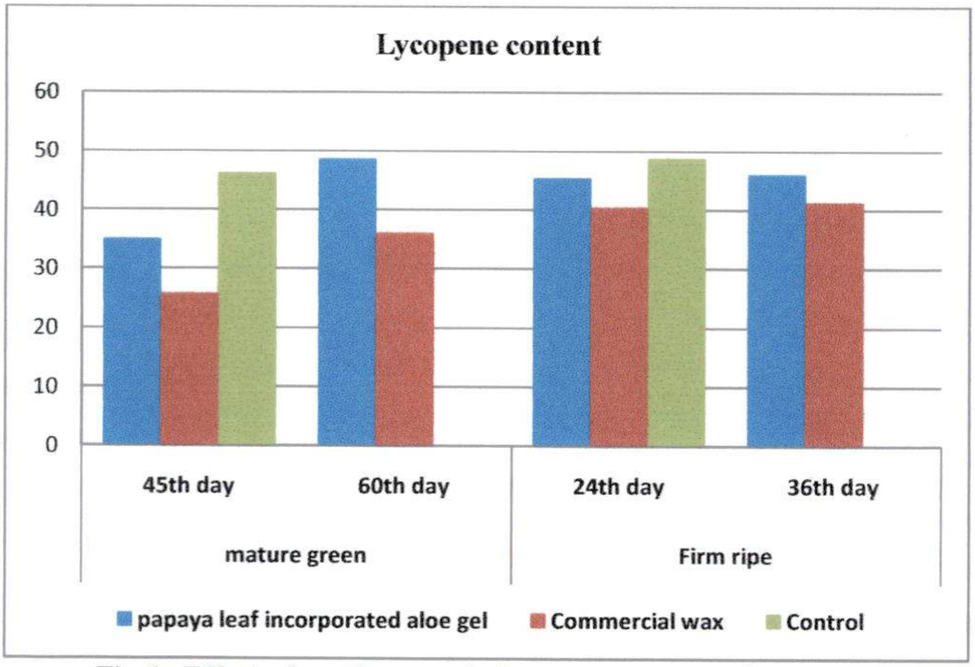
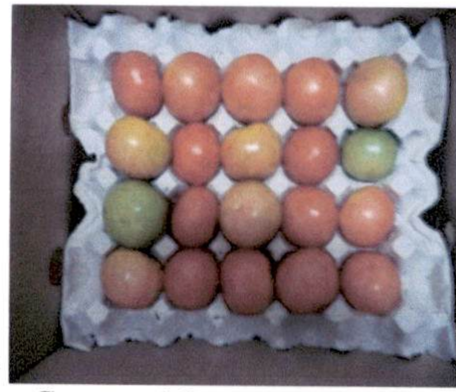


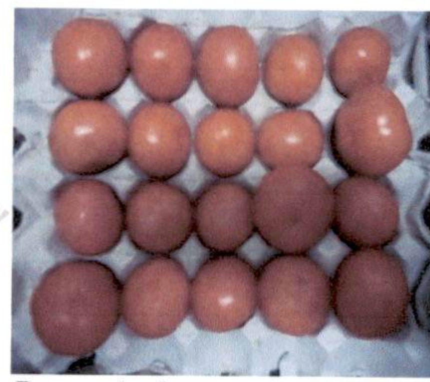
Fig 6. Effect of coatings on the lycopene content of tomatoes

Commercial wax coated fruits on 30 DAS



Commercial wax coated fruits on 45 DAS

Papaya leaf extract incorporated aloe aloe gel coated fruits on 30DAS



Papaya leaf extract incorporated aloe gel coated fruits on 45DAS

Plate 8. Effect of coatings on colour development in mature green tomatoes

controlled atmosphere may not only retard the ethylene production but also the microbial load.

Both the packaging conditions were equally effective in reducing the bacterial load on the fruit surfaces. The effect of coatings on the bacterial load on the surface of mature green and firm ripe fruits revealed the superiority of treatments over the uncoated fruits. The bacterial load in uncoated fruits was too numerous to count in control fruits while both treatments were equally effective in reducing the bacterial load on the fruit surface. Olivas and Barbosa-Cánovas (2005) opined that modified atmosphere created by coating may change the growth rate of spoilage and pathogenic bacteria and modified atmosphere may inhibit the growth of organisms usually responsible for spoilage. Min and Krochta (2005) reported that waxes serve as physical barriers to spoilage microorganisms by preventing their entry and increase the shelf life of fruit and vegetables.

5.5.1.4. Physical parameters

The effect of coatings and packaging on physical parameters like appearance, colour, flavour, taste, texture and overall acceptability revealed the superiority of coating mature green fruits with papaya leaf incorporated aloe gel and packaging in 5% ventilated CFB box with moulded tray under optimum low temperature with highest rank for all the sensory parameters analyzed. Devi and Joshi (2012) reported best sensory qualities for plum treated with edible coatings and Najafi and Shaban (2015) reported a highest flesh colour retention with 1% chitosan coating during storage of strawberry.

Even though both the treatments were equally effective in controlling the physiological parameters of fruits, the wax coated fruits recorded least rank values for appearance, flavour and taste during analysis of physical parameters. The least rank for these parameters might be due to influence of the rice bran oil which was used for the preparation of the commercial bee wax formulation. The non uniform colour development observed on the commercial wax coated fruits might have resulted in least rank and mean score during analysis of physical parameter, colour.

Packaging of mature green fruits in 5% ventilated CFB box with moulded tray was found to be effective in reducing the physiological parameters like PLW and respiration and hence scored highest rank for the physical parameters analyzed. Both the packaging systems were equally effective in maintaining all the physiological, chemical and microbial parameters of firm ripe tomatoes however the highest sensory scores were scored by the fruits packaged in 5% ventilated CFB box with moulded tray and hence selected as the suitable packaging system for firm ripe fruits.

5.5.2. Efficiency in withstanding transportation hazards

Fresh fruits and vegetables are highly susceptible to mechanical injury during transport owing to their tender texture and high moisture content. Poor handling, unsuitable packaging and lack of refrigeration during transportation are the causes of bruising, cutting, breaking, impact wounding and other forms of injury in fresh fruits and vegetables.

Transport is a crucial phase in the distribution of fresh food products, from the harvesting operation to the consumer. However, during transport and handling, fresh products may suffer considerable damage. According to Zeebroeck (2007), the presence of minor mechanical injuries, later lead to fungal diseases. Shewfelt *et al.*, (1987) reported that mechanical damages not only lead to postharvest losses, but also create various stresses to fruits leading to physiological and morphological changes of the fruit subsequently.

Mature green and firm ripe tomato fruits were dipped respectively in 2% and 1% concentrations of papaya leaf extract incorporated aloe gel (1:2) + INS 402 and a commercial bee wax formulation for two and one minute respectively and packaged in 5% ventilated Corrugated Fibre Board (CFB) boxes with and without moulded tray and transported to distant and local market to analyze the efficiency of edible coatings in withstanding transportation hazards. Tomato fruits without any coating were set as control for comparison.

Mature green fruits were transported to a distance of 512 km in a reefer cargo van maintained at a temperature of 18^0C to represent distant market and firm ripe fruits to a distance of 128 km in a cargo van as a symbol of local market transport. Physiological, chemical, microbial and physical parameters were recorded before and after transportation and the results are discussed below.

5.5.2.1. Physiological parameters

Packaging is a fundamental tool for the post-harvest management of highly perishable commodities like fruits. Adequate packaging protects the produce from physical, physiological and pathological deterioration during transportation and storage (Krishnamurthy, 1990).

Coated mature green fruits packaged in 5% ventilated CFB box with moulded tray was superior in reducing the physiological parameters like PLW, respiration rate and percent leakage compared to packaging in 5% ventilated CFB box. In firm ripe fruits both packaging systems were equally effective in maintaining PLW and respiration while percent leakage was reduced by fruits packaged in 5% ventilated CFB box with tray. The 5% ventilations present in the CFB box maintained freshness and turgidity of fruits during transportation and the presence of moulded tray in between the fruits helped to retain the quality parameters by avoiding physical losses especially abrasion and compression damage.

The rate of ripening and the subsequent deterioration in quality depend on respiration and transpiration losses. Packaging has the potential to reduce moisture loss, restrict entrance of oxygen, lower respiration, retard ethylene production, seal in flavor volatiles and retard discoloration during transportation (Luo *et al*., 2004). Lal and Fageria (2004) reported that ber fruits packed in gunny bags lined with polythene recorded a minimum PLW (2.74%) followed by CFB boxes (6.29). According to Kader *et al.,* (1985), the physiological processes can be slowed down by using polyethylene box liners, which has good moisture barrier properties that helps in creating modified atmosphere conditions.

Mature green and firm ripe fruits coated with commercial wax and papaya leaf incorporated aloe gel were found equally effective in maintaining the physiological parameters like PLW, respiration rate and percent leakage compared to the untreated fruits. The reduced physiological parameters might be due to the decrease in the rate of metabolism and prevention of water loss by the coatings. The minimization of weight loss in wax coated fruits might be due to the action of wax as a physical barrier to gas diffusion from fruit stomata through which the gas exchange takes place between tissue and external atmosphere (Islam *et al.,* 2001; Saravanan *et al.,* 2013).

5.5.2.2. Chemical Parameters

Chemical parameters were similar for both mature green and firm ripe fruits packaged in 5% ventilated CFB box with and without tray. The coatings were also equally effective in maintaining the chemical parameters before and after transportation compared to the untreated fruits. This was in line with the findings of Chrysagaris *et al*., (2016) who had found that aloe gel reduces the ethylene production, softening, total acidity and prevents colour development. Hassanpour (2015) reported that aloe vera coating was more effective in the retention of TSS, acidity and ascorbic acid levels because of the resultant lower gas permeability which inhibited the respiratory rate and retarded the overall metabolic activity of raspberry fruits during storage.

5.5.2.3. Microbial parameters

The bacterial load on the surface of mature green and firm ripe fruits treated with papaya leaf incorporated aloe gel packaged in 5% CFB box with and without tray was too less to count before and after transportation, while the bacterial load was too numerous to count in the untreated fruits. The lower bacterial count in the coated fruits might be due to the bioactive compounds present in papaya leaf extract that increases the antimicrobial property of aloe gel and the commercial wax. According to the findings of Castillo *et al*., (2010), aloe gel has been identified as a novel coating agent with good antimicrobial properties.

5.5.2.4. Physical parameters

Mature green and firm ripe fruits coated with papaya leaf incorporated aloe gel packaged in 5% ventilated CFB box with moulded tray scored high mean sensory score for all the physical parameters like appearance, colour, flavour, taste, texture and overall acceptability revealing its superiority.

Cost of preparation for one litre commercial bee wax formulation was Rs.210/- when prepared @ 2%, which could be utilized for dipping 1.5 Kg for mature green tomatoes, thus costing Rs. 14000/- for dipping 100kg fruits. For firm ripe fruits, cost of preparation of one litre commercial bee wax formulation was Rs. 186.50/- when prepared @ 1% concentration and the total cost for dipping 100 Kg firm ripe fruits was calculated as Rs. 12.433/. The cost is extra ordinarily high compared to that of papaya leaf extract incorporated aloe gel formulation, which could be prepared @ Rs. 45.9/- and Rs. 23.6/- for treating 100 Kg mature green and firm ripe tomatoes respectively. The increased cost of production of commercial formulation was due to the high cost of rice bran oil used in the preparation

Based on the physiological, chemical and microbial parameters analyzed, papaya leaf incorporated aloe gel and commercial wax were found equally effective in maintaining the quality parameters on the final day of storage and based on physical parameters and on considering the economics of production, papaya leaf incorporated aloe gel was selected as the best aloe based edible film coating for shelf life extension in tomato.

Combining all the five steps of the experiment, a viable and efficient post harvest management schedule has been formulated for extending shelf life of tomatoes at two different maturity stages.

Mature green tomatoes after surface sanitization using 2 ppm ozonized water for 10 minutes, can be dipped in 2% papaya leaf extract incorporated aloe gel (1:2) + INS 402 for two minutes and can be safely stored for 60 days at optimum low temperature of $12^0 – 20^0$C after packaging in 5% ventilated CFB box with moulded tray. This can be transported to distant markets in reefer cargo van at 18^0C. Firm ripe fruits could be subjected to similar post harvest management practices to have a shelf life of 36 days except that the coating is to be done with 1% papaya leaf extract incorporated aloe gel formulation for one minute, optimum storage temperature being 10-15^0C and transportation is meant for local market in cargo van.

SUMMARY

6. SUMMARY

Tomatoes deteriorate rapidly after harvest either during or after transport, storage or marketing. Due to the consumer's concerns over the safety of foods containing synthetic chemicals and economic impacts of spoiled foods, a lot of attention has been given to naturally derived compounds or natural products. In recent years, the use of *Aloe vera* gel has gained much attention for use as a safe and environment-friendly postharvest treatment and it has been identified as a novel coating agent with good antimicrobial properties.

The results of the investigation on "*Aloe vera* gel based edible film coating for shelf life extension in tomato (Solanum lycopersicum)" conducted with the objectives to standardise an *Aloe vera* gel based edible film coating for tomato fruits to withstand storage and transportation losses, thereby formulating a viable and efficient postharvest management practice for extending shelf life of tomato were statistically analyzed and are summarized below:

The study was conducted in five different continuous experiments; *viz*. preliminary trial for preparation and standardization of aloe extract, standardization of aloe gel as edible film for extension of shelf life, evaluation of plant leaf extract incorporated aloe gel for extension of shelf life, quality evaluation of film coated tomato and assessing the efficiency of aloe based edible film in reducing postharvest loss during storage and transportation.

As the present study is the first to assess the efficiency of *Aloe vera* gel based edible film in extending shelf life of any tropical vegetable in Kerala, a preliminary trial was conducted for standardization of aloe extract. The extracted aloe was mixed with four different gelling agents and tomato fruits were dipped in seven different concentrations of these mixtures for five different durations to form 140 treatment combinations and observations like shelf life and physiological loss in weight (PLW) were recorded to select the 12 superior treatment combinations from treatments.

Fruits coated with different combinations of aloe based extracts had similar shelf life. All the four gelling agents tried were significantly different from one another in reducing the weight loss. Least PLW was recorded by the fruits dipped in aloe gel + potassium alginate (INS 402), which was followed by fruits coated with aloe gel + sodium alginate (INS 401). All the seven different concentrations tried for coating tomato fruits were equally effective in reducing the weight loss during storage. When five different durations were compared, the superiority of one minute dipping was revealed with least PLW which was on par with the fruits dipped for two and five minutes.

Considering all the single and two factor interactions, INS 401and INS 402 were selected as the two best gelling agents for maintaining a thick consistency of aloe gel to act as an edible film. As the seven different concentrations were found equally effective, the least concentrations viz., 1% and 2% were selected considering the economics of treatments. When comparison was made among the five different durations, one, two and five minutes were found equally effective in reducing the PLW and hence they were selected for dipping the fruits. By combining all these parameters, 12 superior treatment combinations were selected for further studies viz., dipping fruits in 1% and 2% concentrations of aloe gel added with INS 401 and INS 402 for one, two and five minutes.

As harvest maturity of tomato depends mainly on distance to market, the study was conducted as two independent experiments separately for fruits of two different maturity stages, viz., mature green and firm ripe meant for distant and local markets respectively, so as to formulate a complete recommendation on post harvest management of tomatoes.

The objective of the second part of the experiment was to select the best aloe vera based edible skin coatings based on its effect on the changes in physiochemical and microbial quality parameters of tomatoes during post harvest life. A vegetable with least respiration rate, percent leakage and physiological loss in weight maintains its turgidity, freshness and quality. Hence these parameters were recorded at 12 days interval for the tomatoes harvested at mature green and firm ripe stages.

During the 24th day of storage, mature green fruits treated with 2% (aloe gel +INS 402) for two minutes had least PLW compared to uncoated fruits. As the untreated mature green fruits were decayed after second interval, comparison could be made among the treated/coated fruits alone on the final *ie.,* 36th day of storage. Fruits dipped in 2% (aloe gel + INS 402) for two minutes recorded the least PLW on the final day also among the different aloe gel based formulations.

In firm ripe tomatoes, almost all the aloe gel based formulations were equally effective in reducing the PLW when compared with untreated fruits on the 12th day of storage. After the second interval and before the 3rd interval, all the untreated fruits were decayed and comparison could be made only among the different aloe gel formulations on the 24th day of storage. Results revealed that fruits dipped in 1% (aloe gel +INS 402) for one minute recorded the least weight loss (5.84%) at the end of storage (24th day).

The coatings had significant effect on the respiration of mature green fruits with least respiration recorded by 2% (aloe gel+ INS 402) for five minutes compared with the control samples on the 24th day of storage.

Percent leakage is the phenomenon related with the membrane integrity of the fruit tissues. On the final day of storage comparing aloe gel formulations alone, all the different concentrations and durations of (aloe gel + INS 402) were equally effective in reducing the percent leakage compared with (aloe gel + INS 401) in case of mature green and firm tomato fruits.

When the effect of aloe gel based formulations on the chemical quality parameters viz., TSS, pH, vitamin C content, titratable acidity and lycopene content of mature green and firm ripe tomato fruits were evaluated, the aloe gel based formulations had significant influence on the chemical parameters when compared with that of the fruits without any coatings. When comparison was made among the different aloe gel formulations alone at the end of storage of mature green (36th day) and firm ripe fruits (24th day), the TSS, vitamin C and pH remained similar for fruits coated with all the aloe gel based edible coatings.

Lycopene content is an important quality parameter associated with ripening of fruits. Mature green fruits dipped in 2% (aloe gel +INS 402) for one and five minutes and 1% (aloe gel + INS 402) for one minute were equally effective in reducing the lycopene content in mature green tomatoes. Though there was no significant difference, the least lycopene content was recorded by the fruits treated with 1% (aloe gel +INS 402) for one minute (57.42 $\mu g g^{-1}$) on the final day of storage (24^{th} day).

All the aloe gel based formulations were equally effective in reducing the bacterial population on the surface of both mature green and firm ripe tomatoes compared with the control fruits during the entire storage period.

Physical parameters of fruits were almost uniform during the initial stages of storage irrespective of harvest maturity stages or edible coatings. There was no significant difference between the physical parameters analyzed and hence the treatments with highest mean sensory score were considered as the efficient aloe gel based edible film coating.

In mature green fruits on the 24^{th} and 36^{th} day of storage when all the physical parameters were analyzed the highest sensory scores were recorded by the fruits dipped in 2% (aloe gel +INS 402) for two minutes except for colour. For firm ripe fruits the sensory scores were highest for the fruits dipped in 1% (aloe gel +INS 402) for one minute on the 12^{th} and 24^{th} day.

The highest mean score was recorded by the mature green fruits treated with 2% (aloe gel +INS 402) for two minutes for flavor and taste. Similarly the highest sensory scores for flavor and taste were recorded by firm ripe fruits treated with 1% (aloe gel + INS 402) for one minute.

Cost of dipping 100 kg mature green tomatoes with the selected aloe based formulation was calculated to be Rs55.48/- and it was Rs.28.62/- for 100 kg firm ripe tomatoes.

In short, on the final day of storage, there was no significant difference in the chemical and microbial parameters of fruits due to different aloe based film coatings. Hence based on the physiological and physical parameters, 2% (aloe gel +INS 402) for two minutes and 1% (aloe gel +INS 402) for one minute were selected as the best aloe gel based edible film coatings for shelf life extension in mature green and firm ripe tomatoes respectively.

The objective of the third part of the experiment was to find out the possibility of increasing the efficiency of aloe gel based edible films selected from the second part, by incorporating natural and cheap plant extracts and to check whether substitution of aloe gel with plant leaf extracts could be possible so as to reduce the cost of preparation of edible films without affecting its efficiency.

Mature green and firm ripe tomato fruits were coated with different plant leaf extract incorporated aloe gels (PLEAG) prepared in different ratios and were compared to the aloe gel based film coated fruits (aloe gel + INS 402) selected from 4.2 of the experiment. The concentration of the extract and duration of the treatment were also selected from previous part.

Mature green tomatoes coated with PLEAG and pure aloe gel based formulation had a shelf life of 36 days and firm ripe tomatoes had 24 days. Hence the observations were recorded at 12 days interval.

Mature green fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 recorded the least physiological loss in weight (PLW) on the final day (36^{th} day) of storage. On the final day of storage (24^{th} day), firm ripe fruits coated with papaya leaf incorporated aloe gel (1:2) + INS 402 recorded the least PLW (1.29%) and this was equally effective as all the other treatments except the ocimum leaf incorporated aloe gel (1:2) + INS 402.

In mature green and firm ripe tomatoes, all the plant leaf extract incorporated aloe gels (PLEAG) and aloe gel coatings were equally effective in reducing the respiration rate in fruits.

On the final day of storage, mature green fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 recorded the least percent leakage. In firm ripe tomatoes, the least percent leakage was for the fruits dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 which was equally effective as fruits dipped in aloe gel + INS 402.

All the PLEAG and aloe based formulations were equally effective in maintaining the chemical parameters on the final day of storage.

PLEAG and aloe based coatings were equally effective in reducing the lycopene content in mature green tomatoes on the 36^{th} day of storage. In firm ripe tomatoes the least lycopene content was observed in fruits dipped in papaya leaf extract incorporated aloe gel (1:1) +INS 402 which was on par with fruits dipped in papaya leaf incorporated aloe gel (1:2) +INS 402 and aloe gel +INS 402 treated tomato fruits. Both papaya LEAG and pure aloe gel coatings were equally effective in reducing the bacterial population.

Mature green fruits coated with papaya leaf incorporated aloe gel + INS 402 recorded the highest mean sensory scores for all the physical parameters compared to coatings made of other plant extract and pure aloe based formulations. In firm ripe fruits both papaya leaf extract incorporated aloe gel and pure aloe gel scored highest mean sensory scores for appearance and colour. For all the other parameters like flavour, taste, texture and overall acceptability highest mean sensory score was for the papaya leaf extract incorporated aloe gel coated fruits. The least PLW and percent leakage recorded in fruits coated with papaya leaf extract incorporated aloe gel + INS 402 resulted in highest sensory score for appearance, texture and overall acceptability.

Cost of dipping 100 kg mature green tomatoes with the selected papaya leaf extract incorporated aloe based formulation was calculated to be Rs45.87/- and it was Rs.23.65/- for 100 kg firm ripe tomatoes proving the possibility of substitution of aloe gel with papaya plant leaf extracts without affecting its efficiency in increasing the shelf life of tomatoes. Considering the efficiency in maintaining the physiological, chemical, microbial and physical parameters, papaya leaf extract incorporated aloe gel was selected as the effective plant leaf extract incorporated aloe gel (PLEAG) for increasing the efficiency of the aloe gel.

The textural and other quality parameters of the coated fruits were analyzed in detail in the fourth part of the experiment to select the most efficient aloe based edible film coating capable of increasing the shelf life of tomato.

Mature green and firm ripe fruits treated with papaya leaf extract incorporated aloe gel recorded a higher firmness and bio yield point compared to fruits treated with aloe gel at the end of storage. But both formulations were equally effective in maintaining the physical parameters as well as the total solids, total and alcohol insoluble solids during the entire storage period.

Papaya leaf extract incorporated aloe gel recorded the least pectin methyl esterase and poly galacturonase activity and a high pectin content in both mature green and firm ripe fruits on the final day of storage.

In vitro antimicrobial assay of these extracts against *Erwinia* and *Rhizopus* showed no formation of inhibition zone. *In vivo* study revealed that the disease symptoms of bacterial soft rot and Rhizopus rot were not observed on surface of coated fruits until two weeks due to the anti-microbial potential of the coated materials.

Based on comparative quality evaluation studies, papaya leaf extract incorporated aloe gel (1:2) + INS 402 at concentration of 1% and 2% for one and five minutes were selected as the best edible film coating for shelf life extension of firm ripe and mature green tomato fruits respectively.

In the fifth part of the experiment, tomato fruits were coated with the papaya leaf extract incorporated aloe gel based edible film selected from fourth part of the experiment and were compared with commercial bee wax coated fruits and untreated fruits with the objective of assessing the efficiency of edible films in reducing postharvest losses during storage and transportation.

Mature green tomato fruits were dipped in papaya leaf extract incorporated aloe gel (1:2) + INS 402 and a commercial bee wax formulation each at 2% for two minutes and packaged in 5% ventilated Corrugated Fibre Board (CFB) boxes with and without moulded tray and stored under the ambient and optimum low temperature condition along with untreated fruits to find out the efficiency in extending storage life. Firm ripe fruits were subjected to the same type of packaging and storage except that the fruits were dipped in 1% concentration for one minute.

The coated and packaged mature green and firm ripe fruits under low temperature storage had a shelf life of 60 and 36 days respectively.

Significant difference was noticed between the two packaging systems viz., 5% ventilated CFB box with and without moulded tray in reducing PLW and respiration rate of mature green fruits. But both the packaging systems were equally effective in maintaining all the physiological, chemical and microbial parameters of firm ripe tomatoes and chemical parameters of mature green tomatoes. However the highest sensory scores were for the fruits packaged in 5% ventilated CFB box with moulded tray and hence selected as the suitable packaging system for firm ripe fruits.

When papaya leaf incorporated aloe gel and commercial bee wax formulation were compared with uncoated fruits, it was found that on the 45th day of storage the treatments were superior in physiological quality parameters compared to uncoated fruits. The standardized papaya leaf incorporated aloe gel was equally effective in maintaining physiological quality parameters of firm ripe and mature green tomatoes compared to commercial wax coated fruits on the final day of storage. The coatings had not influenced the chemical parameters like TSS, pH, vitamin C content and titratable acidity of tomato fruits except lycopene content. Mature green fruits and firm ripe fruits treated with commercial wax recorded least lycopene which was significantly different from papaya leaf incorporated aloe gel on the final day of storage.

Storage temperature had not influenced the TSS and pH of the fruits; however the mature green and firm ripe fruits stored under low temperature had increased vitamin C content and titratable acidity as well as reduced lycopene content.

The bacterial load on the surface of coated mature green and firm ripe fruits was least when stored under low temperature condition. Both the packaging conditions were equally effective in reducing the bacterial load on the fruit surfaces. The effect of coatings on the bacterial load on the surface of mature green and firm ripe fruits revealed the superiority of treatments over the uncoated fruits.

The effect of coatings and packaging on physical parameters like appearance, colour, flavour, taste, texture and overall acceptability revealed the superiority of coating mature green fruits with papaya leaf incorporated aloe gel and packaging in 5% ventilated CFB box with moulded tray under optimum low temperature with highest rank for all the sensory parameters analyzed.

Eventhough both the treatments were equally effective in controlling the physiological parameters of fruits., the wax coated fruits recorded least rank values for appearance, flavour and taste during analysis of physical parameters. The least rank for these parameters might be due to influence of the oil which was used for the preparation of the bee wax formulation. The non uniform colour developed on the commercial wax coated fruits resulted in least rank scored for colour.

Mature green and firm ripe tomato fruits were dipped in 2% and 1% concentrations each of papaya leaf extract incorporated aloe gel (1:2) + INS 402 and a commercial bee wax formulation for two and one minute respectively and packaged in 5% ventilated CFB boxes with and without moulded tray and transported to distant and local market to analyze the efficiency of edible coatings in withstanding transportation hazards. Tomato fruits without any coating were set as control for comparison.

Mature green fruits were transported to a distance of 512 km in a reefer cargo van maintained at a temperature of 18^0C to represent distant market and firm ripe fruits to a distance of 128 km in a cargo van as a symbol of local market transport. Physiological, chemical, microbial and physical parameters were recorded before and after transportation.

Coated mature green fruits packaged in 5% ventilated Corrugated Fibre Board (CFB) box with moulded tray was superior in reducing the PLW, respiration rate and percent leakage compared to packaging in 5% ventilated CFB box, where as in firm ripe fruits both packaging systems were equally effective in maintaining PLW and respiration while percent leakage was reduced by fruits packaged in 5% ventilated CFB box with tray. Chemical parameters were similar for both fruits packaged in 5% ventilated CFB box with and without tray.

The bacterial load on the surface of mature green and firm ripe fruits treated with papaya leaf incorporated aloe gel packaged in 5% CFB box with and without tray was too less to count before and after transportation, while the bacterial load was too numerous to count in the untreated fruits.

Mature green and firm ripe fruits coated with papaya leaf incorporated aloe gel packaged in 5% ventilated CFB box with moulded tray scored high mean sensory score for all the physical parameters revealing its superiority.

Cost of dipping 100 kg mature green fruits using commercial bee wax formulation was calculated as Rs. 14000/- and it was Rs. 12.433/ for firm ripe fruits.

Based on the physiological, chemical and microbial parameters analyzed, papaya leaf incorporated aloe gel and commercial wax was found equally effective in maintaining the quality parameters on the final day of storage and based on physical parameters and considering the high cost of commercial formulations, papaya leaf incorporated aloe gel was selected as the best aloe based edible film coating for shelf life extension in tomato.

Combining all the five steps of the experiment, a viable and efficient post harvest management schedule has been formulated for extending shelf life of tomatoes at two different maturity stages.

Mature green tomatoes after surface sanitization using 2 ppm ozonized water for 10 minutes can be dipped in 2% papaya leaf extract incorporated aloe gel(1:2) + INS 402 for two minutes and can be safely stored for 60 days at optimum low temperature of $12^0 - 20^0$C after packaging in 5% ventilated CFB box with moulded tray. This can be transported to distant markets in reefer cargo van at 18^0C.

Firm ripe fruits could be subjected to similar post harvest management practices to have a shelf life of 36 days except that the coating is to be done with 1% papaya leaf extract incorporated aloe gel for one minute, optimum storage temperature being $10\text{-}15^0$C and transportation is meant for local market in cargo van.

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APPENDIX

APPENDIX I

Kerala Agricultural University
College of Agriculture
Department of Post Harvest Technology

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF COATED TOMATOES

Name of student: Thushara.T.Chandran (2014-22-103)

Title of Thesis: **"*Aloe vera* based edible film coating for shelf life extension in tomato (*Solanum lycopersicum*)"**

Criteria	SAMPLES				
	1	**2**	**3**	**4**	**5**
Appearance					
Colour					
Flavour					
Texture					
Taste					
Overall acceptability					

SCORE

Like Extremely -9
Like Very Much -8
Like Moderately -7
Like Slightly -6
Neither Like Nor Dislike -5
Dislike Slightly -4
Dislike Moderately -3
Dislike Very Much -2
Dislike Extremely -1

Date :

Name:

Signature:

APPENDIX II
Kerala Agricultural University
College of Agriculture
Department of Post Harvest Technology

SCORE CARD FOR SENSORY PERCEPTION OF TEXTURAL PARAMETERS IN COATED TOMATOES

Name of student: Thushara.T.Chandran (2014-22-103)

Title of Thesis: **"*Aloe vera* based edible film coating for shelf life extension in tomato (*Solanum lycopersicum*)"**

Criteria	SAMPLES				
	1	**2**	**3**	**4**	**5**
A. Finger Feel Characters					
Fruit firmness					
Skin tightness					
Nature of coating material					
Roughness of skin					
B. Mouth Feel Characters					
Oral Texture					
Juiciness					
C. Textural Appearance					
Glossiness					

SCORES

Fruit Firmness
3- Firm
2- Firm with give
1- Soft

Skin tightness
3- Compact
2- Spongy
1-Loose

Nature of coating material
3- None
2- Slightly
1-Clearly visible

Roughness of skin
2 -Smooth
1-Rough

Oral Texture
2 – Hard
1 – Soft

Juiciness
2 - Juicy
1 - Dry

Glossiness
3 – High
2 - Medium
1 - Low

Date :

Name:
Signature

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ALOE VERA BASED EDIBLE FILM COATING FOR SHELF LIFE EXTENSION IN TOMATO (*Solanum lycopersicum*)

THUSHARA.T.CHANDRAN

(2014-22-103)

Abstract of the thesis
submitted in partial fulfillment of the
requirement for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

(Post Harvest Technology)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

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2018

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ABSTRACT

ABSTRACT

The present investigation on "*Aloe vera* based edible film coating for shelf life extension in tomato (Solanum lycopersicum)" was carried out at the Department of Post Harvest Technology, College of Agriculture, Vellayani during the period of 2014-2017, with the objective to standardise an Aloe vera gel based edible film coating for tomato fruits to withstand storage and transportation losses and thereby formulate a viable and efficient post harvest management practice for extending shelf life of tomato.

A preliminary trial was conducted for standardization of Aloe vera gel based edible film using four different gelling agents (INS 401, 402, 440 and 508), seven concentrations (1, 2, 5, 10, 15, 25 and 35%) and five durations (1, 2, 5,10 and 15 minutes) for extending shelf life of tomatoes. Based on the physiological loss in weight and shelf life obtained, 12 superior treatment combinations including INS 401 and 402 at 1 and 2% concentrations dipped for 1, 2 and 5 minutes were selected for further study of the experiment.

Further experiments were carried out as four different steps using tomato variety Akshaya, harvested independently at two different maturity stages viz., mature green and firm ripe which were meant for distant and local market transportation respectively.

Evaluation of the selected 12 aloe gel based edible films on quality parameters revealed the superiority of aloe gel based treatments over untreated fruits harvested in both the maturity stages. Shelf life of aloe gel based edible film coated mature green and firm ripe tomatoes were 36 and 24 days respectively.

On the 36th day of storage all the aloe gel based treatments were equally effective in maintaining chemical and microbial quality parameters of the mature green tomato fruits, but fruits dipped in 2% aloe gel + INS 402 for two minutes recorded least PLW and percent leakage and hence had higher scores for sensory

parameters. Firm ripe fruits dipped in aloe gel +INS 402 (1%) for one minute had superior physical and physiological parameters on 24th day of storage.

The possibility of increasing the efficiency of aloe gel based formulation by incorporation of natural and cheap plant leaf extracts from papaya, guava and ocimum in 1:1 and 1:2 ratios for shelf life extension in tomato was assessed. Considering the economics and efficiency in maintaining better physiological quality parameters, 2% papaya leaf incorporated aloe gel (1:2) + INS 402 for two minutes was selected as the best plant leaf extract incorporated aloe gel (PLEAG) treatment for mature green fruits and 1% papaya leaf incorporated aloe gel (1:2) + INS 402 for one minute for firm ripe tomatoes.

Quality evaluation of edible coatings revealed better efficiency of papaya leaf incorporated aloe gel (1:2) in reducing the activity of texture affecting enzymes viz., pectin methyl esterase and polygalactouronase and increasing total pectin content resulting in higher fruit firmness in both mature green and firm ripe tomatoes. Even though no antimicrobial activity against Erwinia and Rhizopus was noticed when tested under in vitro condition, the aloe based extracts had suppressed the post harvest infection by these pathogens in vivo.

Efficiency of the selected papaya leaf incorporated aloe gel (1:2) in reducing post harvest loss during storage and transportation was compared with that of a commercial wax formulation independently for mature green and firm ripe tomato fruits after packaging in 5% ventilated corrugated fiber board (CFB) boxes with and without moulded tray.

When packaged fruits were stored under optimum low temperature (12-20^{0}C for mature green and 10-15^{0}C for firm ripe) and ambient temperature (28-30^0), low temperature storage was superior in maintaining the quality parameters for both the maturity stages of tomato.

Packaging in 5% ventilated CFB boxes with moulded tray was effective in maintaining the physical and physiological parameters of mature green tomato during storage. Papaya leaf incorporated aloe gel (1:2) was equally effective as the commercial bee wax formulation in maintaining the physiological, chemical, and microbial parameters. Fruits coated with commercial bee wax had reduced lycopene content and a non- uniform fruit colour development and hence recorded poor sensory scores.

Though both the packaging systems were equally effective in maintaining all the quality parameters during storage of firm ripe tomatoes, overall acceptability was higher for fruits kept in 5 % ventilated CFB box with molded trays. Papaya leaf incorporated aloe gel (1:2) was equally effective as the commercial wax formulation for the stored firm ripe tomatoes too.

Studies to analyze the efficiency of aloe gel based coatings to withstand transportation losses revealed the superiority of 5% ventilated CFB box with moulded tray and effectiveness of papaya leaf extract incorporated aloe gel (1:2) in maintaining all the quality parameters in fruits of both maturity stages. Cost of production for coating the standardized papaya leaf incorporated aloe gel was Rs. 45.87/- for 100 Kg mature green tomatoes and Rs.23.65/- for 100 Kg firm ripe tomatoes.

Based on the study, an efficient postharvest management practice for shelf life extension in tomato fruits of both maturity stages could be formulated. Mature green tomato fruits cv. Akshaya after washing and surface sanitization using 2ppm ozonized water for five minutes followed by coating with papaya leaf incorporated aloe gel (1:2) + INS 402, (2%) for two minutes, air drying and packaging in 5% ventilated CFB boxes with moulded tray had a storage life of 60 days under optimum low temperature (12-20^{0}C) or could be transported to distant markets without transportation hazards.

Firm ripe tomato fruits cv. Akshaya could be stored for 36 days using the same protocol except coating with papaya leaf incorporated aloe gel (1:2) + INS 402, (1%) for one minute and storing at an optimum low temperature of 10-15^{0}C or could be transported to local markets without any hazards.