PROTOCOL DEVELOPMENT FOR MINIMALLY PROCESSED JACKFRUIT (*Artocarpus heterophyllus* L.) BULBS

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by

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THESIS

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2020

DECLARATION

I, hereby declare that this thesis entitled **"PROTOCOL DEVELOPMENT FOR MINIMALLY PROCESSED JACKFRUIT (*Artocarpus heterophyllus* L.) BULBS)"** 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani

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CERTIFICATE

Certified that this thesis entitled **"PROTOCOL DEVELOPMENT FOR MINIMALLY PROCESSED JACKFRUIT (*Artocarpus heterophyllus* L.) BULBS"** is a record of bonafide research work done independently by Ms. Gayathri. G. S under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	: Per cent
cm	: Centimetre
et al.	: Co-workers
g	: Gram
Kg	: Kilogram
hr	: Hour
KAU	: Kerala Agricultural University
mg	: Milligram
min	: Minutes
mL	: Millilitre
mm	: Millimetre
L	: Litre
ºC	: Degree celsius
rpm	: Revolutions per minute
Sec	: Second
viz.	: Namely
ºB	: Degree Brix
CO_2	: Carbon dioxide
cv.	: Cultivar
Fig.	: Figure
$CaCl_2$	: Calcium chloride
nm	: Nanometer
NS	: Non Significant
O_2	: Oxygen
PLW	: Physiological Loss in Weight
ppm	: Parts per million
CD	: Critical difference

SE	: Standard Error
TSS	: Total Soluble Solids
Sl.	: Serial
Via	: through

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Introduction

1. INTRODUCTION

Minimally processed fruits or vegetables are made with a very little physical alteration from its original form while its freshness and quality are maitained. The International Fresh cut Produce Association (IFPA) defines minimally processed products as fruits or vegetables that have been peeled and cut into 100% usable product, that are packaged to offer consumers high nutrition, convenience and flavor while still maintaining freshness. It is known by various names such as fresh cuts, partially processed, lightly processed, pre prepared and fresh processed.

Consumer demand for minimally processed products has shown an increasing trend over the past decades due to its health benefits, fresh like quality and convenience they offer. The changing consumer lifestyle and time constraints also contribute to its increasing popularity. This growing consumer demand poses challenge for researchers and food processors to develop safe foods with minimal processing. Fresh cut products are highly perishable in nature due to absence of their natural protective outer cover and hence must be stored under refrigerated condition. Microbial contamination from various sources like raw materials, processing environment etc. posses a great risk for the shelf life of the produce.

Quality aspect of minimally processed products plays an important role in consumer acceptance. Food safety, quality and sensory quality are required while providing extended shelf life and freshness. Sensory parameters like appearance, flavor, texture, colour, taste are the most appealing characters to the consumers. Minimally processed products require various preparatory steps like washing, cutting, peeling, shredding etc. which will cause injuries to the tissue resulting in microbial and enzymatic spoilage. Enzymatic browning, texture decay and microbial contamination are the major constraints in minimal processing. Surface treatments with anti-browning agents, firming agents, preservatives and antimicrobials help in extension of shelf life, while maintaining its quality.

Many factors influence the shelf life of minimally processed products and packaging is one of the key factors. Several packaging technologies like modified atmospheric packaging, controlled atmospheric packaging etc. have been applied to the minimal processing industry to keep the product quality and to increase its shelf life.

Jackfruit (*Artocarpus heterophyllus* L.) is a tropical climacteric fruit which belongs to the family Moraceae. It contains a lot of essential nutrients and antioxidants which imparts to its nutritional benefits. Declaration of jackfruit as Kerala's official fruit has helped it in giving a real boost in production and sale. Even then it has not been fully utilized in the food industry due of its large amount of inedible portion and short shelf life. Transportation and storage are also problems due to the bulky nature of the fruit. Jackfruit has a high potential for minimal processing as its edible portion makes up only 30-35% of the whole fruit. By developing an efficient protocol for minimally processed jackfruit bulbs, consumers will be able to purchase and consume quality bulbs with freshness character and convenience and thereby increasing its per-capita consumption. Hence a study on "Protocol development for minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs" was undertaken at Department of Post Harvest Technology, College of Agriculture, Vellayani with the objective to standardize an efficient and economic protocol for development of minimally processed jackfruit bulbs with extended shelf life.

Review of literature

2. REVIEW LITERATURE

Minimally processed (MP) products are fruits or vegetables that have been peeled and cut into 100% usable product, that are packaged to offer consumers high nutrition, convenience and flavor while still maintaining freshness (IFPA, 2004). They are also referred to as fresh cut, lightly processed, fresh processed, partially processed or pre prepared products. Minimally processed products or fresh cut products have gained an increasing demand in the recent years. Convenience and the practical advantages made them a fastest growing sector in food industry and has a high potential for growth world wide. It retains the same quality as that of whole or intact product, requiring reduced storage space and preparation time.

2.1 Physiology of minimally processed produce

Physiology of minimally processed products is similar to tissues that are wounded or exposed under stressed condition (Brecht, 1995). Increased respiration causes tissue deterioration as enzymes and substrates become mixed with other cytoplasmic and nucleic substrates. Wound induced ethylene production is also a major factor that affects the quality of minimally processed products (Gonalez- Anguilar *et al*., 2010).

Quality of fresh cut fruits may be affected due to the development of off flavours and off odours. Excessive low oxygen and/or high carbon dioxide levels results in fermentative metabolism inside the package of minimally processes food products. Cutting operations during minimal processing results in the release of pectic enzymes which cause tissue softening. Water may leak from the vacuoles of the damaged tissue which is attributed to the textural changes in the fresh cut fruits. It is therefore important to keep low temperature during storage and proper packaging for better moisture retention. Usage of sharp instruments in cutting operations reduces mechanical damage, induced enzymatic browning and microbial development (Artes *et al*., 2007).

Enzymatic browning is an important cause for the quality loss in minimally processed products which is due to the oxidation of phenolic compounds catalyzed by the enzyme polyphenol oxidase (Toivonen and Delaquis, 2006).

2.2 Manufacturing practices

Manufacturing practices during minimal processing include operations like cutting, slicing, peeling, coring etc thereby removing the inedible portions. During these operations the natural protective intact layer of the skin is removed and the produce is more prone to microbial attacks resulting in spoilage.

2.2.1 Sanitization

Sanitization of raw fruits is necessary to remove pesticide residues, plant debris and other microorganisms which will cause quality loss and decay (Soliva-Fortuny and Martin-Belloso, 2003).

Chlorinated water, sulphites, sodium hypochlorite, neutral electrolyzed oxidizing water (EOW) and peroxy acetic acid are the common sanitizers used in the fresh cut industry that extends their shelf life (Nascimento *et al*., 2003).

Electrolyzed oxidizing water (EOW) is a decontaminating agent with strong bactericidal effect (Ongeng *et al*., 2006). It has got negligible residual contamination, minimal corrosion of processing equipment or skin irritation and low operational cost (Hao *et al*., 2015; Hricova *et al*., 2008; Mukhopadhyay and Ramaswamy, 2012). Rahman *et al.* (2011) found that a combination of alkaline electrolyzed water and 1% citric acid in shredded carrot significantly reduced the total microbial load, yeasts and mould count by 3.7 log CFU/g. Treatment with neutral electrolyzed water in lettuce for 5 minute reduced the population of aerobic bacteria and Enterobacteriaceae by approximately 1.7 log CFU/g (Pinto *et al*., 2015).

pH, temperature and concentration of the sanitizer have an influence on the effectiveness of NaOCl on microbicidal activity (Beauchat, 1992). Gil *et al.* (1996) reported a shelf life of 7 days at 1^0C for minimally processed pomegranate seeds washed with chlorine (100 mg/kg) along with 5 g/L of ascorbic acid and 5 g/L of citric acid without fungal attacks and off flavor development. Lanciotti *et al.* (1999) reported that chlorine at a concentration not greater than 200ppm is an effective sanitization treatment of both whole and fresh cut fruits. In melon and watermelon, dips ranging from 50 to 1000 ppm of sodium hypochlorite is found to be effective (Portela and Cantwell, 2001). Sodium hypochlorite is the most widely used decontaminant in the food industry and has got a broad antimicrobial action (Fukuzaki., 2006). Chandran (2013) reported that minimally processed beans, beetroot, carrot and cabbage can be sanitized with 30 ppm sodium hypochlorite for 15 minutes which reduced the total microbial load on the product surface.

Hot water immersion treatments are used to reduce microbial load on the surface of the fruits and vegetables like lettuce (Campos- Vargas *et al.,* 2005). Heat treatment at 40^0C for 70 min and 50^0C for 10 min effectively control browning and retained firmness thereby extending the shelf life of fresh cut peach slices (Koukounaras *et al.*, 2008). Hot water immersion treatments can be used to reduce microbial load on fruit surface and browning development in fresh cut fruits and vegetables (Dea *et al.*, 2010).

Ozonated water (1mg/L for 1 min) prevented the browning of fresh cut lettuce by inhibiting the browning enzymes (Rico *et al*., 2006). Akbas and Olmez (2007) reported that treatment with ozonated water for 2 minutes at a concentration of 4 mg/L significantly reduced the population of mesophilic, psychotropic and Enterobacteriaceae bacteria in fresh cut iceberg lettuce by 1.7, 1.5 and 1.6 log CFU g^{-1} respectively. Aguayo *et al.* (2014) found that ozone treated tomato slices at a concentration of 0.4 mg/L for 3 min retained the firmness and microbial quality even after 10 days of storage. Treatment with gaseous ozone for 20 minutes significantly reduced microbial population on fresh cut papaya (Yeoh *et al.*, 2014). In 2001, ozone has been declared as Generally Recognised As Safe (GRAS) substance by the US Food and Drug Adminmistration and is a commercially used disinfectant and sanitizer in the food industry (Aguayo *et al*., 2014). Ozone has been used in fresh cut industry in its aqueous or gaseous state due to its broad anti microbial effect and for extending the shelf life of the produce (Ali *et al*., 2018).

2.2.2 Pre-storage treatments

Minimally processed fruits and vegetables are given a pre-storage treatment mainly for controlling decay, reducing browning, and retaining firmness (Brecht, 1995). Dipping fruit or vegetable pieces into aqueous solution of chemical preservatives, anti-browning agents, firming agents, edible coatings and bio preservatives are widely practiced to improve quality of fresh cut produce.

2.2.2.1 Anti microbials

Antimicrobials may be added to fresh cut fruits and vegetables to inhibit the action of microorganisms. Minimally processed products are highly susceptible to microbial spoilage since their natural outer covering is removed during the initial preparatory steps. In addition cross-contamination can also occur during the cutting and shredding operations (Oms-Oliu *et al*., 2010).

UV treatments are a non-thermal alternative to chemical sanitization and can be used on fresh cut products that will reduce the total microbial load (FDA, 2000). Direct exposure of UV radiation for 5 minutes on minimally processed jackfruit could reduce total plat count (TPC) and total coliform (TC) for 14 days storage at 5^0C (Bizura-Hasida *et al*., 2012).

Acedo *et al.* (2013) reported that jackfruit bulbs dipped in an aqueous solution of 2.5% calcium lactate for 2 minute reduced microbial load (aerobic bacteria, coliform, yeast and moulds) by 85-99% without any changes in colour, TSS and sensory quality as compared to the untreated control.

Dip pretreatment of citric acid (0.25%) could reduce the microbial load (mesophillic aerobes, coliforms, yeast and moulds) of jackfruit bulbs when stored at 3-5^0C (Taj *et al*., 2016).

Dip pretreatment of 200 mg/L of sodium chlorite inhibited microbial growth (total bacteria, yeast and moulds, E. coli and coliforms) of fresh cut rose apple. Further a combination treatment of sodium chlorite, calcium chloride and calcium ascorbate was found to be effective against microbial contamination while maintaining firmness and delayed browning (Mola *et al*., 2016).

Fresh cut pineapple treated with calcium ascorbate and calcium lactate at a concentration of 2.5% retained quality by reducing aerobic and coliform bacteria as well as yeast and mould while maintaining sensory acceptability (Troyo and Acedo, 2019).

2.2.2.2 Firming agents

Calcium treatments have been used to extend the shelf-life of fruit and vegetables. It maintain the cell wall integrity by interacting with pectin to form calcium pectate. Calcium treatments are done in various forms of calcium like calcium lactate, calcium chloride, calcium phosphate, calcium propionate and calcium gluconate (Aguayo *et al*., 2008).

Calcium chloride is a widely used firming agent and preservative in fresh cut fruits and vegetable industry. Firmness of fresh cut cantaloupe was found to be improved by using calcium chloride dips and firmness increased with increasing concentrations of calcium chloride (Luna- Guzman *et al*., 1999).

Luna Guzman and Barrett (2000) compared calcium chloride and calcium lactate in maintaining shelf stability and quality of fresh cut cantaloupe and found that calcium lactate is a better alternative to calcium chloride since it provides better tissue firming without the development of an undesirable bitterness.

Rico *et al.* (2007) studied the effect of wash treatments using calcium lactate and chlorine in sliced carrots. It was found that calcium lactate wash at 50^0C was very effective in maintaining the texture of slices during storage by preventing softening than chlorine treatment.

Minimally processed jackfruit bulbs pretreated with calcium salt had recorded minimum juice leakage and maintained firmness (Saxena *et al*., 2012).

Use of calcium chloride or 1- methyl cyclopropene in fresh cut pomegranate arils maintained overall quality and firmness (Aguayo *et al*., 2012).

Barbagallo *et al.* (2012) studied the effect of calcium citrate and ascorbate in inhibiting browning and softening of minimally processed 'Birgah' eggplants and reported that treatment with 0.4% calcium ascorbate for 1 minuite at 60^0C was more effective than calcium citrate in maintaining firmness and retarding browning.

Guava slices treated with 2.7% calcium chloride maintained firmness and reduced browning rate up to 8days of storage at 5^0C along with preserving its sensory attributes (Inam-ur-Raheem *et al*., 2013).

Effect of calcium chloride and calcium lactate on the texture and sensory qualities of fresh cut mangoes were investigated by Ngamchuachit *et al.* (2014). Calcium chloride retarded softening of mangoes and the effect increased with calcium concentration. Dip pretreatment of 0.036M calcium chloride at 10^0C for 2.5 min and 1 min were effective for Tommy Atkins and Kent mangoes respectively in retaining the firmness.

Shaarawi *et al.* (2016) reported that pomegranate arils treated with salicylic acid, calcium chloride and calcium lactate can be stored up to 12 days at 5^0C with no decay and off odour development and maintained good quality and appearance.

Aslam *et al.* (2018) studied the effect of calcium lactate combined with anti-browning agents like ascorbic acid and citric acid on the quality of fresh cut papaya cubes. Calcium lactate at 2.4% along with citric acid (1.7%) and calcium lactate at 2.4% in combination with ascorbic acid (1.7%) retained firmness, colour and pH and also extended the shelf life up to 16 days at 4^0C.

2.2.2.3 Browning inhibitors

Anti-browning agents prevent the activity of the enzyme and browning. Anti-browning agents can be acidulants, reducing agents, chelating agents, complexing agents and enzyme inhibitors (Suttirak and Manurakchinakorn, 2010).

Dip pretreatment with mixture of ascorbic acid and citric acid (10+2g/L) and of ascorbic acid and sodium chloride (10+0.5 g/L) resulted in inhibition of PPO enzyme in ‘Golden delicious’ apple cubes (Pizzocaro *et al*., 1993).

Ascorbic acid is the widely used anti browning agent. It causes slight reduction in pH in addition to its reducing activity and has a direct effect on PPO enzyme (Whitaker and Stauffer, 1994).

Minimally processed chinese cabbage pretreated with citric acid inhibited the development of black speck and extended storage life to 14 days at 5^0C (Kim and Klieber, 1997). Dip pretreatment in solutions containing sodium erythorbate, $CaCl_2$ and 4-hexylresourcinol followed by modified atmospheric packaging retarded browning on the cut surfaces of fresh cut pears (Sapers and Miller, 1998).

Citric acid inactivates the poly phenol oxidase enzyme by exerting a double inhibitory effect by pH reduction and chelating copper in the active site of enzyme (Son *et al*., 2001).

A combination of 1% ascorbic acid or citric acid with less than 0.02% oxalic acid effectively prevents browning in apple slices (Son *et al*., 2001). It was also established that oxalic acid and oxaloacetic acid were the most potent browning inhibitors among the carboxylic acids.

A combined dip of 2% ascorbic acid, 1% calcium lactate and 0.5% cysteine prevented surface browning and extended shelf life by maintaining firmness in fresh cut pears (Gorny *et al*., 2002).

Fresh cut bananas dipped in a mixture of 1% $CaCl_2$, 1% ascorbic acid and 0.5% cysteine for 2 minutes greatly retarded browning and softening of slices for 6 days at 5^0C (Vilas-Boas and Kader, 2006).

Fresh cut green jackfruit when pretreated with 1% citric acid along with 2% ascorbic acid maintained quality attributes and inhibited browning retaining a shelf life of 15 days at 2-4^0C (Navindra *et al*., 2009). Fresh cut apple treated with 6% calcium ascorbate reduced browning and extended the overall acceptability from less than 7 days to 14 days (Aguayo *et al*., 2010).

The effect of dipping treatments on physicochemical and microbiological quality of minimally processed jackfruit bulbs were investigated by Uloa *et al.* (2010). The samples were dipped in an aqueous solution of potassium sorbate (1.5g/L), citric acid (10g/L) and ascorbic acid (10g/L) for 5 minutes and stored at 6^0C. Treatment maintained the quality parameters like pH, water activity , TSS and colour and also reduced the microbial counts.

Bico *et al.* (2010) reported that dipping of banana slices in 1% calcium chloride, 0.5% ascorbic acid and 0.75% cysteine effectively retards softening and browning of the slices while providing a shelf life of 5 days at 5^0C.

Sally (2011) found that minimally processed jackfruit bulbs pretreated with citric acid and packed in PE packages retained most of the quality parameters like colour, flavor, ascorbic acid content etc. Jackfruit bulbs treated with 10,000 ppm calcium chloride and packed in 100 gauge polypropylene bags showed minimum spoilage with extended shelf life at 4^0C (Velankanni, 2012).

Ekanayaka *et al.* (2015) studied the effect of different pretreatments on immature minimally processed jackfruit and found that pretreatments of 3% citric acid, 1.5% citric acid + 1.5% ascorbic acid and 1% sodium metabisulphite could effectively control browning.

A combination treatment of carboxy methyl cellulose and ascorbic acid reduced surface browning of fresh cut apples and maintained fruit quality (Saba and Sogvar, 2016).

2.2.2.4 Edible coatings

Quality of minimally processed products can be maintained by the use of edible coatings by preventing changes in aroma, taste, texture and appearance (Tharanathan, 2003).

Lee *et al.* (2003) observed an increase in shelf life of minimally processed apple slices for 2 weeks by the use of edible coatings along with anti browning agents at 3^0C.

Application of chitosan coating extended shelf life of peeled litchi fruit by maintaining quality attributes including sensory quality (Dong *et al.*, 2004).

Strawberries coated with 1.5% chitosan retained firmness and reduced weight loss of the berries (Hernandez-Munoz *et al*., 2006).

Water loss is also a major problem in minimally processed products and this can be controlled by the use of edible coatings as carriers of calcium salts. Edible coatings form a barrier on the fruit surface and decreases the water vapour transmission rate thereby preventing water loss and texture decay (Olivas and Barbosa-Canovas, 2009).

Chitosan coating effectively retarded tissue softening and enzymatic browning on minimally processed 'Fuji' apple slices (Qi *et al*., 2011).

Controlled Atmosphere Storage of fresh cut jackfruit bulbs pretreated with calcium chloride, ascorbic acid, citric acid and sodium benzoate followed by chitosan coating minimized loss in total phenolics and ascorbic acid content. The chitosan coating also rendered microbial stability to the fresh cut produce (Saxena *et al*., 2013).

Coating of Aloe vera gel in minimally processed kiwifruit slices retained quality by retarding the yellowning of pieces, reducing microbial growth along with texture retention (Benitez *et al*., 2013).

Martinez- Romero *et al.* (2013) coated aloe vera gel on minimally processed pomegranate arils and found that the coating retained the firmness, colour and bioactive compounds of the arils. Further it reduced the microbial counts of both mesophilic aerobics, yeast and moulds and received highest sore in sensory analysis for flavour, texture, aroma and colour.

2.2.3 Packaging and storage

Modified atmospheric packaging (MAP) and controlled atmosphere storage (CAS) are the methods available for extending the shelf life of minimally processed foods by modifying the package atmosphere (O'Conner *et al*., 1992).

Mohd-Som *et al.* (1994) found that high CO_2 and low O_2 obtained by MAP of broccoli florets reduced the growth of yeast and mould, aerobic plate count and coliform counts. Nicoli *et al.* (1994) reported that browning reactions were effectively prevented for 9 days of storage with N_2/CO_2 atmospheric packaging in fresh apple slices.

Moderate vacuum packaging of shredded iceberg lettuce in PE bags inhibited enzymatic browning over 10 days when stored at 5^0C (Heimdal *et al*., 1995).

MAP protects minimally processed products by preventing contamination from micro organisms and slows down the physiological process of ageing by reducing metabolic reactions (Gunes and Lee, 1997). Quality of minimally processed chinese cabbage was retained by low oxygen and carbon dioxide atmospheres during storage at 5^0C. (Kim, 1999).

Soliva- Fortuny *et al.* (2001) studied the activity of poly phenol oxidase enzyme and colour of fresh-cut Golden delicious apples under modified atmospheres and found that an initial atmosphere of 90.5% N_2 + 7% CO_2 + 2.5% O_2 extended shelf life to several weeks.

Martinez-Ferrer *et al*. (2002) developed a MAP system for minimally processed mango and pineapple. Gas mixture combination containing 10% CO_2, 4% O_2 and 86% N_2 reported a shelf life of 25 days at 5^0C with good colour, texture, odour taste and delayed spoilage.

Modified atmosphere packed fresh cut green bell pepper can be stored up to 21 days at 5^0C and maintained quality attributes like better visual quality, less juice leakage and better firmness (Gonzalez-Aguilar *et al*., 2004).

Modified atmospheric packaging of celery sticks in an atmosphere of 6 kPa O2 + 7 kPa CO2 provides better quality with minimum loss of green colour, slower development of pithiness, safer microbial counts and higher nutritional value (Gomez and Artes, 2005).

Fresh cut pineapples pretreated with 0.25% ascorbic acid and 10% sucrose for 10 minutes along with MAP (4% O_2, 10% CO_2 and 86% N_2) maintained texture, colour and overall sensory quality for 7 days with reduced ethylene production and respiration rate (Liu *et al*., 2007).

Controlled atmospheric storage of bread fruit in 5% O2 and 5% CO2 at 16^0C maintained quality of bread fruit with a shelf life of 3-4 weeks (Sankat and Maharaj, 2007).

Ayhan and Esturk (2009) reported a shelf life of 18 days for minimally processed pomegranate arils when packed in PP tray sealed with BOPP film in combination with active or passive atmospheric packaging.

Modified atmospheric packaging of 'Braeburn' apple slices dipped in 6-12% calcium ascorbate showed a shelf life of 21-28 days (Aguayo *et al*., 2010).

Ediriweera *et al*. (2012) reported a shelf life of seven days and highest overall acceptability when fresh cut pineapple was treated with1% sodium chloride or a combination of 1% sodium chloride and 1% calcium chloride.

The shelf life of fresh cut papaya could be extended up to 25 days at 25^0C after pretreatment and subjecting to Modified Atmospheric Packaging (Waghmare and Annapure, 2013).

Roopa *et al.* (2015) obtained a shelf life of 45 days when minimally processed and modified atmosphere packed bread fruit sticks were stored at a low temperature (6^0C) without the incidence of coliforms and pathogen.

Application of calcium ascorbate along with modified atmospheric packaging extended the shelf life of fresh cut cantaloupe with delayed browning and also reduced mould and yeast growth (Shin *et al*., 2019).

Jackfruit bulbs packed in polyethylene packages at 80% vacuum after dip pretreatment of citric acid (0.25%) could reduced the microbial load (mesophillic aerobes, coliforms, yeast and moulds) when stored at 3-5^0C. (Taj *et al*., 2016).

2.3 Protocol for minimally processed products

Fresh cut fruits or vegetables are to be processed under strict sanitary conditions, because the natural protective barrier of skin is removed and damage is inflicted to the fruit tissues and can be spoiled by human pathogen (FDA, 2001)

Protocol for any fresh cut fruit or vegetables include surface sanitization, followed by preliminary operations like removal of inedible portions, size reduction, pretreatment of the cut pieces, air drying packaging and storage. (Yildiz, 2007)

Risk of contamination prior to processing can be reduced by appropriate handling of whole fruits during harvest and post harvest practices (Artes *et al*., 2007).

Amith (2012) developed protocol for fresh cut mango, papaya, pineapple and pomegranate arils and Chandran (2013) developed protocol for fresh cut beans, beetroot, cabbage and carrot.

Surface sanitization of amaranthus (var. Arun) with 2ppm ozonized water and pretreatment with sodium benzoate + citric acid (0.1%) and pre-packaging in micro ventilated polyethylene could extend the shelf life of minimally processed amaranthus up to 8 days when stored under refrigerated condition (Ambareesha, 2016).

Materials and Methods

3. MATERIALS AND METHODS

The study on “Protocol development for minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs” was carried out during the period of 2018-2020, at the Department of Post Harvest Technolgy, College of Agriculture, Vellayani. The objective of the research work was to standardize an efficient and economic protocol for the development of minimally processed jackfruit bulbs with extended shelf life.

The materials used and methodology adopted during the course of study are described in this chapter.

Good quality, fresh, optimum mature jackfruit cv. Muttom Varikka, free from visual defects, with relatively uniform size, weight and colour were collected from Instructional Farm, College of Agriculture, Vellayani or from the progressive farmers registered under Jackfruit Promotion Council, Kerala. Colour change from green to yellow, widening and flattening of spines and 12-16 weeks after flower anthesis were considered as the maturity indices for the selection of fruits. The harvested fruits were allowed to ripe and used for the study.

The study was carried out as four different continuous experiments.

1. Evaluation of sanitizing agents
2. Evaluation of pre-storage treatments
3. Development of packaging system
4. Assessment of acceptability

3.1. Evaluation of sanitizing agents

The ripe whole fruits were completely immersed in the following sanitizing solutions for 15 minutes for surface decontamination.

S_1- 40^0C water

S_2- 100 ppm sodium hypochlorite

S_3- 120 ppm sodium hypochlorite

S_4- 2 ppm ozonized water

S_5- Absolute control (No sanitization)

No. of treatments: 5

No. of replications: 4

Design: CRD

Fruits were removed from the sanitizing solution after the prescribed period of 15 minutes and solutions were drained after the treatment. The outer green peel pieces of 1 cm^2 area were removed from the sanitized fruits using a sharp knife and were evaluated for the microbial count.

Knives, cutting boards and other equipment coming in contact with the fruits were sanitized using 1000 ppm sodium hypochlorite solution for 10 minutes in order to avoid cross contamination.

3.1.1 Enumeration of total microbial load

Microbial load on the surface of the peel was determined by serial dilution spread plate technique (Somashegaran and Hoben, 1985). Nutrient agar and rose bengal agar were the media used for the enumeration of bacterial and fungal populations respectively.

Peel piece of $1cm^2$ area removed from the sanitized fruit was suspended in 100 ml distilled water and shaken thoroughly for 2 minutes in order to get 10^{-1} dilution. 0.1ml of the suspension was pippeted out into eppendroff tube containing 0.9 ml of sterile distilled water and mixed thoroughly to get 10^{-2} dilution. The procedure was repeated to get 10^{-3} dilution.

0.1 ml of each dilution was spread plated on both nutrient agar and rose bengal agar medium. Bacterial count was recorded for the first three days of inoculation whereas fungal count was recorded after three days of inoculation. Numbers of bacterial and fungal colonies were counted independently and the results were expressed as colony forming units as per the following formula.

$$No.of\ colony\ forming\ units/cm^2 = \frac{Total\ number\ of\ colony\ formed\ X\ dilution\ factor}{Aliquot\ taken}$$

The best sanitizing agent was selected based on the efficiency in reducing microbial load and the selected treatment was utilized for further studies.

3.2. Evaluation of pre-storage treatments

Good quality harvested fruits of uniform maturity were surface sanitized using the best treatment selected from the first part (3.1) of the experiment.

Good quality bulbs were extracted from the sanitized fruits and seeds were removed. Jackfruit bulbs were dipped in the following different solutions for 10 minutes.

T1- 0.1% Ascorbic acid

T2- 0.1% Citric acid

T3- 1% Calcium chloride

T4- Control (without any treatment)

The bulbs were removed from the solutions after specified period, air dried, kept in aluminium foil trays wrapped with cling film and stored under refrigerated conditions.

No. of treatments : 4

No. of replication : 4

No. of bulbs/ replication : 10

Design : CRD

The following physical, physiological, microbial and chemical quality parameters of the treated bulbs were recorded at the time of storage and at regular intervals till the end of shelf life so as to analyse the comparative efficiency of the different solution in extending the shelf life of minimally processed jackfruit bulbs.

3.2.1 Physical parameters

Physical parameters like colour, texture, appearance, flavor and taste of the treated jackfruit bulbs were determined by conducting a sensory scoring by a members of a 30 member semi- trained panel comprising of staff and students of

Plate 1. Pretreatment of de-seeded jackfruit bulbs

Plate 2. Air drying of de-seeded jackfruit bulbs after pretreatment

Plate 3. Bulbs kept in aluminium tray wrapped with cling film

COA, vellayani at the time of storage and at an interval of three days. The panel was asked to score the bulbs for different sensory attributes on a numerical scoring method using a nine point hedonic scale as shown below (Amerine *et al.*, 1965) (Appendix I).

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

3.2.2 Physiological parameters

Physiological parameters of the jackfruit bulbs were recorded at the time of storage and at an interval of three days till the end of shelf life.

3.2.2. 1 Physiological loss in weight (PLW)

Physiological loss in weight of jackfruit bulb was determined on initial weight basis during the storage period, till the end of its shelf life. The bulbs were weighed at the time of storage and at three days intervals using a laboratory level weighing balance having 0.01 g accuracy. Physiological loss in weight was calculated using the following formula and is expressed as percentage.

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

3.2.2.2 Percent leakage

Jackfruit bulbs were made into uniform thin slices, immersed in 20 ml distilled water for three hours and the absorbance was read in a UV spectrophotometer at 273 nm. The immersed slices were heated in water bath at 100^{0}C for 20 minutes and filtered. The filtrate was made up to 20 ml and the absorbance was again read at 273 nm. Percent leakage was calculated using the following formula.

$$Percent\ leakage\ = \frac{Initial\ absorbance\ \ value}{Final\ absorbance\ \ value} \times 100$$

3.2.2.3 Shelf life (days)

Shelf life jackfruit bulbs were assessed as number of days from extraction or storage till they remain in fresh and marketable condition. Freshness assessment was based on physical appearance as judged by retention of quality, colour variation, level of pathogenic decay, glossy appearance without any desiccation and juiciness of bulbs (Nanda *et al*., 2001).

3.2.3 Chemical parameters

Chemical parameters of the jackfruit bulbs viz., acidity, TSS, sugars, vitamin C, carotenoids and total phenol were evaluated at the time of storage and at an interval of three days till the end of shelf life.

3.2.3.1 Acidity

Acidity of the jackfruit bulb was determined by titration. Five grams of the bulb was extracted and was digested with distilled water by boiling for thirty minutes. Solution was filtered and was made up to 100 ml with distilled water. 25 ml of the aliquot was mixed with 25 ml of distilled water and was titrated with standard alkali using phenolphthalein indicator. Acidity of the sample was expressed as percentage in terms of citric acid and was calculated by the following formula.

$$Acidity = \frac{Titre\ value\ XNormality\ of\ NaOH(0.1N)X \\ Volume\ make\ up(100\ mL)X \\ Equivelent\ weight\ of\ citric\ acid((0.064)}{Volume\ of\ aliqot\ (25mL)X\ Weight\ of\ sample\ (5g)}$$

3.2.3.2 Total Soluble Solids (TSS)

Total soluble solids of jackfruit bulb was recorded using Erma hand refractometer (range 0-32^{0}B) and was expressed in degree brix (^{0}B).

3.2.3.3 Sugars (%)

Reducing sugar, non- reducing and total sugar of the jackfruit bulbs were determined.

Reducing sugar

Reducing sugar was determined by the method described by Ranganna (1986).

Twenty five gram of jackfruit bulb was blended in 100 ml distilled water with mortar and pestle. The solution was neutralized with 1N NaOH and 2 ml of neutral lead acetate was added to it. It was allowed to stand for 10 minutes after shaking thoroughly. Excess lead was removed by adding 2 ml of potassium oxalate, solution filtered and made up the solution to 250 ml.

Fehling's solutions A and B, each of 5 ml were pipetted into a 250ml conical flask and added 50 ml of water. The solution was boiled vigorously and added filtered sample drop by drop taken in a burette. While boiling methylene blue indictor (0.5 ml) was added when the colour of the Fehling's solution disappeared. Titration was completed when the indicator was completely decolourized and a brick red colour of cuprous oxide was developed. Percentage of sugar was calculated by the formula

$$Reducing\ Sugar(\%) = \frac{Glucose\ Eq.(0.05)\ X\ Total\ volume\ made\ up(mL)}{Titre\ value(mL)\ X\ Weight\ of\ the\ sample}$$

Total sugar

Total sugar was expressed as percent in terms of invert sugar according to the method described by Ranganna (1986).

Filtered sample solution (25 ml) was pipetted into a 250 ml conical flask and added 5g of citric acid and 50 ml distilled water into it. The solution was boiled for 10 minutes to complete the inversion and cooled. 1 N NaOH was added in order to neutralize the acidity using phenolphthalein indicator and made up the volume to 250 ml. This solution was filled in burette.

Fehling's solutions A and B solution (5ml each) were pipetted into a 250 ml conical flask and added 50 ml distilled water. The solution was boiled vigorously and the filtered sample solution was added to the boiling Fehling's solution drop by drop from the burette. While boiling, methylene blue indicator was added when the blue colour of the solution disappeared. Titration was completed when there was development of a brick red colour of cuprous oxide.

Total sugar was calculated by the formula,

$$Total\ Sugar = \frac{\begin{array}{c} Glucose\ Eq.(0.05) X\ Total\ volume\ made\ up(mL) X \\ Volume\ made\ after\ inversion(mL) \end{array}}{\begin{array}{c} Titre\ value(mL) X\ Weight\ of\ pulp\ taken(g) X \\ Aliquot\ taken\ for\ inversion(mL) \end{array}} X\ 100$$

Non reducing sugar

Non reducing sugar content of the jackfruit bulb was calculated by subtracting reducing sugar from total sugar.

2.3.4 Vitamin C

Vitamin C content of the jackfruit bulb was estimated as ascorbic acid content by 2,6- dichloro phenol indophenol (DCPIP) dye method described by Sadasivam and Manickam (1992) and expressed as mg $100g^{-1}$.

Five gram jackfruit bulb was ground using a mortar and pestle with 4% oxalic acid and made up the volume to 100 ml. 5 ml of the supernatant was pipetted out and 10 ml of 4% oxalic acid was added to it. This was titrated against the dye solution until development of a pink colour (V_2 ml) and ascorbic acid content was calculated using the following formula

$$Vitamin\ C\ (mg\ 100g^{-1}) = \frac{\begin{matrix} Titrevalue(V1)XDye\ factorX \\ Volume\ made\ up(mL) \end{matrix}}{\begin{matrix} Aliquot\ of\ extract\ taken(mL)X \\ Weightof\ sample(g) \end{matrix}}$$

Dye factor = 0.5/ V_1 mL

3.2.3.5 Total carotenoids (mg 100g^{-1})

Total carotenoid content of the jackfruit bulbs was determined using spectrophotometer by the method described by Saini *et al*. (2001).

One gram of jackfruit bulb was ground thoroughly with mortar and pestle by adding 20 ml of 80% acetone. It was centrifuged at 5000 rpm for five minutes and transferred the supernatant to 100 ml volumetric flask. The remaining residue was again ground using 20 ml of 80% acetone and centrifuged. The supernatant was transferred to same volumetric flask. This process was repeated until the residue became colourless. The volume was made up to 100 ml with 80% acetone and absorbance was read at 480 nm and 510 nm using a spectrophotometer. Carotenoid content of the sample was calculated by the formula and expressed as mg 100g^{-1}of the fruit.

$$Total\ carotenoids(mg\ 100g^{-1}) = \frac{(7.6X\ OD_{\ 480} - 1.49X\ OD_{510})X\ \ V}{Weight\ of\ sample\ X\ \ 1000}$$

3.2.3.6 Total phenol (mg 100g^{-1})

Polyphenol content of the jackfruit bulb was determined by the method described by Sadasivam and Manickam (1992).

One gram of the jackfruit bulb was ground in a mortar and pestle with 10 times the volume of 80% ethanol. The homogenate was centrifuged for 20 minutes at 10000 rpm. The supernatant was collected and residue was re extracted with 10 ml of 80% ethanol, centrifuged and pooled the supernatant. Supernatant was evaporated to dryness and the residue was dissolved in 5 ml distilled water. Pippeted out 0.5 ml of the aliquot in test tube and volume made up using 3 ml distilled water and 0.5 ml of Folin- Ciocalteau was added. After 3 minutes 2 ml of 20% Na_2CO_3 was added to the test tube and mixed thoroughly. The test tube was placed in boiling water for one minute, cooled and the absorbance was measured at 765 nm against reagent blank. Using different concentrations of gallic acid, standard curve was prepared and phenol content of the sample was expressed as mg $100g^{-1}$of the sample.

Based on the efficiency in maintaining the physical, physiological, and chemical quality parameters, the best pre-storage treatment solution was selected and the selected treatment was utilized for further studies.

3.3. Evaluation of packaging systems

The best sanitizing agent and pre-storage treatment selected from the first and second part of the experiments were adopted in this part of study.

Good quality Muttom Varikka jackfruit of optimum maturity was harvested, surface sanitized using the best sanitizing agent, selected from the part 1 (3.1) of the study. Good quality bulbs were extracted, seeds removed and treated with the best pretreatment solution selected from second part (3.2) of the study. After surface sanitization and pre-storage treatment, jackfruit bulbs were subjected to the following different packaging systems or materials with the objective of evolving an efficient packaging for minimally processed jackfruit bulbs.

P1- Laminated pouches - Transparent laminated pouches (PP/ LDPE)

` P2- Shrink wrapping in 15 µ polyolefin film

Pretreated and air dried jackfruit bulbs were packed using shrink wrapping machine (SEVANA’S QS4020DSTV). The machine consists of a tunnel through which the product moves and a L-sealer which seals the produce. Jackfruit bulbs were initially sealed using heat shrinkable 15 µ PVC polyolefin film. The

Plate 4. Shrink wrapping machine

sealed produce moves through the tunnel of the machine, where the package tightly shrinks around the product.

P3- Cling film wrapping

P4- Aluminium tray wrapped with cling film

The packaged bulbs were stored under refrigerated condition (5-7^{0}C).

No. of packaging material : 4

No. of treatments : 4

No. of replication : 4

No. of bulbs/ replication : 10

Design : CRD

The physical, physiological and chemical quality parameters of the stored jackfruit bulbs were recorded at the time of storage and at an interval of 2 days till the end of shelf life.

3.3.1 Physical parameters

Physical quality parameters like colour, texture, appearance, flavor and taste of packaged bulbs were evaluated by a thirty member semi trained panel comprising of staff and students of College of Agriculture, Vellayani using a nine point hedonic scale as described in 3.2.1.

3.3.2 Physiological parameters

The following physiological parameters were recorded at the time of storage and at an interval of two days till the end of shelf life.

3.3.2.1 Physiological loss in weight

Physiological loss in weight of the packaged bulb was calculated as percentage using the method described as in 3.2.2.1.

3.3.2.2 Percent leakage

Percent leakage of packaged jackfruit bulb was determined and expressed as percentage as described in 3.2.2.2.

Plate 5. Packaging of pretreated jackfruit bulbs.

P_1- Bulbs packed in laminated pouch

P_2- Shrink wrapped bulbs

P_3- Bulbs wrapped in cling film

P_4- Bulbs packed in aluminium tray wrapped with cling film

3.3.2.3 Shelf life

Shelf life of packaged jackfruit bulb was determined as described in 3.2.2.3.

3.3.3 Chemical parameters

Chemical quality parameters of packaged jackfruit bulb viz, acidity, TSS, sugars, vitamin C, carotenoids and total phenol were evaluated at the time of storage and at an interval of two days till the end of shelf life.

3.3.3.1 Acidity

Acidity of packaged jackfruit bulb was determined by titration method as described in 3.2.3.1

3.3.3.2 Total Soluble Solids

TSS of the packaged jackfruit bulbs were determined by hand refractometer and were expressed in degree brix (^{0}B).

3.3.3.3 Sugars

Reducing sugar, total sugar and non reducing sugar content of the packaged jackfruit bulbs were determined.

Reducing sugar

Reducing sugar of packaged jackfruit bulbs was determined by the procedure described in 3.2.3.3. and was expressed as percentage.

Total sugar

Total sugar of packaged jackfruit bulbs was determined in percentage as described in 3.2.3.3.

Non reducing sugar

Non reducing sugar of the packaged jackfruit bulb was determined as described in 3.2.3.3.

3.3.4 Vitamin C

Vitamin C content of the packaged jackfruit bulb was calculated as ascorbic acid content as described in 3.2.3.4 and expressed as mg 100g^{-1}.

3.3.5 Carotenoids

Carotenoid content of the packaged jackfruit bulb was calculated and expressed as mg 100g^{-1}of the fruit as described in 3.2.3.5.

3.3.6 Total phenol

Total phenol content of the packaged jackfruit bulb was estimated using the method described in 2.3.6 and expressed in mg 100g^{-1}of the sample.

Based on the efficiency in maintaining the physical, physiological and chemical quality parameters to the maximum level, the best packaging material was selected for minimally processed jackfruit bulb.

3.4. Assessment of acceptability

Minimally processed jackfruit bulbs were prepared adopting the selected protocol for sanitization, pretreatment and packaging. The following parameters of the product developed using the standardized protocol were worked out.

3.4.1 Acceptability of the standardized protocol

The acceptability of the minimally processed jackfruit bulb prepared using the selected protocol was assessed by conducting an organoleptic scoring by thirty member semi trained panel, comprising of staffs and students of College of Agriculture, vellayani using a nine point hedonic scale, as described in 3.2.1.

3.4.2 Cost of production

Cost of production for one kg minimally processed jackfruit bulb was calculated based on the current market price taken into account all aspects of fixed and variable costs involved.

Statistical analysis

Data generated from the experiment were analyzed statistically using ANOVA and treatments in the final stage were compared using two sample case T test. The sensory score of different commodities were statistically analysed using Kruskall-Wallis test (Chi-Square value) and ranked (Shamrez *et al*.,2013).

Results

4. RESULT

The experimental data collected from the study “Protocol development for minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs” were analysed statistically, the results are tabulated and presented below.

The whole study was carried out as four different continuous experiments

1. Evaluation of sanitizing agents
2. Evaluation of pre-storage treatments
3. Development of packaging system
4. Assessment of acceptability

4.1 Evaluation of different sanitizing agents

The ripe fruits were treated with four different sanitizing solutions viz 40^0C water, 100 ppm sodium hypochlorite solution, 120 ppm sodium hypochlorite solution and 2 ppm ozonized water by dipping for 15 minutes.

The drained sanitized fruits along with un sanitized fruit as control were subjected to a storage study to evaluate the effect of different sanitizing solutions in reducing the microbial load on fruit surface.

Enumeration of total bacterial load

Effect of different sanitizing solutions in reducing the bacterial load on jack fruit surface is shown in Table 1.

Bacterial count on surface of sanitized jack fruit was significantly influenced by the sanitizing solutions.

Jackfruit sanitized using 120 ppm sodium hypochlorite (S_3) recorded minimum bacterial count (2.97 log cfu/ cm^2) which was on par with the fruits sanitized using 100 ppm sodium hypochlorite (3.14 log cfu/ cm^2)(S_2).

Maximum bacterial count was observed in untreated fruits (4.92 log cfu/ cm^2) (S_5), which was on par with fruits washed with 40^0C water (4.82 log cfu/ cm^2) (S_1).

Table 1. Bacterial population on fruit surface as influenced by surface sanitization

Treatments	Bacterial population (log cfu×10^3/ cm^2)
S_1 (40^0C water)	4.82
S_2 (100 ppm sodium hypochlorite)	3.14
S_3 (120 ppm sodium hypochlorite)	2.97
S_4 (2 ppm ozonized water)	4.68
S_5 (Absolute control)	4.92
C. D SE(m)	0.225 0.074

Enumeration of total fungal load

Effect of different sanitizing solutions in reducing the fungal load on jack fruit surface is shown in Table 2.

Minimum fungal count was recorded in jackfruit sanitized using 120 ppm sodium hypochlorite solution (1.82 log cfu/ cm^2) (S_3) and it was on par with the fruits treated with 2 ppm ozonized water (1.82 log cfu/ cm^2) (S_4) and fruits treated with100 ppm sodium hypochlorite (1.94 log cfu/ cm^2).

Untreated jackfruit (S_5) recorded the highest fungal count (3.04 log cfu/ cm^2), which was on par with fruits washed with 40^0C water(2.74 log cfu/ cm^2) (S_1).

In general, when the efficiency of different sanitizers in reducing the microbial load on fruit surface was considered, 120 ppm and 100pm sodium hypochlorite were equally effective in reducing both the bacterial and fungal load. Since both concentrations of sodium hypochlorite have same effect, considering the economics and efficiency, sanitization using 100 ppm sodium hypochlorite was selected as the best treatment for surface de-contamination of jackfruit and was selected for the next part of the experiment.

4.2. Evaluation of pre-storage treatments

Harvested jack fruits were surface sanitized using 100 ppm sodium hypochlorite solution, the best method selected from the first step of experiment (4.1).

Physical, physiological and chemical quality parameters of the pretreated bulbs were recorded at the time of storage and at regular intervals till the end of shelf life.

4.2.1 Physiological parameters

Physiological quality parameters viz., physiological loss in weight and percent leakage of the bulbs subjected to pre-storage treatments were recorded till the end of shelf life.

Table 2. Fungal population on fruit surface as influenced by surface sanitization

Treatments	Fungal population ($cfu \times 10^3 / cm^2$)
S_1 (40^0C water)	2.74
S_2 (100 ppm sodium hypochlorite)	1.94
S_3 (120 ppm sodium hypochlorite)	1.82
S_4 (2 ppm ozonized water)	1.82
S_5 (Absolute control)	3.04
C. D SE(m)	0.352 0.116

4.2.1.1 Shelf life (Days)

Effect of pre-storage treatments on shelf life of jackfruit bulbs are depicted in Table 3.

Jackfruit bulbs treated with 1% calcium chloride (T_3) recorded the highest shelf life (5.00 days) followed by the bulbs treated with 0.1% ascorbic acid (T_1) and 0.1% citric acid (4.00 days) (T_2) . Lowest shelf life was recorded by the bulbs that were untreated (3.00 days) (T_4).

4.2.1.2 Physiological loss in weight (PLW) (%)

Effects of different pre-storage treatments on physiological loss in weight of jackfruit bulbs are depicted in Table 4.

Jackfruit bulbs treated with 1% calcium chloride (T_3) recorded the lowest mean physiological loss in weight (2.03), followed by the bulbs treated with 0.1% ascorbic acid (T_1) (2.65) after 3 days of storage. Untreated jackfruit bulbs (T_4) recorded the highest mean loss in weight (5.12) after 3 days of storage.

Jackfruit bulbs pretreated with 1% calcium chloride recorded the least PLW as 1.34%, 2.72% on 1st, and 3rd day of storage respectively. Highest loss in weight was recorded for untreated bulbs on 1st (3.43) and 3rd (6.82) day of storage.

Physiological Loss in Weight ranges from 2.27% on 1st day of storage to 4.21% on 3rd day of storage.

All the bulbs except the one treated with 1% calcium chloride (T_3) were discarded by 5th day of storage and T_3 recorded mean loss in weight of 4.4% after 5 days of storage.

4.2.1.3 Percent leakage (%)

Effects of different pre-storage treatments on percent leakage of the jack fruit bulbs are depicted in Table 5.

Percent leakage of the bulbs did not show any significant variation among treatments and it ranged from 72.41% to 72.49% at the time of storage.

1% calcium choride treated jackfruit bulbs recorded the least percent leakage during the 1st (77.37) and 3rd day (87.93) of storage which was significantly different

Table 3. Effects of pre-storage treatments on shelf life of jackfruit bulbs

Treatments	Shelf life (Days)
T_1 (0.1% Ascorbic acid)	4.00
T_2 (0.1% Citric acid)	4.00
T_3 (1% Calcium chloride)	5.00
T_4 (Absolute control)	3.00
CD	0.002
SE±(m)	0.001

Table 4. Effects of pre-storage treatments on physiological loss in weight of jackfruit bulbs

Treatments	Physiological Loss in Weight (%)			
	Days after storage			
	1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	2.04(1.74)	3.27(2.06)	2.65(1.90)	-
T_2 (0.1% Citric acid)	2.27(1.81)	4.03(2.24)	3.15(2.02)	-
T_3 (1% Calcium chloride)	1.34(1.53)	2.72(1.93)	2.03(1.73)	4.4
T_4 (Absolute control)	3.43(2.1)	6.82(2.79)	5.12(2.45)	-
Day mean	2.27(1.79)	4.21(2.26)		
	SE±(m)	CD (0.05)		
Treatment(T)	- 0.046	0.135		
Days (D)	- 0.032	0.095		
Treatment (T)× Days (D)	- 0.065	0.190		
(Value in parenthesis is the square root transformed value)				

Table 5. Effects of pre-storage treatments on percent leakage of jackfruit bulbs

Treatments	Percent leakage (%)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	72.43	80.98	90.42	81.27	-
T_2 (0.1% Citric acid)	72.41	82.43	90.28	81.71	-
T_3 (1% Calcium chloride)	72.43	77.37	87.93	79.24	89.52
T_4 (Absolute control)	72.49	83.87	92.96	83.11	-
Day mean	72.44	81.16	90.4		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.438	1.262
Days (D)	- 0.379	1.093
Treatment (T)× Days (D)	- 0.759	2.185

from the other treatments. Highest percent leakage was recorded in untreated bulbs during 1^{st} (83.87) and 3^{rd} (92.96) day of storage. Jack fruit bulbs treated with 0.1% citric acid was on par with untreated bulbs during 1^{st} day of storage.

Jackfruit bulbs treated with 1% calcium chloride (T_3) recorded the least mean leakage (79.24) after 3 days of storage followed by the bulbs treated 0.1% ascorbic acid (T_1). The highest mean percent leakage (83.11) was observed in untreated bulbs (T_4) after 3 days of storage.

All the bulbs except those treated with 0.1% calcium chloride were discarded by 5^{th} day of storage and T_3 had recorded a percent leakage of 89.52% on 5^{th} day of storage.

Percent leakage increased with increase in storage period and it was 72.44% at the time of storage, 81.16% and 90.4% on 1^{st} and 3^{rd} day of storage respectively.

4.2.2 Physical parameters

Effects of pre-storage treatments on physical parameters like colour, texture, appearance, flavor and taste of the jackfruit bulbs were analysed using Kruskall-Wallis chi square test. Observations were recorded at the time of storage and at regular intervals till the end of shelf life.

4.2.2.1 Colour

Effects of different pre-storage treatments on mean colour scores of the jackfruit bulbs as assessed by organoleptic scoring are depicted in Table 6.

Mean colour scores of jackfruit bulbs did not show any significant difference between the treatments at the time of storage and on 1^{st} day of storage.

1% calcium chloride treated bulbs recorded the highest mean score for colour (7.96) on 3^{rd} day of storage and lowest mean score (6.86) was observed in untreated jackfruit bulbs.

All bulbs except those treated with 1% calcium chloride were discarded on 5^{th} day of storage and it recorded a mean score of 7.56 on 5^{th} day.

4.2.2.2 Texture

Effects of different pre-storage treatments on texture of the jackfruit bulbs are depicted in Table 7.

Table 6. Effects of pre-storage treatments on colour of jackfruit bulbs

Treatments	Colour (Mean sensory scores)			
	Days after storage			
	0	1	3	5
T_1 (0.1% Ascorbic acid)	8.56	8.50	7.76	-
T_2 (0.1% Citric acid)	8.53	8.53	7.56	-
T_3 (1% Calcium chloride)	8.46	8.43	7.96	7.56
T_4 (Absolute control)	8.57	8.3	6.86	-
KW value	0.796	2.806	45.90	
$\chi 2$ (0.05)	7.814			

Table 7. Effects of pre-storage treatments on texture of jackfruit bulbs

Treatments	Texture (Mean sensory scores)			
	Days after storage			
	0	1	3	5
T_1 (0.1% Ascorbic acid)	8.46	8.06	7.56	-
T_2 (0.1% Citric acid)	8.56	7.93	7.70	-
T_3 (1% Calcium chloride)	8.60	8.13	8.03	7.66
T_4 (Absolute control)	8.60	7.90	5.60	-
KW value	1.441	3.515	77.327	-
$\chi 2$ (0.05)	7.814			

Texture of jackfruit bulbs did not show any significant variation among treatments at the time of storage and on 1st day of storage.

Highest mean score for texture (8.03) was recorded for 1% calcium chloride treated bulbs and lowest score (5.6) was recorded in untreated jackfruit bulbs on 3rd day of storage.

1% calcium chloride treated bulbs recorded a mean score of 7.66 for texture on 5th day of storage and all other bulbs were discarded on 5th day.

4.2.2.3 Appearance

Effects of different pre-storage treatments on appearance of jackfruit bulbs are illustrated in Table 8.

Sensory scores for appearance did not show significant difference among treatments at the time of storage and at 1st day of storage.

1% calcium chloride treated bulbs recorded the highest mean score for appearance (8.2) on 3rd day of storage and the minimum score was obtained for untreated bulbs (6.86).

All bulbs except those treated with 1 % calcium chloride were discarded by 5th day of storage and 1 % calcium chloride treated bulb recorded a mean score of 7.53 for appearance on 5th day.

4.2.2.4 Flavor

Flavor of jackfruit bulbs as influenced by pre-storage treatments is depicted in Table 9.

Sensory scores for flavor showed no significant difference among treatments at the time of storage and on 1st day of storage. Highest mean score for flavor (8.13) was recorded in 1% calcium chloride treated bulbs on 3rd day of storage and the lowest score was recorded in untreated bulbs (6.86).

Mean score of 7.46 was recorded in bulbs treated with 1% calcium chloride on 5th day of storage and all other bulbs were discarded by 5th day.

Table 8. Effects of pre-storage treatments on appearance of jackfruit bulbs

Treatments	Appearance (Mean sensory scores)			
	Days after storage			
	0	1	3	5
T_1 (0.1% Ascorbic acid)	8.56	8.40	8.06	-
T_2 (0.1% Citric acid)	8.53	8.50	7.56	-
T_3 (1% Calcium chloride)	8.60	8.43	8.20	7.53
T_4 (Absolute control)	8.56	8.13	6.86	-
KW value	0.269	6.204	48.480	-
$\chi 2$ (0.05)	7.814			

Table 9. Effects of pre-storage treatments on flavor of jackfruit bulbs

Treatments	Flavor (Mean sensory scores)			
	Days after storage			
	0	1	3	5
T_1 (0.1% Ascorbic acid)	8.53	8.10	7.60	-
T_2 (0.1% Citric acid)	8.50	8.06	7.56	-
T_3 (1% Calcium chloride)	8.56	8.33	8.13	7.46
T_4 (Absolute control)	8.60	8.23	6.86	-
KW value	0.667	3.124	34.882	
$\chi2$ (0.05)	7.814			

4.2.2.5 Taste

Effects of pre-storage treatments on taste of jackfruit bulbs are illustrated in Table 10.

Sensory scores for taste showed no significance among treatments at the time of storage. Highest mean score for taste was recorded by untreated bulbs (8.46) on 1st day of storage, which was followed by bulbs treated with 1% calcium chloride with score of 8.26.

1% calcium chloride treated bulbs recorded maximum mean score for taste (7.83) on 3rd day of storage and least score of 6.43 was recorded by untreated bulbs.

All bulbs except those treated with 1% calcium chloride were discarded by 5th day of storage and a mean score of 7.43 was recorded by calcium chloride treated bulbs on 5th day.

4.2.3 Chemical parameters

Chemical quality parameters viz., acidity, total soluble solids, sugars, vitamin C, carotenoids and total phenol of the bulbs subjected to pre-storage treatments were recorded initially and at regular intervals till the end of shelf life.

4.2.3.1 Acidity (%)

Effects of different pre-storage treatments on acidity content of jackfruit bulbs are illustrated in Table 11.

Acidity of jackfruit bulbs were significantly influenced by treatments and storage period.

Jackfruit bulbs pretreated with 1% calcium chloride (T_3) recorded least acidity (0.36%), followed by the bulbs treated with 0.1% ascorbic acid (T_1) (0.35%) after 3rd day of storage. Highest acidity (0.43) was observed in 0.1% citric acid treated bulbs (T_2).

Acidity decreased from 0.45% at the time of storage to 0.39% and 0.36% on 1st and 3rd day of storage respectively.

Table 10. Effects of pre-storage treatments on taste of jackfruit bulbs

Treatments	Taste (Mean sensory scores)			
	Days after storage			
	0	1	3	5
T_1 (0.1% Ascorbic acid)	8.63	8.03	7.36	-
T_2 (0.1% Citric acid)	8.57	8.13	7.66	-
T_3 (1% Calcium chloride)	8.50	8.26	7.83	7.43
T_4 (Absolute control)	8.73	8.46	6.43	-
KW value	3.711	8.666	58.44	-
$\chi 2$ (0.05)	7.814			

Table 11. Effects of pre-storage treatments on acidity of jackfruit bulbs

Treatments	Acidity (%)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	0.46	0.39	0.35	0.40	-
T_2 (0.1% Citric acid)	0.46	0.43	0.39	0.43	-
T_3 (1% Calcium chloride)	0.43	0.33	0.31	0.36	0.26
T_4 (Absolute control)	0.43	0.43	0.38	0.41	-
Day mean	0.45	0.39	0.36		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.009	0.026
Days (D)	- 0.008	0.023
Treatment (T)× Days (D)	- 0.016	NS

There was no significant difference between the treatments at the time of storage.

All the bulbs except those treated with 0.1% calcium chloride were discarded by 5th day of storage and T_3 had recorded 0.26% acidity on 5th day of storage.

4.2.3.2 Total Soluble Solids (^{0}B)

Effects of different pre-storage treatments on total soluble solids of jackfruit bulbs are depicted in Table 12.

TSS of jackfruit bulbs ranged from 19.23 ^{0}B to 19.55 ^{0}B at the time of storage and it did not differed significantly among the treatments.

Untreated jackfruit bulbs (T_4) recorded the highest TSS (20.68) during the 1st day of storage which was on par with the bulbs treated with 1% calcium chloride (20.48) (T_3). On 3rd day of storage highest TSS was noticed in untreated jackfruit bulbs (21.13) (T_4).

Lowest TSS was recorded on 0.1% citric acid (T_2) treated bulb on 1st day (19.45), which was on par with the bulbs treated with 0.1% ascorbic acid (19.58) (T_1). 0.1% citric acid treated bulbs (T_2) recorded the lowest TSS on 3rd day (19.60) which was on par with the bulbs treated with 0.1% ascorbic acid (19.78) (T_1).

Highest mean TSS (20.45) was recorded in untreated jackfruit bulbs (T_4) which was on par with the bulbs treated with 1% calcium chloride (20.20) (T_3) after 3 days of storage. 0.1% citric acid treated bulb (T_2) recorded the lowest mean TSS which was on par with the bulbs treated with 0.1% ascorbic acid (19.53) (T_1).

TSS increased with days of storage from 19.39^{0}B at the time of storage to 20.04^{0}B and 20.28^{0}B on 1st and 3rd days respectively.

All the bulbs except those treated with 1% calcium chloride (T_3) were discarded on 5th day of storage and T_3 had recorded a TSS of 20.85 ^{0}B on 5th day of storage.

4.2.3.3 Sugars

Total sugar, reducing and non reducing sugar of the jackfruit bulbs were recorded initially and at regular intervals till the end of shelf life.

Table 12. Effects of pre-storage treatments on Total Soluble Solids of jackfruit bulbs

Treatments	Total Soluble Solids (^{0}B)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	19.23	19.58	19.78	19.53	-
T_2 (0.1% Citric acid)	19.28	19.45	19.60	19.44	-
T_3 (1% Calcium chloride)	19.50	20.48	20.63	20.20	20.85
T_4 (Absolute control)	19.55	20.68	21.13	20.45	-
Day mean	19.39	20.04	20.28		
	SE±(m)		CD (0.05)		
Treatment(T)	- 0.094		0.269		
Days (D)	- 0.081		0.233		
Treatment (T)× Days (D)	- 0.162		0.467		

Total sugars (%)

Effects of different pre-storage treatments on total sugar content of the jackfruit bulbs are depicted in Table 13.

Total sugar content of the jackfruit bulbs was same for all treatments at the time of storage and it was 32.47%.

Untreated jackfruit bulbs (T_4) recorded the highest total sugar content on 1st day (33.96%) of storage followed by the bulbs treated with 1% calcium chloride (33.45%) (T_3). Lowest total sugar content was noticed on 0.1% citric acid treated bulbs (T_2) (33.11%) which was on par with the bulbs treated with 0.1% ascorbic acid (T_1) on 1st day (33.22%).

Highest total sugar content was noticed in bulbs treated with 1% calcium chloride (36.50%) (T_3), which was on par with the untreated jackfruit bulbs (36.43%) (T_4) on 3rd day of storage. Lowest total sugar content was noticed on 0.1% citric acid treated bulbs (T_2) (34.19%) which was on par with the bulbs treated with 0.1% ascorbic acid (T_1) (34.25%).

Jackfruit bulbs that was untreated (T_4) recorded the highest mean total sugar content (34.29%) after 3 days of storage which was on par with the bulbs treated with 1% calcium chloride (34.14%) (T_3). Lowest total sugar (33.26%) was recorded in 0.1% citric acid (T_2) treated bulbs which was on par with the bulbs treated with 0.1% ascorbic acid (33.31%) (T_1) after 3 days of storage.

Total sugar content increased from 32.47% at the time of storage to 33.43% and 35.34% on 1st and 3rd days of storage respectively.

All the jackfruit bulbs except those treated with 1% calcium chloride were discarded after 5 days of storage and T_3 recorded 36.50% of total sugar on 5 days after storage.

Reducing sugars (%)

Effects of different pre-storage treatments on reducing sugar content of the jackfruit bulbs are illustrated inTable 14.

Table 13. Effects of pre-storage treatments on total sugar of jackfruit bulbs

Treatments	Total sugar (%)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	32.47	33.22	34.25	33.31	-
T_2 (0.1% Citric acid)	32.47	33.11	34.19	33.26	-
T_3 (1% Calcium chloride)	32.47	33.45	36.50	34.14	36.50
T_4 (Absolute control)	32.47	33.96	36.43	34.29	-
Day mean	32.47	33.43	35.34		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.058	0.167
Days (D)	- 0.050	0.144
Treatment (T)× Days (D)	- 0.100	0.289

Table 14. Effects of pre-storage treatments on reducing sugar of jackfruit bulbs

Treatments	Reducing sugar (%)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	13.15	14.09	14.72	13.99	-
T_2 (0.1% Citric acid)	13.33	14.10	14.50	13.98	-
T_3 (1% Calcium chloride)	13.24	14.92	16.27	14.81	16.40
T_4 (Absolute control)	13.33	15.24	16.39	14.99	-
Day mean	13.26	14.59	15.47		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.094	0.271
Days (D)	- 0.082	0.235
Treatment (T)× Days (D)	- 0.163	0.470

Reducing sugar content of the jackfruit bulbs ranged from 13.15% to 13.33% at the time of storage and it did not show any significant variation among the treatments.

Untreated jackfruit bulbs (T_4) recorded the highest reducing sugar content on 1^{st} (15.24%) and 3^{rd} day (16.39%) which was on par with the bulbs treated with 1% calcium chloride (T_3) on 1^{st} (14.92%) and 3^{rd} day (16.39%) respectively. 0.1% ascorbic acid (T_1) treated bulbs recorded the least reducing sugar content (14.09%) on 1^{st} day which was on par with the bulbs treated with 0.1% citric acid (14.10%) (T_2). On 3^{rd} day of storage, least reducing sugar (14.50%) was observed in 0.1% citric acid treated bulbs (T_2) which was on par with the bulbs treated with 0.1% ascorbic acid (14.72%) (T_1).

Highest mean reducing sugar content was noticed in untreated jackfruit bulbs (14.99%) (T_4) which was on par with the jackfruit bulbs treated with 1% calcium chloride (14.81%) (T_3) after 3 days of storage. 0.1% citric acid (T_2) treated bulbs recorded the lowest mean reducing sugar (13.98%) which was on par with the bulbs treated with 0.1% ascorbic acid (13.99%) (T_1) after 3 days of storage.

Reducing sugar increased from 13.26% at the time of storage to 14.59% and 15.47% on 1^{st} and 3^{rd} day respectively.

All the jackfruit bulbs except those treated with 1% calcium chloride were discarded on 5^{th} day of storage and T_3 recorded 16.40% of reducing sugar on 5^{th} day of storage.

Non reducing sugar (%)

Effects of different pre-storage treatments on non reducing sugar content of the jackfruit bulbs are depicted in Table 15.

Non reducing sugar was significantly influenced by days of storage and interaction between days and treatment.

Non reducing sugar content ranged from 19.14% to 19.32% at the time of storage and did not show any significant variation among treatments.

Table 15. Effects of pre-storage treatments on Non reducing sugar of jackfruit bulbs

Treatments	Non reducing sugar (%)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	19.32	19.13	19.53	19.33	-
T_2 (0.1% Citric acid)	19.14	19.01	19.69	19.28	-
T_3 (1% Calcium chloride)	19.23	18.53	20.23	19.33	20.10
T_4 (Absolute control)	19.14	18.72	20.04	19.30	-
Day mean	19.21	18.85	19.87		
	SE±(m)		CD (0.05)		
Treatment(T)	- 0.102		NS		
Days (D)	- 0.089		0.255		
Treatment (T)× Days (D)	- 0.177		0.511		

Jackfruit bulbs treated with 0.1% ascorbic acid (T_1) recorded the highest non reducing content (19.13%) on 1st day of storage which was on par with the bulbs treated with 0.1% citric acid (19.01%) (T_2) and the untreated bulbs (18.72%) (T_4). Lowest reducing sugar was observed in 1% calcium chloride treated bulbs (18.53%) (T_3)

1% calcium chloride treated bulbs (T_3) recorded highest non reducing sugar (20.23%) on 3rd day of storage which was on par with the untreated bulbs (20.04%) (T_4). Lowest reducing sugar was observed in 0.1% ascorbic acid (T_1) treated bulbs (19.53%).

All the jackfruit bulbs except those treated with 1% calcium chloride were discarded at 5th day of storage and the treatment recorded 20.10% of non-reducing sugar on 5th day of storage.

4.2.3.4 Vitamin C content (mg100g^{-1})

Effects of different pre-storage treatments on vitamin C content of jackfruit bulbs are depicted in Table 16.

Vitamin C content ranged from 26.32 mg100g^{-1} to 31.58 mg100g^{-1} at the time of storage and varies significantly with the treatments. 0.1% ascorbic acid treated jackfruit bulbs (T_1) recorded highest vitamin C content (31.58 mg100g^{-1}) at the time of storage.

Ascorbic acid 0.1% (T_1) treated bulb recorded highest vitamin C content on 1st (28.95) and 3rd day (26.32), followed by bulbs treated with 1% calcium chloride (T_3) on 1st (22.37) and 3rd day (22.37%) respectively.

Lowest vitamin C content was noticed in untreated bulbs (18.42) (T_4) which was on par with the bulbs treated with 0.1% citric acid (19.74) (T_2) on 1st day of storage. On 3rd day of storage untreated jackfruit bulbs (T_1) recorded the lowest vitamin C content (11.85).

Mean vitamin C content was highest for 0.1% ascorbic acid treated bulbs (28.95) (T_1) and lowest was recorded in untreated jackfruit bulbs (18.86) (T_4) after 3 days of storage.

Table 16. Effects of pre-storage treatments on vitamin C content of jackfruit bulbs

Treatments	Vitamin C content ($mg100g^{-1}$)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	31.58	28.95	26.32	28.95	-
T_2 (0.1% Citric acid)	26.32	19.74	17.11	21.05	-
T_3 (1% Calcium chloride)	26.32	22.37	22.37	23.69	21.05
T_4 (Absolute control)	26.32	18.42	11.85	18.86	-
Day mean	27.64	22.37	19.41		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.705	2.030
Days (D)	- 0.611	1.758
Treatment (T)× Days (D)	- 1.221	3.516

Vitamin C content of jackfruit bulbs decreased from 27.64 $mg100g^{-1}$ at the time of storage to 22.37 $mg100g^{-1}$ and 19.41 $mg100g^{-1}$ on 1^{st} and 3^{rd} days of storage respectively.

All jackfruit bulbs except those treated with 1%calcium chloride (T_3) were discarded after 5 days of storage and vitamin C content of 21.05 $mg100g^{-1}$ was observed in T_3 on 5^{th} day of storage.

4.2.3.5 Total carotenoid content ($mg100g^{-1}$)

Effects of different pre-storage treatments on total carotenoid content of the jackfruit bulbs are illustrated in Table 17.

Total carotenoid content of bulbs was 0.86 $mg100g^{-1}$ at the time of storage for all the treatments.

Highest total carotenoid content was observed in 1% calcium chloride (T_3) treated bulbs (0.83) followed by 0.1% ascorbic acid treated bulbs (0.79) (T_1) on 1^{st} day of storage. Untreated bulbs (T_4) recorded the least total carotenoid content (0.75) on 1^{st} day of storage followed by the bulbs treated with 0.1% citric acid (0.78) (T_2).

Bulbs treated with 1% calcium chloride (T_3) recorded highest carotenoid content (0.79) on the 3^{rd} day of storage, which was on par with the bulbs treated with 0.1% ascorbic acid (0.77) (T_1). On 3^{rd} day of storage, both the bulbs treated with 0.1% citric acid (T_2) and untreated bulbs (T_4) recorded the lowest total carotenoid content.

Bulbs treated with 1% calcium chloride (T_3) recorded the highest mean total carotenoid content (0.83) after 3 days of storage , followed by the bulbs treated with 0.1% ascorbic acid (0.81) (T_1). Lowest total carotenoid content was observed in untreated jackfruit bulbs (0.79) (T_4) which was on par with the bulbs treated with 0.1% citric acid (0.80) (T_2).

Total carotenoid content of the jackfruit bulbs decreased from 0.86 $mg100g^{-1}$ at the time of storage to 0.79 $mg100g^{-1}$ and 0.76 $mg100g^{-1}$ on 1^{st} and 3^{rd} days of storage respectively.

Table 17. Effects of pre-storage treatments on total carotenoid content of jackfruit bulbs

Treatments	Total carotenoid content ($mg100g^{-1}$)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	0.86	0.79	0.77	0.81	-
T_2 (0.1% Citric acid)	0.86	0.78	0.75	0.80	-
T_3 (1% Calcium chloride)	0.86	0.83	0.79	0.83	0.76
T_4 (Absolute control)	0.86	0.75	0.75	0.79	-
Day mean	0.86	0.79	0.76		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.005	0.015
Days (D)	- 0.004	0.013
Treatment (T)× Days (D)	- 0.009	0.025

1% calcium chloride treated bulbs (T_3) recorded 0.76 $mg100g^{-1}$ of total carotenoid content on 5th day of storage and all the other jackfruit bulbs were discarded on 5th day of storage.

4.2.3.6 Total phenolic content ($mg100g^{-1}$)

Effects of different pre-storage treatments on total phenolic content of the jackfruit bulb are depicted in Table 18.

Total phenolic content of the jackfruit bulbs were significantly influenced by treatments and days of storage.

Total phenolic content decreased from 42.59 $mg100g^{-1}$ at the time of storage to 41.20 $mg100g^{-1}$ and 39.20 $mg100g^{-1}$ on 1st and 3rd day respectively.

Untreated jackfruit bulbs recorded highest mean total phenolic content (42.29) after 3 days of storage and 1% calcium chloride treated bulbs recorded lowest total phenolic content (39.77).

All jackfruit bulbs except those treated with 1% calcium chloride were discarded after 5 days of storage and calcium chloride treated bulbs had recorded 35.83 $mg100g^{-1}$ of total phenolic content on 5th day of storage.

4.3 Development of packaging system

Good quality harvested jackfruits of optimum maturity were surface sanitized using 100 ppm sodium hypochlorite solution, the best method selected from the first step of experiment (4.1). Good quality bulbs were extracted, seeds removed and pre-treated with 1% calcium chloride for 10 minutes, the best pre-storage treatment selected from the second step of the experiment (4.2). The pre-treated bulbs were packed in four different packaging systems viz., laminated pouch, shrink wrapping, cling film wrapping and aluminium tray wrapped with cling film and stored under refrigerated (5-7 ^{0}C) conditions with the objective to develop an efficient packaging system for minimally processed jackfruit bulbs.

Physical, physiological and chemical quality parameters of the pre-treated jackfruit bulbs were recorded initially and at regular intervals till the ends of shelf life.

Table 18. Effects of pre-storage treatments on total phenolic content of jackfruit bulbs

Treatments	Total phenolic content ($mg100g^{-1}$)				
	At the time of storage	Days after storage			
		1	3	Treatment mean	5
T_1 (0.1% Ascorbic acid)	42.59	40.74	39.81	41.15	-
T_2 (0.1% Citric acid)	42.59	41.66	38.42	40.90	-
T_3 (1% Calcium chloride)	42.59	40.28	36.43	39.77	35.83
T_4 (Absolute control)	42.59	42.13	42.13	42.29	-
Day mean	42.59	41.20	39.20		

	SE±(m)	CD (0.05)
Treatment(T)	- 0.528	1.520
Days (D)	- 0.457	1.316
Treatment (T)× Days (D)	- 0.914	NS

4.3.1 Physiological parameters

Physiological quality parameters viz., physiological loss in weight and percent leakage of the jackfruit bulbs subjected to different packaging systems were analyzed at the time of storage and at regular intervals till the end of shelf life.

4.3.1.1 Shelf life (Days)

Effect of packaging on shelf life of the pretreated jackfruit bulbs are illustrated in Table 19.

Jackfruit bulbs pretreated with 1% calcium chloride and packed in laminated pouch (P_1)recorded the highest shelf life (7.00 days) followed by the bulbs packed that were shrink wrapped (6.00 days) (P_2). Lowest shelf life (4.00 days) was recorded by the bulbs that were wrapped in cling film (P_3).

4.3.1.2 Physiological loss in weight (PLW) (%)

Effects of different packaging materials on physiological loss in weight of jackfruit bulbs are depicted in Table 20.

Physiological loss in weight recorded was least for the bulbs packed in laminated pouch (P_1) on 2^{nd} (0.88) and 4^{th} (1.46) days of storage .

Highest loss in weight was noticed on cling film wrapped bulbs (P_3) as 2.77% and 4.49% on 2^{nd} and 4^{th} days of storage respectively.

Jackfruit bulbs packed in laminated pouch (P_1) recorded the least mean loss in weight (1.17) , followed by shrink wrapped bulbs (1.95) (P_2) after 4 days of storage. Highest mean loss in weight was observed on bulbs wrapped in cling film (3.63) (P_3).

Physiological loss in weight increased from 1.57% on 2^{nd} day of storage to 2.82% on 4^{th} day of storage.

All jackfruit bulbs except those packed in laminated pouch (P_1) and shrink wrapped bulbs (P_2) were discarded by 6^{th} day of storage. Low physiological loss in weight was recorded in bulbs packed in laminated pouch (4.00) (P_2) followed by shrink wrapped bulbs (4.72) (P_2).

Table 19. Effect of packaging on shelf life of jackfruit bulbs

Treatments	Shelf life (Days)
P_1 (Laminated pouch)	7.00
P_2 (Shrink wrapping)	6.00
P_3 (Cling film wrapping)	4.00
P_4 (Aluminum tray wrapped with cling film)	5.00
CD SE±(m)	0.004 0.001

Tables 20. Effect of packaging on physiological loss in weight of jackfruit bulbs

Treatments	Physiological Loss in Weight (%)			
	Days after storage			
	2	4	Treatment mean	6
P_1 (Laminated pouch)	0.88(1.37)	1.46(1.57)	1.17(1.47)	4.00
P_2 (Shrink wrapping)	1.28(1.51)	2.63(1.91)	1.95(1.71)	4.72
P_3 (Cling film wrapping)	2.77(1.94)	4.49(2.34)	3.63(2.14)	-
P_4 (Aluminum tray wrapped with cling film)	1.35(1.53)	2.69(1.92)	2.02(1.73)	-
Day mean	1.57(1.59)	2.82(1.93)		
	SE±(m)	CD (0.05)		P value
Treatment(T)	- 0.018	0.053		-
Days (D)	- 0.013	0.038		0.0000
Treatment (T)× Days (D)	- 0.026	0.075		3
(Value in parenthesis is the square root transformed value)				

4.3.1.3 Percent leakage (%)

Effect of packaging on percent leakage of the jackfruit bulbs are illustrated in Table 21.

Percentage leakage was significantly influenced by treatments, days of storage and interaction between treatment and storage days.

Percent leakage of jackfruit bulbs was 61.92% at the time of storage. There was significant variation between treatments on 2nd and 4th day of storage.

Jackfruit bulbs packed in laminated pouch (P_1) recorded the least percent leakage on 2nd (66.10) and 4th days (69.68) of storage which was significantly different from the other treatments. Highest percent leakage was observed in bulbs wrapped in cling film (P_3) on 2nd (73.42) and 4th days (80.96) of storage.

Mean percent leakage was lowest (65.90) for the bulbs packed in laminated pouch (P_1) followed by shrink wrapped bulbs (67.78) (P_2) after 4 days of storage. Bulbs wrapped in cling film (P_3) recorded the highest mean percent leakage (72.10) after 4 days of storage.

Percent leakage of jackfruit bulbs increased with increase in storage period. It was 61.92% at the time of storage, increased to 68.92%, 74.76% on 2nd and 4th days of storage respectively.

All bulbs except those packed in laminated pouch and shrink wrapping were discarded by 6th day of storage. Bulbs packed in laminated pouch recorded a lower percent leakage on 6th day of storage compared to shrink wrapped bulbs (75.37).

4.3.2 Physical parameters

Physical parameters like colour, texture, appearance, flavor and taste of jackfruit bulbs as influenced by different packaging systems were analyzed using Kruskall- Wallis chi square test. Observations were recorded at the time of storage and at regular intervals till the end of shelf life.

4.3.2.1 Colour

Effects of different packaging materials on mean colour scores of the jackfruit bulbs as assessed by organoleptic scoring are depicted in Table 22.

Tables 21. Effect of packaging on percent leakage of jackfruit bulbs

Treatments	Percent leakage (%)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	61.92	66.10	69.68	65.90	72.08
P_2 (Shrink wrapping)		68.36	73.05	67.78	75.37
P_3 (Cling film wrapping)		73.42	80.96	72.10	-
P_4 (Aluminum tray wrapped with cling film)		67.82	75.37	68.37	-
Day mean	61.92	68.92	74.76		

	SE±(m)	CD (0.05)	P value
Treatment(T)	- 0.192	0.552	-0.014
Days (D)	- 0.166	0.478	
Treatment (T)× Days (D)	- 0.332	0.96	

Tables 22. Effect of packaging on colour of jackfruit bulbs

Treatments	Colour (Mean sensory scores)			
	At the time of storage	Days after storage		
		2	4	6
P_1 (Laminated pouch)	8.70	8.36	7.73	6.53
P_2 (Shrink wrapping)	8.60	8.16	7.43	6.00
P_3 (Cling film wrapping)	8.66	8.16	6.70	-
P_4 (Aluminum tray wrapped with cling film)	8.60	8.23	7.16	-
KW value	0.970	2.479	49.34	14.277
$\chi 2$ (0.05)	7.814			

Mean colour scores of the jackfruit bulbs did not show any significant variation among treatments at the time of storage and on 2nd day after storage.

Highest mean score for colour (7.73) was recorded in bulbs packed in laminated pouch (P_1) and lowest mean score (6.7) was noticed in cling film wrapped bulbs (P_3) on 4th day of storage.

All the jackfruit bulbs except those packed in laminated pouch (P_1) and by shrink wrapping (P_2) were discarded by 6th day of storage. Bulbs packed in laminated pouch (P_1) recorded a higher mean score for colour (6.53) on 6th day of storage.

4.3.2.2 Texture

Effects of different packaging materials on texture of the jackfruit bulbs are illustrated in Table 23.

Sensory scores for texture of packaged bulbs show no significant variation among treatments at the time of storage. Texture scores were significantly influenced by the packaging treatments from 2nd day of storage onwards.

Bulbs packed in laminated pouch (P_1) recorded the highest mean score for texture on 2nd (8.2) and 4th (7.53) day of storage. Lowest mean score for texture was noticed in bulbs wrapped in cling film (P_3) on 2nd (7.5) and 4th (5.6) day of storage.

All jackfruit bulbs except those packed in laminated pouch (P_1) and in shrink wrapping (P_2) were discarded by 6th day of storage. Higher mean score for texture (7.26) was recorded in bulbs packed in laminated pouch (P_1) on 6th day of storage.

4.3.2.3 Appearance

Effects of different packaging materials on appearance of jackfruit bulbs are depicted in Table 24.

Appearance of jackfruit bulbs as influenced by packaging shows no significant variation among treatments at the time of storage and on 2nd day of storage.

Tables 23. Effect of packaging on texture of jackfruit bulbs

Treatments	Texture (Mean sensory scores)			
	At the time of storage	Days after storage		
		2	4	6
P_1 (Laminated pouch)	8.60	8.20	7.53	7.26
P_2 (Shrink wrapping)	8.50	8.13	6.26	6.46
P_3 (Cling film wrapping)	8.53	7.50	5.60	-
P_4 (Aluminum tray wrapped with cling film)	8.60	7.96	7.20	-
KW value	0.904	8.352	83.742	18.734
$\chi 2$ (0.05)	7.814			

Tables 24. Effect of packaging on appearance of jackfruit bulbs

Treatments	Appearance (Mean sensory scores)			
	At the time of storage	Days after storage		
		2	4	6
P_1 (Laminated pouch)	8.40	8.03	7.56	6.73
P_2 (Shrink wrapping)	8.43	8.00	7.46	6.13
P_3 (Cling film wrapped)	8.36	7.93	6.93	-
P_4 (Aluminum tray wrapped with cling film)	8.40	8.00	7.03	-
KW value	0.275	0.377	16.49	11.576
$\chi 2$ (0.05)	7.814			

Bulbs packed in laminated pouch (P_1) recorded the highest mean score for appearance (7.56) on 4th day of storage and lowest mean score was noticed in cling film wrapped jackfruit bulbs (6.93) (P_3).

Bulbs packed in aluminium tray wrapped with cling film (P_4) and cling film wrapped bulbs (P_3) were discarded by 6th day of storage.

Higher mean score for appearance was observed in bulbs packed in laminated pouch (6.73) (P_1) on 6th day of storage.

4.3.2.4 Flavor

Effects of different packaging material on flavor of the jackfruit bulbs are depicted in Table 25.

Mean sensory scores for flavor show no significant variation among the treatments at the time of storage.

Highest mean score for flavor (7.97) was noticed in bulbs packed in laminated pouch (P_1) on 1st day of storage and the lowest mean score was recorded in cling film wrapped jackfruit bulbs (6.23) (P_3) .

Both the bulbs packed in laminated pouch (P_1) and the shrink wrapped bulbs (P_2) recorded the highest score for flavor on 4th day of storage and cling film wrapped bulbs(P_3) recorded the minimum mean score (6.23).

All the jackfruit bulbs except the bulbs packed in laminated pouch and shrink wrapped bulbs were discarded by 6th day of storage. Higher mean score for flavor was recorded in bulbs packed in laminated pouch (6.43) (P_1) on 6th day of storage.

4.3.2.5 Taste

Effects of different packaging materials on taste of the jackfruit bulbs are illustrated in Table 26.

Taste of jackfruit bulbs did not show any significant variation among treatments at the time of storage and on the 2nd day of storage.

Tables 25. Effect of packaging on flavor of jackfruit bulbs

Treatments	Flavor (Mean sensory scores)			
	At the time of storage	Days after storage		
		2	4	6
P_1 (Laminated pouch)	8.47	7.97	7.30	6.43
P_2 (Shrink wrapping)	8.57	7.53	7.30	6.03
P_3 (Cling film wrapping)	8.63	7.26	6.23	-
P_4 (Aluminum tray wrapped with cling film)	8.57	7.36	6.80	-
KW value	1.709	22.098	37.36	6.324
$\chi 2$ (0.05)	7.814			

Tables 26. Effect of packaging on taste of jackfruit bulbs

Treatments	Taste (Mean sensory scores)			
	At the time of storage	Days after storage		
		2	4	6
P_1 (Laminated pouch)	8.63	8.56	7.60	6.70
P_2 (Shrink wrapping)	8.70	8.63	7.06	6.06
P_3 (Cling film wrapping)	8.53	8.46	6.16	-
P_4 (Aluminum tray wrapped with cling film)	8.43	8.63	6.6	-
KW value	4.971	2.265	56.57	14.785
$\chi2$ (0.05)	7.814			

On 4^{th} day of storage, highest mean score for taste (7.6) was recorded in jackfruit bulbs packed in laminated pouch (P_1). Cling film wrapped bulbs (P_3) recorded the minimum mean score for taste on 4^{th} day.

All jackfruit bulbs except those packed in laminated pouch (P_1) and shrink wrapped bulbs (P_2) were discarded by 6^{th} day of storage. Bulbs packed in laminated pouch (P_1) recorded the highest mean score for taste on 6^{th} day of storage.

4.3.3 Chemical parameters

Chemical quality parameters viz., acidity, total soluble solids, sugars, vitamin C, carotenoids and total phenol content of the bulbs subjected to different packaging treatments were recorded initially and at regular intervals till the end of shelf life.

4.3.3.1 Acidity (%)

Effects of different packaging treatments on acidity of jackfruit bulb are depicted in Table 27.

Acidity of the jackfruit bulb was 0.4% at the time of storage period. But acidity was significantly influenced by treatments, day of storage and interaction between treatment and storage days.

Highest acidity (0.38) was noticed on jackfruit bulbs that were cling wrapped (P_3) on 2^{nd} day of storage followed by bulbs packed in aluminium tray wrapped with cling film (0.34) (P_4). Bulbs packed in laminated pouch (P_1) recorded least acidity percentage (0.30) followed by shrink wrapped bulbs (0.33) (P_2) on 2^{nd} day of storage.

Bulbs packed in laminated pouch (P_1) recorded the least acidity (0.23) followed by the bulbs packed in aluminium tray wrapped with cling film (0.30) (P_4) and shrink wrapped bulbs (0.30) (P_2) whereas highest acidy was recorded on bulbs wrapped in cling film (0.35) (P_3) on 4^{th} day of storage.

Lowest mean acidity percentage was noticed in bulbs packed in laminated pouch (0.31) (P_1) followed by shrink wrapped bulbs (0.34) (P_2) after 4 days of

Tables 27. Effect of packaging on acidity of jackfruit bulbs

Treatments	Acidity (%)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	0.40	0.30	0.23	0.31	0.22
P_2 (Shrink wrapping)		0.33	0.30	0.34	0.25
P_3 (Cling film wrapping)		0.38	0.35	0.38	-
P_4 (Aluminum tray wrapped with cling film)		0.34	0.30	0.35	-
Day mean	0.40	0.33	0.30		
	SE±(m)		CD (0.05)		NS
Treatment(T)	- 0.005		0.014		
Days (D)	- 0.004		0.012		
Treatment (T)× Days (D)	- 0.009		0.025		

storage period. Highest acidity (0.38) was observed on cling film wrapped jackfruit bulbs (P_3).

Acidity of the jackfruit bulbs decreased from 0.40% at the time of storage to 0.33% and 0.30% on 2^{nd} and 4^{th} days of storage period.

All jackfruit bulbs except those packed in laminated pouch and shrink wrapped were discarded by 6^{th} day of storage. Acidity percentage did not show any significant variation among the treatments on 6^{th} day of storage.

4.3.3.2 Total Soluble Solids (TSS) (^{0}B)

Effects of different packaging systems on total soluble solids of jackfruit bulbs are depicted in Table 28.

TSS of jackfruit bulbs were significantly influenced by packaging treatments, storage days and interaction between packaging and storage days. TSS of all jackfruit bulbs were 18^0B at the time of storage.

Jackfruit bulbs packed in laminated pouch (P_1) recorded the highest TSS content (18.75^0B) which was on par with the shrink wrapped bulbs (18.68^0B) (P_2) on 2^{nd} day of storage. Lowest TSS (18.25^0B) was noticed in cling film wrapped bulbs (P_3) which was on par with the bulbs packed in aluminium tray wrapped with cling film (18.75^0B) (P_4) .

On 4^{th} day of storage highest TSS content (19.50^0B) was noticed in bulbs packed in laminated pouch (P_1) which was on par with shrink wrapped bulbs (19.25^0B) (P_2). Bulbs packed in aluminium tray wrapped with cling film (P_4) recorded the lowest TSS (18.75) which was on par with the bulbs wrapped in cling film (18.80^0B) (P_3).

Mean TSS content was highest (18.92^0B) for the bulbs packed in laminated pouch (P_1) which was on par with the shrink wrapped bulbs (18.55^0B) (P_2) after 4 days of storage period. Bulbs wrapped in cling film (18.35^0B) (P_3) recorded the least mean TSS which was on par with the bulbs packed in aluminium tray wrapped with cling film (18.37^0B) (P_4).

Tables 28. Effect of packaging on Total Soluble Solids of jackfruit bulbs

Treatments	Total Soluble Solids(^{0}B)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	18.00	18.75	19.50	18.92	20.5
P_2 (Shrink wrapping)		18.68	19.25	18.55	19.63
P_3 (Cling film wrapping)		18.25	18.80	18.35	-
P_4 (Aluminum tray wrapped with cling film)		18.35	18.75	18.37	-
Day mean	18.00	18.51	19.08		

	SE±(m)	CD (0.05)	P value
Treatment(T)	- 0.058	0.168	-0.010
Days (D)	- 0.051	0.146	
Treatment (T)× Days (D)	- 0.101	0.292	

TSS content of the jackfruit bulbs increased with the increase in storage days and it ranged from 18^0B at the time of storage to 18.51 ^{0}B and 19.08 ^{0}B on 2nd and 4th days of storage period respectively.

All jackfruit bulbs except those packed in laminated pouch (P_1) and shrink wrapped bulbs (P_2) were discarded by 6th day of storage. Higher TSS (20.5^0B) was recorded by bulbs packed in laminated pouch (P_1) compared to shrink wrapped bulbs (19.63^0B) on 6th day of storage.

4.3.3.3 Sugar

Total, reducing and non-reducing sugar of the packaged jackfruit bulbs were recorded initially and at regular intervals till the end of shelf life.

Total sugar (%)

Effects of different packaging systems on total sugar content of the jackfruit bulbs are depicted in Table 29.

Total sugar content of jackfruit bulbs was 34.48% at the time of storage.

Highest total sugar (37.75%) was noticed in bulbs packed in laminated pouch (P_1) which was on par with shrink wrapped bulbs (37.04%) (P_2) on 2nd day of storage period. Bulbs wrapped in cling film (35.46%) (P_3) recorded the lowest total sugar content which was on par with the bulbs packed in aluminium tray wrapped with cling film (35.97%) (P_4).

Bulbs packed in laminated pouch (P_1) recorded the highest total sugar (39.62%) on 4th day of storage and was on par with the shrink wrapped bulbs (39.23%) (P_2). Lowest total sugar content of 36.77% was recorded by the bulbs wrapped in cling film (P_3).

Highest mean total sugar content (37.28%) was noticed in bulbs packed in laminated pouch (P_1) which was on par with the shrink wrapped bulbs (36.92%) (P_2) after 4 days of storage. Bulbs wrapped in cling film (P_3) recorded the lowest mean total sugar (35.57%).

Total sugar content increased from 34.48% at the time of storage to 36.55% and 38.31% on 2nd and 4th day of storage period respectively.

Tables 29. Effect of packaging on total sugar of jackfruit bulbs

Treatments	Total sugar (%)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	34.48	37.75	39.62	37.28	41.51
P_2 (Shrink wrapping)		37.04	39.23	36.92	40.16
P_3 (Cling film wrapping)		35.46	36.77	35.57	
P_4 (Aluminum tray wrapped with cling film)		35.97	37.61	36.02	
Day mean	34.48	36.55	38.31		

	SE±(m)	CD (0.05)	P value
Treatment(T)	- 0.154	0.445	-0.04
Days (D)	- 0.134	0.385	
Treatment (T)× Days (D)	- 0.268	0.771	

Bulbs packed in laminated pouch (P_1) recorded a higher total sugar content (41.51%) compare to shrink wrapped bulbs (40.16%) on 6th day of storage. All other jackfruit bulbs were discarded by 6th day of storage.

Reducing sugar (%)

Effects of different packaging systems on reducing sugar content of the jackfruit bulbs are illustrated in Table 30.

Reducing sugar content of the jackfruit bulbs was 14.71% at the time of storage period.

Jackfruit bulbs packed in laminated pouch (P_1) recorded the highest reducing sugar (16.67%) content on 2nd day of storage followed by the shrink wrapped bulbs (15.63%) (P_2). Lowest reducing content was recorded by cling film wrapped bulbs (15.15%) (P_3) which was on par with the bulbs packed in aluminium tray wrapped with cling film (15.39%) (P_4).

On 4th day of storage highest reducing sugar content was recorded by bulbs packed in laminated pouch (18.87%) (P_1) which was on par with the shrink wrapped bulbs (18.53%) (P_2). Bulbs wrapped in cling film (P_3) recorded the lowest reducing sugar (16.67%) on 4th day.

Maximum mean reducing sugar (16.75%) was noticed in bulbs packed in laminated pouch (P_1) followed by the shrink wrapped bulbs (16.29%) and the cling film wrapped bulbs recorded the minimum reducing sugar (15.51%) after 4 days of storage.

Reducing sugar content of the jackfruit bulbs increased from 14.71% at the time of storage to 15.71% and 17.83% on 2nd and 4th days of storage respectively.

All jackfruit bulbs except those packed in laminated pouch (P_1) and the shrink wrapped bulbs (P_2) were discarded by the 6th day of storage. High reducing sugar content was recorded in bulbs packed in laminated pouch (21.06%) (P_1) followed by shrink wrapped bulbs (19.24%) (P_2).

Tables 30. Effect of packaging on reducing sugar of jackfruit bulbs

Treatments	Reducing sugar (%)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	14.71	16.67	18.87	16.75	21.06
P_2 (Shrink wrapping)		15.63	18.53	16.29	19.24
P_3 (Cling film wrapping)		15.15	16.67	15.51	-
P_4 (Aluminum tray wrapped with cling film)		15.39	17.27	15.79	-
Day mean	14.71	15.71	17.83		

	SE±(m)	CD (0.05)	P value
Treatment(T)	- 0.085	0.245	-0.003
Days (D)	- 0.074	0.212	
Treatment (T)× Days (D)	- 0.147	0.424	

Non reducing sugar (%)

Effects of different packaging materials on non reducing content of the jackfruit bulbs are depicted in Table 31.

Non reducing content of jackfruit bulbs was 19.77% initially at the time of storage.

Non reducing sugar content of the jackfruit bulbs were significantly influenced by the treatments and the days of storage.

Highest mean non reducing sugar (20.63%) was recorded for the shrink wrapped bulbs (P_2) which was on par with the bulbs packed in laminated pouch (20.53%) (P_1) and those which packed in aluminium tray wrapped with cling filmn (20.23%) (P_4). Bulbs wrapped in cling film (P_3) recorded the least (20.06%) non reducing content.

All the bulbs except those packed in laminated pouch (P_1) and shrink wrapped bulbs (P_2) were discarded by 6^{th} day of storage. Non reducing sugar shows no significant variation among treatments on 6^{th} day.

4.3.3.4 Vitamin C content ($mg100g^{-1}$)

Effects of different packaging systems on vitamin C content of the jackfruit bulbs are depicted in Table 32.

Vitamin C content varied significantly with respect to treatments, days of storage as well as their interactions.

Jackfruit bulbs recorded a vitamin C content of 29.17 $mg100g^{-1}$ at the time of storage.

Highest vitamin C content of 27.09 $mg100g^{-1}$ was observed in bulbs packed in laminated pouch (P_1) and the bulbs packed in aluminium tray wrapped with cling film (P_4) on 2^{nd} day of storage.

Bulbs wrapped in cling film (P_3) recorded the lowest vitamin C content of 22.92 $mg100g^{-1}$ and 18.75 $mg100g^{-1}$ on 2^{nd} and 4^{th} days of storage respectively.

Tables 31 . Effect of packaging on non reducing sugar of jackfruit bulbs

Treatments	Non reducing sugar (%)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	19.77	21.08	20.75	20.53	20.46
P_2 (Shrink wrapping)		21.41	20.71	20.63	20.92
P_3 (Cling film wrapping)		20.31	20.10	20.06	-
P_4 (Aluminum tray wrapped with cling film)		20.58	20.35	20.23	-
Day mean	19.77	20.84	20.47		
	SE±(m)		CD (0.05)		NS
Treatment(T)	- 0.153		0.440		
Days (D)	- 0.132		0.381		
Treatment (T)× Days (D)	- 0.265		NS		

Tables 32. Effect of packaging on vitamin C of jackfruit bulbs

Treatments	Vitamin C ($mg100g^{-1}$)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	29.17	27.09	26.04	27.43	23.96
P_2 (Shrink wrapping)		25.00	25.00	26.39	22.92
P_3 (Cling film wrapping)		22.92	18.75	23.61	-
P_4 (Aluminum tray wrapped with cling film)		27.09	25.00	27.09	-
Day mean	29.17	25.52	23.70		

	SE±(m)	CD (0.05)	NS
Treatment(T)	- 0.437	1.259	
Days (D)	- 0.378	1.090	
Treatment (T)× Days (D)	- 0.757	2.180	

Bulbs packed in laminated pouch (P_1) recorded the highest vitamin C content of 26.04 mg100g^{-1} on 4th day of storage which was on par with the shrink wrapped bulbs (25 mg100g^{-1}) and the bulbs packed in aluminium tray wrapped with cling film (25 mg100g^{-1}).

Highest mean vitamin C content (27.43) was noticed in bulbs packed in laminated pouch (P_1) which was on par with the bulbs packed in aluminium tray wrapped with cling film (27.09) (P_4) and the shrink wrapped bulbs (26.39) (P_2) after 4 days of storage. Bulbs wrapped in cling film (P_3) recorded the least vitamin C content of 23.61 mg100g^{-1}.

Vitamin C content of jackfruit bulbs decreased with increase in storage period and it ranged from 29.17 mg100^{-1} at the time of storage to 25.52 mg100g^{-1} and 23.70 mg100g^{-1} on 2nd and 4th days of storage respectively.

All jackfruit bulbs except those packed in laminated pouch (P_1) and the shrink wrapped bulbs (P_2) were discarded by 6th day of storage. Vitamin C content showed no significant variation among treatments on 6th day of storage.

4.3.3.5 Total carotenoid content (mg100g^{-1})

Effects of different packaging systems on total carotenoid content of the jackfruit bulbs are depicted in Table 33.

Total carotenoid content of jackfruit bulbs varied significantly with respect to packaging, storage days as well as interaction between packaging and storage period. Jackfruit bulbs recorded 0.85 mg100g^{-1} of total carotenoid content at the time of storage.

Highest total carotenoid content (0.84) was reported in jackfruit bulbs packed in laminated pouch (P_1) and was on par with the shrink wrapped bulbs (0.83) (P_2) on 2nd day of storage. Bulbs wrapped in cling film (P_3) recorded the least total carotenoid content (0.79) on 2nd day.

Bulbs packed in laminated pouch (P_1) recorded the highest total carotenoid content (0.81) on 4th day of storage which was on par with the bulbs packed in

Tables 33. Effect of packaging on total carotenoids of jackfruit bulbs

Treatments	Total carotenoids ($mg100g^{-1}$)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	0.85	0.84	0.81	0.83	0.78
P_2 (Shrink wrapping)		0.83	0.79	0.82	0.73
P_3 (Cling film wrapping)		0.79	0.72	0.79	-
P_4 (Aluminum tray wrapped with cling film)		0.82	0.80	0.82	-
Day mean	0.85	0.82	0.78		

	SE±(m)	CD (0.05)	P value -
Treatment(T)	- 0.002	0.006	0.004
Days (D)	- 0.002	0.005	
Treatment (T)× Days (D)	- 0.004	0.010	

aluminium tray wrapped with cling film (0.80) (P_4). Lowest total carotenoid content (0.72) was recorded on bulbs wrapped in cling film (P_3) on 4th day.

Highest mean total carotenoid content (0.83) was noticed on bulbs wrapped in laminated pouch (P_1) followed by the shrink wrapped bulbs (0.82) (P_2) and the bulbs packed in aluminium tray wrapped with cling film (0.82) (P_4) after 4 days of storage. Bulbs wrapped in cling film (P_3) recorded the least mean total carotenoid content (0.79).

Total carotenoid content of the jackfruit bulb ranged from 0.85 mg100g^{-1} at the time of storage to 0.82 mg100g^{-1} and 0.78 mg100g^{-1} respectively on 2nd and 4th days of storage respectively.

All jackfruit bulbs except those packed in laminated pouch (P_1) and shrink wrapped bulbs (P_2) were discarded by 6th day of storage. Higher total carotenoid content (0.78) was observed in bulbs packed in laminated pouch (P_1) compared to shrink wrapped bulbs (0.73) (P_2) on 6th day.

4.3.3.6 Total phenolic content (mg100g^{-1})

Effects of different packaging systems on total phenolic content of the jackfruit bulbs are depicted in Table 34.

Total phenolic content of jackfruit bulbs varied significantly with respect to packaging, storage days as well as interaction between packaging and storage period. Jackfruit bulbs recorded 42.59 mg100g^{-1} of total phenolic content at the time of storage.

Least total phenolic content (39.81) was recorded by both shrink wrapped bulbs (P_2) and the bulbs packed in laminated pouch (P_1). Bulbs packed in aluminium tray wrapped with cling film (P_4) and cling film wrapped (P_3) jackfruit bulbs recorded the highest total phenolic content (42.59) on 2nd day of storage.

Least total phenolic content (36.11) was reported in bulbs packed in laminated pouch (P_1). Highest total phenolic content (41.67) was recorded by the bulbs wrapped in cling film (P_3).

Tables 34. Effect of packaging on total phenols of jackfruit bulbs

Treatments	Total phenols ($mg100g^{-1}$)				
	At the time of storage	Days after storage			
		2	4	Treatment mean	6
P_1 (Laminated pouch)	42.59	39.81	36.11	39.50	34.72
P_2 (Shrink wrapping)		42.59	39.81	41.66	37.49
P_3 (Cling film wrapping)		42.59	41.67	42.28	-
P_4 (Aluminum tray wrapped with cling film)		39.81	38.88	40.43	-
Day mean	42.59	41.20	39.12		

	SE±(m)	CD (0.05)	NS
Treatment(T)	- 0.321	0.925	
Days (D)	- 0.278	0.801	
Treatment (T)× Days (D)	- 0.557	1.603	

Lowest mean total phenolic content (39.50) was reported in bulbs packed in laminated pouch (P_1). Bulbs wrapped in cling film (P_3) recorded the highest mean total phenolic content (42.28) after 4 days of storage which was on par with the shrink wrapped bulbs (41.66) (P_2).

Total phenolic content of the jackfruit bulbs decreased with increase in storage period and it ranged from 42.59 mg100g^{-1} at the time of storage to 41.20 mg100g^{-1} and 39.12 mg100g^{-1} on 2nd and 4th days of storage respectively.

All the jackfruit bulbs except those packed in laminated pouch (P_1) and shrink wrapped bulbs (P_2) were discarded by 6 days of storage. Total phenolic content of bulbs under those two treatments showed no significance on 6th day of storage.

4.4. Assessment of acceptability

The protocol for minimally processed jackfruit bulbs was standardized combining the steps like sanitization, pre-storage treatment and packaging.

Harvested fruits were surface sanitized using 100 ppm sodium hypochlorite solution which was the best treatment selected from first part of the experiment (4.1). Good quality bulbs were extracted, seeds removed and pre-treated with 1% calcium chloride, the best treatment selected from second part of the experiment (4.2). The pretreated bulbs were packed in laminated pouch, which was the best packaging system selected from third part of the experiment (4.3).

The minimally processed bulbs were kept in refrigerated storage and subjected to organoleptic scoring to analyze the consumer acceptability of the standardized protocol.

4.4.1 Acceptability of the standardized protocol (organoleptic scoring)

Consumer acceptability of the minimally processed jackfruit bulbs prepared as per the standardized protocol was assessed by organoleptic scoring. Physical parameters like colour, texture, appearance, flavor, taste and overall acceptability of the jackfruit bulbs were recorded and illustrated in Table 35.

All the sensory scores were gradually reduced during storage.

Table 35. Acceptability of the standardized protocol

Physical parameters	Mean sensory scores of minimally processed jackfruit bulbs			
	Days after storage			
	0	2	4	6
Appearance	8.63	8.20	7.70	7.10
Colour	8.70	8.46	7.83	6.96
Texture	8.60	8.20	7.60	7.26
Taste	8.63	8.56	7.60	6.90
Flavor	8.66	8.13	7.30	6.60
Overall acceptability	8.60	8.50	7.80	7.43

Appearance score of the jackfruit bulb was 8.60 at the time of storage. It was reduced to 8.20 on 2^{nd} day of storage, 7.70 on 4^{th} and 7.10 on 6^{th} day of storage.

Colour score was 8.70 at the time of storage, which was reduced to 8.46, 7.83 and 6.96 on 2^{nd}, 4^{th} and 6^{th} day of storage respectively.

Minimally processed jackfruit bulbs had a textural score of 8.60 at the time of storage and it was reduced to 8.20 on 2^{nd} day of storage, 7.60 on 4^{th} and 7.26 on 6^{th} day of storage.

Mean sensory score of 8.63 was recorded by jackfruit bulbs for taste at the time of storage and it was reduced to 8.56, 7.60 and 6.90 on 2^{nd}, 4^{th} and 6^{th} days of storage respectively.

Flavour of jackfruit bulbs recorded mean sensory score of 8.66 at the time of storage, which was reduced to 8.13, 7.30 and 6.60 on 2^{nd}, 4^{th} and 6^{th} days of storage respectively.

Overall acceptability score of minimally processed jackfruit bulbs was 8.60 at the time of storage and it reduced to 8.50 on 2^{nd} day of storage, 7.80 on 4^{th} day and 7.43 on 6^{th} day of storage.

4.4.2 Cost of production

Cost of production for 1 kg minimally processed jackfruit bulb was carried out as per the current market rate and is depicted in Table 36.

One kilogram of bulbs can be extracted from 2.78 kg jackfruit, after subjecting the fruits to sanitization with 223 ml sodium hypochlorite. Seeds of bulbs are to be removed and given a pretreatment using 1% calcium chloride (30 gram calcium chloride in 3 litre water). The pretreated bulbs can be air dried, four units of 250 g each can be packaged in laminated pouch and stored under refrigerated condition. Thus total cost for preparation of 1Kg. minimally processed jack fruit bulbs was worked out to be Rs. 206.89 /-

Table 36. Cost of production of the standardized protocol

COST OF PRODUCTION (1kg of minimally processed jackfruit bulbs)			
Raw materials	**Rate**	**Quantity required**	**Price**
Fruits			
Jackfruit	25 Rs/ kg	2.78 kg	69.5 Rs
Chemicals required			
Sodium hypochlorite solution	191 Rs/ L	223 ml	42.59 Rs
Calcium chloride	1180 Rs/ 500 gm	30 gm	70.8 Rs
Packaging material			
Laminated pouch	150 rs/ 150 no.s	4 no.s	4 Rs
Others			
Labour cost			10 Rs
Miscellaneous including sealing and storage			10 Rs
Total cost for production of 1 kg minimally processed jackfruit bulbs			
1 kg jackfruit bulbs			206.89 Rs

Discussion

5. DISCUSSION

Consumption of fresh fruits and vegetables has shown an increased demand among the consumers in the past decades mainly due to their nutritional properties and increased awareness of health consciousness. The consumer demand for high quality foods requiring only minimum amount of effort and time for preparation has led to the introduction of ready-to-use, convenience foods preserved by mild methods (so-called minimal processing methods) only. However minimally processed fruits and vegetables are highly perishable and subjected to fast degradation of quality. The processing operations like cutting, slicing, shredding etc, storage conditions like temperature, humidity, use of modified atmosphere etc. can influence the microclimate there by influencing the safety and quality of the fresh cut produce. Various physiological processes like oxidative browning, elevated respiration, water loss etc are the important factors contributing to the reduced shelf life of minimally processed products. They are highly prone to microbial spoilage because of the handling operations during its preparation time and sanitization treatments can ensure microbial safety of the products. Various sanitization and pre-storage treatments are given to fresh cut products for retarding quality degradation thereby extending their shelf life. Different pre-storage treatments include dipping the fresh cut produce in anti browning agents, firming agents and preservative treatments. Packaging of the minimally processed products is another important factor affecting its shelf life by minimizing mechanical damage during transportation and storage. It also provides a good sensory appeal to the consumers. Development of a standardized protocol containing various processes like surface sanitization, pre-storage treatments and an efficient packaging system ensures the quality of minimally processed products with extended shelf life. Establishing an efficient and economic protocol for development of fresh cut produce will help the consumers to buy fresh fruits in ready to use form and also increase the dietary consumption of fruits in the present day busy life schedule. Hence a study on "Protocol development for minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs" was carried out in Department of Post Harvest Technology, College of

Agriculture, Vellayani with the objective to standardize an efficient and economic protocol for development of minimally processed jackfruit bulbs with extended shelf life. The results obtained in the experiment are discussed in this chapter.

The whole experiment was carried out as four different continuous experiments as,

1. Evaluation of sanitizing agents
2. Evaluation of pre-storage treatments
3. Development of packaging system
4. Assessment of acceptability

5.1 Evaluation of sanitizing agents

Good quality, fresh and optimum mature jackfruit cultivar Muttom varikka were harvested, ripened and subjected to four different sanitization treatments viz., 40^0C water, 100 ppm sodium hypochlorite, 120 ppm sodium hypochlorite and 2 ppm ozonized water for 15 minutes along with untreated jackfruit kept as absolute control in order to study the efficiency of different sanitizing solutions in controlling the total microbial load on the fruit surface.

Microbial load is a major concern of minimally processed food products since they are consumed raw without any intervening processing step. Under minimally processed conditions, fruits and vegetables are vulnerable to microbial attack. Fresh cut produce can be contaminated at any stage from harvest, processing, handling and storage. Therefore proper sanitization is utmost desired in order to remove dirt and microbes present on the surface of the fruits. All surface sanitization treatments resulted in reduced total microbial load on the jackfruit surface compared to the untreated fruits (Figure 1 & 2). 120 ppm and 100pm sodium hypochlorite were equally effective in reducing both the bacterial and fungal load on jackfruit surface. This is in accordance with the findings of Amith (2012), who had proved sodium hypochlorite as an effective sanitizer in reducing the bacterial population in fruit surface of mango, papaya and pineapple. Francis and O'Beirne (2002) had observed a similar reduction in microbial population in chlorine dipped lettuce than un-dipped lettuce during the first 12 days of storage. Chandran (2013) reported a reduction in total microbial load when minimally processed vegetables like beans, beetroot and cabbage were surface sanitized using 30 ppm sodium hypochlorite.

Fig1. Effect of sanitizers on bacterial population on jackfruit surface

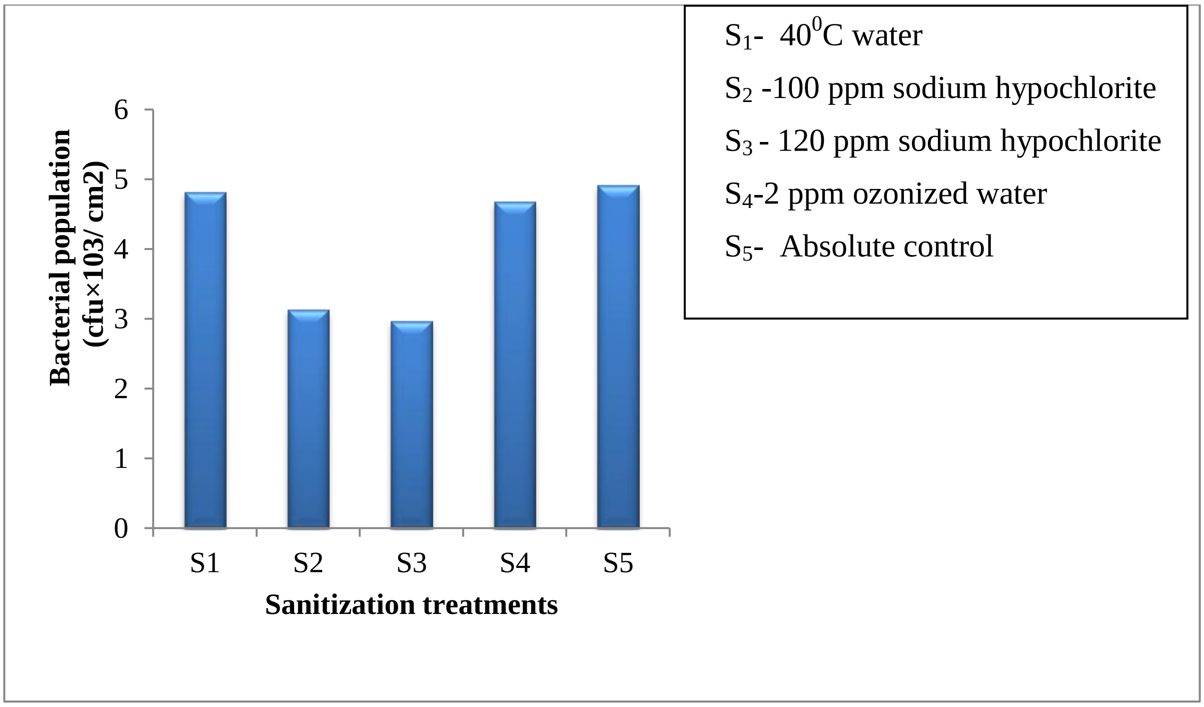
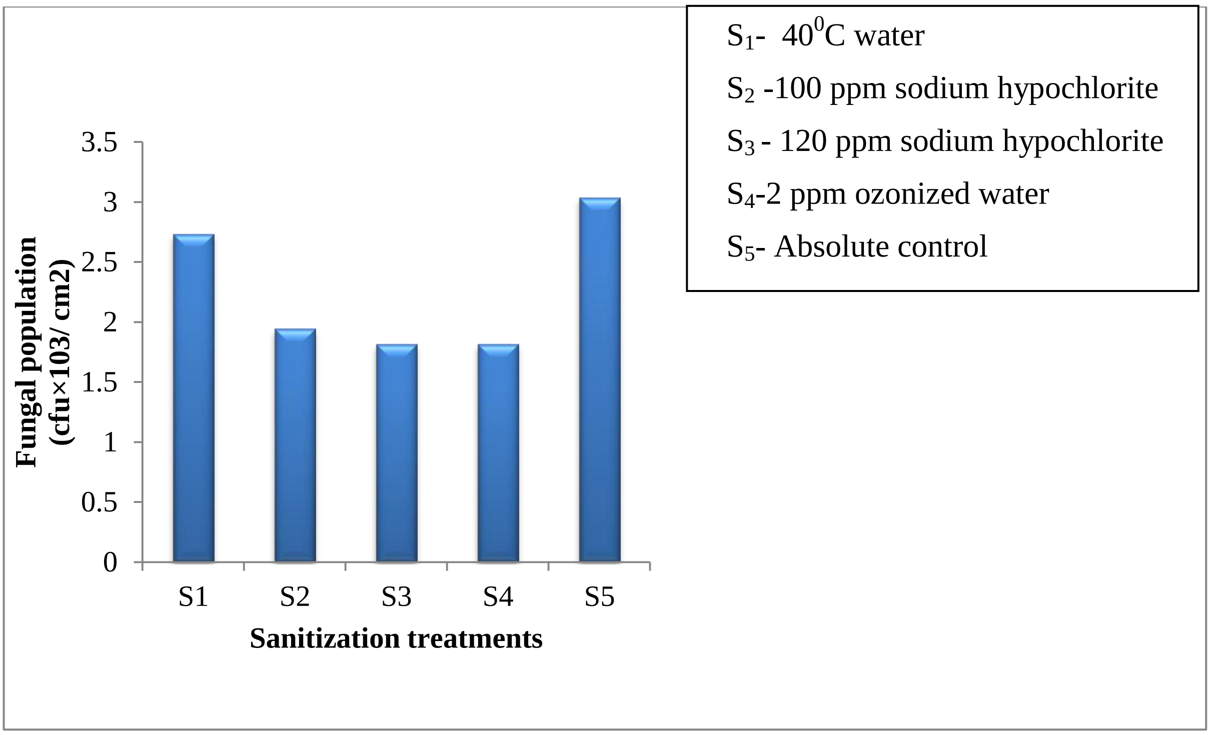


Fig2. Effect of sanitizers on fungal population on jackfruit surface



S1- 40 0C water
S2 -100 ppm sodium hypochlorite
S3 - 120 ppm sodium hypochlorite
S4-2 ppm ozonized water
S5- Absolute control
3.5
3
2.5
2
1.5
1
0.5
0
Fungal population (cfu×103/ cm2)
S1
S2
S3
S4
S5
Sanitization treatments

Similar reduction in microbial load was reported in cabbage also, when it was surface sanitized with 200 ppm sodium hypochlorite solution (Fantuzzi *et al.,* 2004)

Chlorine-based sanitizers, especially sodium hypochlorite, are the most commonly used chemical sanitizers in the food industry which is used to sanitize produce and surfaces (Beuchat, 1996). It is used in the concentration of 50 to 200 ppm range with a contact time of 1 to 2 minutes. Reduction in microbial load is due to the broad antimicrobial spectrum and germicidal activity of sodium hypochlorite which is governed by its ability to diffuse through the microbial cell membrane as reported by Fukuzaki (2006).

Sodium hypochlorite is an ideal disinfectant which has got an excellent cleansing action and its effectiveness depends on the available chlorine concentration and pH of the solution. Hypochlorous acid dissociates into hypochlorite ion and proton, depending on the pH, where HOCL is the active species in germicidal action and $^{-}$OCL determines the cleaning efficiency.

Untreated jackfruit had maximum bacterial (4.923 log cfu/ cm^2) and fungal count (3.039 log cfu/ cm^2), which was on par with the fruits treated with 40^0C. This is in accordance with the findings of Li *et al*. (2002) who had observed that that mild heat treatment enhances the growth of several microbes like *L. monocytogenes* of cut lettuce leaves during subsequent storage.

The application of ozone has gained importance in the food industry due to its effectiveness to extend the shelf life of fresh or fresh-cut produce by inhibiting the growth of microorganisms. Jackfruit sanitized using 2 ppm ozonized water recorded a lesser microbial load after those treated with sodium hypochorite solution. This is in accordance with the findings of several workers where, ozonation had reduced the microbial load on iceberg lettuce (Galgano *et al*. 2015), amaranth (Ambareesha, 2016) and rambutan (Shetty *et al.*, 2018). Ozone is a powerful oxidizing agent and can be used as an effective antimicrobial agent in food industry. Gaseous ozone at a concentration of 0.1 to 1 ppm for a period of 360 min effectively reduced microbial population in pistachio nuts (Akbas and Ozdemir, 2006). Rico *et al*. (2006) reported that ozonated water (1mg/L for 1 min) prevented the browning of fresh cut lettuce by inhibiting the browning enzymes.

Efficiency and economics are the two factors that must be considered while selection of the best treatment. In the present study concentrations of 120 and 100 ppm sodium hypochlorite were equally effective in controlling the total microbial load on jackfruit surface. Therefore lower concentration of sodium hypochlorite i.e. 100 ppm sodium hypochlorite was selected as the best treatment after considering the efficiency, economics and safety aspects and utilized for the second part of the experiment.

5.2 Evaluation of pre-storage treatments

Minimally processed fruits and vegetables are given a pre-storage treatment mainly for controlling decay, reducing browning and for retaining firmness (Brecht, 1995). Dipping into aqueous solution of chemical preservatives, anti-browning agents, firming agents, edible coatings and bio preservatives are widely practiced to improve quality of fresh cut produce.

Pre-storage treatments are done in maintaining the quality of fresh cuts and also for its shelf life extension. Any treatment done should also not compromise its sensorial qualities like colour, texture, taste etc. In the present study, harvested jack fruits were ripened, surface sanitized using 100 ppm sodium hypochlorite solution, the best sanitizing solution selected from part1 of the experiment and good quality bulbs were extracted. Seeds were removed and the bulbs were dipped in three different pre-storage treatment solutions for 10 minutes viz., 0.1% Ascorbic acid, 0.1% Citric acid, 1% Calcium Chloride and untreated bulbs were kept as absolute control to analyse the efficiency of different pre-treatment solutions. The treated bulbs and the untreated ones were stored under refrigerated conditions after keeping in aluminium foil trays wrapped with cling film. Effects of different pre-storage treatments on physical, physiological and chemical quality parameters of the bulbs were analysed.

5.2.1 Physiological parameters

All the pre-storage treatments resulted in better physiological quality parameters in jackfruit bulbs than the untreated bulbs. Jackfruit bulbs treated with 1% calcium chloride recorded the highest shelf life (5.00 days) followed by the bulbs treated with 0.1% ascorbic acid and 0.1% citric acid (4.00 days).

Jackfruit bulbs treated with 1% calcium chloride recorded the lowest mean physiological loss in weight (2.03) (Figure 3) and percent leakage (79.24) after 3 days of storage resulting in highest shelf life.

During the initial 1st and 3rd days also, the physiological parameters were superior for calcium chloride treated bulbs. Jackfruit bulbs pretreated with 1% calcium chloride recorded the least PLW as 1.34%, 2.72% on 1st, and 3rd day of storage respectively. 1% calcium chloride treated jackfruit bulbs recorded the least percent leakage during the 1st (77.37) and 3rd day (87.93) of storage which was significantly different from the other treatments.

Calcium chloride was proved to be most effective in reducing weight loss of pear fruits compared to non treated fruit during a 75 days storage period by Mahajan and Dhatt (2004). Calcium dips have been used as firming agents to extend postharvest shelf life in several fruits viz., apples (Mir *et al*., 1993; Sams *et al*., 1993), strawberries (Garcı´a *et al*., 1996), sliced pears and sliced strawberries (Rosen and Kader, 1989) and zucchini slices (Izumi and Watada, 1995).

The lower weight loss found in calcium treated fruits may be due the effectiveness of calcium in terms of membrane functionality and integrity maintenance as reported by Lester and Grusak (1999). Luna-Guzman *et al*. (1999) reported unchanged ethylene production and inhibited respiration throughout the storage by application of calcium dips in fresh cut cantaloupe. Calcium has a role in controlling the membrane stability and senescence of plant cells as reported by Simon (1977) and (Mortazavi *et al*., 2007).

Physiological Loss in Weight increased from 2.27% on 1st day of storage to 4.21% on 3rd day of storage. This weight loss is due to the natural consequence of the catabolic process of the produce which is accelerated by minimal processing operations as reported by Bhatia *et al.* (2013). Loss in weight may be attributed to respiration and other senescence related metabolic process during storage. Similar increase in physiological loss in weight was observed by Krishna *et al.* (2018) in minimally processed papaya cubes.

Percent leakage increased with storage period and it was 72.44% at the time of storage, 81.16% and 90.4% on 1st and 3rd day of storage respectively. The increased leakage during storage period indicates the increase in cell membrane permeability that results in leakage as reported by Nyanjage *et al*. (1999).

0.1% ascorbic acid was the second best treatment next to calcium chloride. Jackfruit bulbs treated with 0.1% ascorbic acid recorded 2.65% PLW and 81.27 % percent leakage. The reduced loss in weight may be attributed to reduced respiration rate. Similar reduction in respiration has been noticed by Liu *et al*. (2007) for 0.25% ascorbic acid treated fresh cut pineapples.

Untreated jackfruit bulbs (T_4) recorded the highest mean loss in weight (5.12) and percent leakage (83.11) and had the lowest shelf life (3.00 days) .

All the bulbs except the one treated with 1% calcium chloride were discarded by 5th day of storage and T_3 recorded mean loss in weight of 4.4% and percent leakage of 89.52% on 5th day of storage.

5.2.2 Physical parameters

Mean sensory scores for colour, texture, appearance, taste and flavor of jackfruit bulbs were similar for the treatments at the time of storage and significant differences were noticed among the treatments from third day onwards. All pretreated jackfruit bulbs recorded high sensory scores compared to the untreated bulbs.

1% calcium chloride treated bulbs recorded the highest mean sensory score for colour (7.96), texture (8.03), appearance (8.2), flavor (8.13) and taste (7.83) on 3rd day of storage. This is in accordance with the results of Prathbita *et al*. (2019) and Chandran (2013) who had reported a higher sensory rating for calcium chloride treated jackfruit bulbs and shredded vegetables respectively. Calcium interacts with pectin present in cell walls and form calcium pectate which results in maintaining the cell wall integrity. They maintain firmness by cross-linking with cell wall and middle lamella pectins as reported by Grant *et al*. (1973). The maintenance of texture by calcium chloride treated bulbs might have been reflected in the scoring for appearance, colour and overall acceptability of the jackfruit bulbs.

All the sensory parameters gradually decreased with the increase in storage period. This result is in accordance with the findings of Prathibha *et al*. (2019) that significant decrease in sensory scores was observed in dip pretreated jackfruit bulbs during its storage period.

5.2.3 Chemical parameters

All the pre-treated bulbs had shown a better chemical quality parameters compared to untreated bulbs.

Jackfruit bulbs pretreated with 1% calcium chloride recorded least acidity (0.36%) after 3 days of storage (Figure 4). Highest TSS content (20.45) was observed in untreated jackfruit bulbs which were on par with the bulbs treated with 1% calcium chloride (20.20) after three days. Least acidity and higher TSS made 1% calcium chloride treated bulbs superior over the other treatments, making it more palatable recording maximum sensory score for taste and flavor. This is in accordance with the findings of Bhat *et al.* (2011), who had reported reduced acidity in calcium treated pear fruits during the storage period. Higher TSS was also reported in untreated fresh cut papaya and pineapple pieces than the other pre-storage treatments (Amith, 2012). Increased TSS has been reported by Rajkumar *et al.* (2005) in papaya fruit when it was treated with calcium chloride at 2% along with gibbellic acid at 100ppm.

0.1% citric acid treated bulbs recorded highest acidity (0.43) and lowest TSS content (19.53). Untreated jackfruit bulbs recorded the highest TSS (20.68) during the 1st day of storage which was on par with the bulbs treated with 1% calcium chloride (20.48). On 3rd day of storage highest TSS was noticed in untreated jackfruit bulbs (21.13).

Acidity decreased from 0.45% at the time of storage to 0.39% and 0.36% on 1st and 3rd day of storage respectively. Titratable acidity is directly related to the concentration of organic acids present in the fruit. Decrease in acidity may be due to utilization of stored acids in respiration process as reported by Chulaki (2015) in jackfruit bulbs. Organic acids are considered to be used quickly by respiration reactions comparison with other compounds (Kim *et al*. 1993). This reduction in acidity is in accordance with the findings of Taj *et al*. (2014) in minimally processed

Fig 3. Effects of pre-treatments on physiological loss in weight (%) of jackfruit bulbs

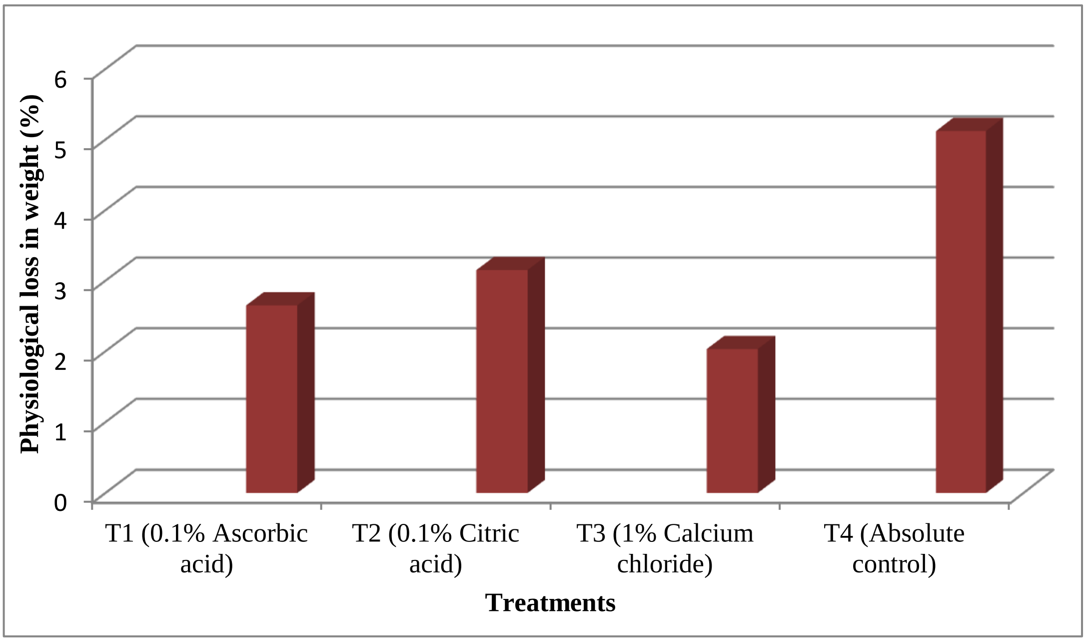
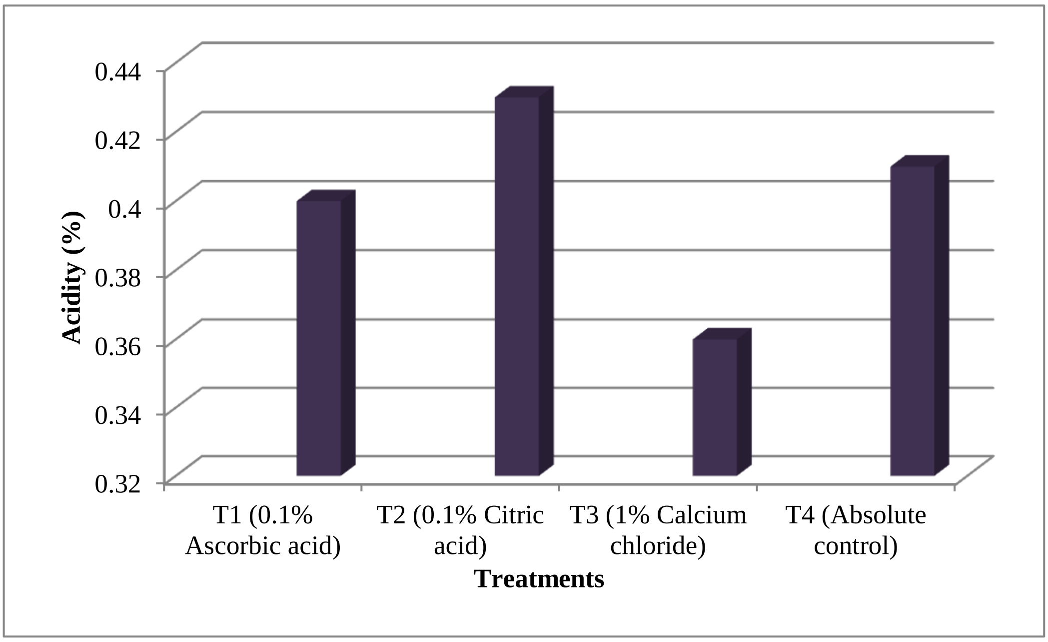


Fig 4. Effects of pre-treatments on acidity (%) of jackfruit bulbs



jackfruit bulbs, Fan *et al*. (2005) in fresh cut apple slices, Bico *et al*. (2009) in fresh cut banana, Alam *et al*., (2013) in fresh cut papaya and Rocha *et al*. (1995) in cut oranges.

TSS increased with days of storage from 19.39^0B at the time of storage to 20.04^0B and 20.28^0B on 1^{st} and 3^{rd} days respectively. Increase in Total Soluble Solids with increase in storage period may be due to conversion of starch in to sugars during storage which has impact on decreased acidity and increased sweetness of the jackfruit bulb. Increased TSS can also be attributed to the conversion of organic acids into sugar through the process of gluconeogenesis as reported by Prathibha *et al.* (2019).

Untreated bulbs recorded the highest mean total sugar (34.29%) and reducing sugar content (14.99%) after three days of storage. This was on par with the bulbs treated with 1% calcium chloride, which recorded 34.14% of total sugar and 14.81% of reducing sugar after three days. The result is in accordance with Velankanni (2012) who had reported a high total and reducing sugar in jackfruit bulbs, pretreated with 10000 ppm calcium chloride. Similar result was also reported in guava fruit applied with calcium chloride at 1, 2 and 3 percent (Mahajan *et al*., 2011).

Non reducing sugar was significantly influenced by days of storage and interaction between days and treatment, whereas no significant variation was noticed among the treatments.

Total sugar content increased from 32.47% at the time of storage to 33.43% and 35.34% on 1^{st} and 3^{rd} days of storage respectively. Reducing sugar increased from 13.26% at the time of storage to 14.59% and 15.47% on 1^{st} and 3^{rd} day respectively. Non reducing sugar decreased from 19.21% at the time of storage to 18.85% on first day of storage and then increased to 19.87% on 3^{rd} day of storage. The increase in sugars may be the result of hydrolysis of starch to sugars during storage. The increase in reducing sugar may be due to the conversion of sucrose into glucose and fructose, thereby resulting in reduction of non reducing sugar at the beginning of storage period. Non reducing sugar increased towards the end of storage period due to metabolism of the cell wall polysaccharide producing sugars as suggested by Rocha *et al.* (1995) and Chulaki *et al.* (2017)

Lowest total sugar (33.26%) and non reducing sugar (13.98%) were reported by 0.1% citric acid treated bulbs after three days of storage which was on par with the bulbs treated with 0.1% ascorbic acid with 33.31% of total sugar and 13.99% of reducing sugar.

All jackfruit bulbs except those treated with 1% calcium chloride were discarded by 5 days of storage and it recorded 36.50%, 16.40% and 20.10% of total sugar, reducing sugar and non reducing sugar respectively.

Mean vitamin C content was highest for 0.1% ascorbic acid treated bulbs (28.95) after 3 days of storage followed by the bulbs treated with 1% calcium chloride (23.69) (Figure 5). This is in line with the findings of Sakimin *et al*. (2017) who reported that ascorbic acid pre-storage treatment positively influence the ascorbic acid content of minimal processed jackfruit in both ambient and cold storage. Addition of ascorbic acid as a dip pre-storage treatment resulted in a 3.5 fold increase in ascorbic acid content in pre-treated samples during storage as reported by Saxena *et al*. (2012).

1% calcium chloride treated bulbs retained ascorbic acid next to 0.1% ascorbic acid treated bulbs. Calcium has been proven to be effective in retaining ascorbic acid as reported by Ali *et al.* (2011). This might be due to the delayed rapid oxidation of ascorbic acid by higher concentration of calcium chloride as reported by Akhtar *et al*. (2010). Calcium chloride treatment has been reported to retain ascorbic acid content in loquat fruit (Akhtar *et al*., 2010), peaches (Ruoyi *et al*., 2005), fresh cut mangoes (González-Aguilar *et al*., 2008) and Zucchini slices (Izumi and Watada, 1995).

Vitamin C of jackfruit bulbs decreased from 27.64 $mg100g^{-1}$ at the time of storage to 22.37 $mg100g^{-1}$ and 19.41 $mg100g^{-1}$ on 1^{st} and 3^{rd} days of storage respectively. The decrease in vitamin C may be due to the oxidation of ascorbic acid during storage period as reported by Sally *et al*. (2011) who had reported oxidation to dehydroascorbic acid, followed by hydrolysis of the latter to 2,3-diketogulonic acid, which then become nutritional inactive product after undergoing polymerization process (Dewanto *et al*., 2002).

Bulbs treated with 1% calcium chloride recorded the highest mean total carotenoid content (0.83) and lowest total phenols (39.77) after 3 days of storage indicating its superiority in maintaining the colour of the jackfruit bulbs thus receiving maximum sensory score for colour during the storage period (Figure 6). Fresh cut fruit should have low phenol content in order to avoid enzymatic browning. The result is in accordance with the findings of Prathibha *et al*. (2019) who had reported that bulbs treated with 1% calcium chloride and 0.25% ascorbic acid retained maximum carotenoid content during the storage period. Similar findings were also reported by Krishna *et al*. (2018) in fresh cut papaya cubes. Lowest phenol content was observed in fresh cut cabbage, beans, carrot and beetroot that were treated with calcium chloride as reported by Chandran (2013).

Jackfruits are rich in carotenoids and antioxidants, rendering golden yellowish colour to the bulbs. Total carotenoid content of the jackfruit bulbs decreased from 0.86 $mg100g^{-1}$ at the time of storage to 0.79 $mg100g^{-1}$ and 0.76 $mg100g^{-1}$ on 1^{st} and 3^{rd} days of storage respectively. The decrease in carotenoid content in minimally processed jackfruit bulbs is attributed mainly due to its oxidative deterioration as reported by Prathibha *et al*. (2019).

Total phenol content decreased from 42.59 $mg100g^{-1}$ at the time of storage to 41.20 $mg100g^{-1}$ and 39.20 $mg100g^{-1}$ on 1^{st} and 3^{rd} day respectively. Decrease in phenolic content may be due to postharvest fruit metabolic processes, such as respiration, ethylene production and enzyme activity as reported by Ghasemnezhad *et al.* (2011).

0.1% ascorbic acid treated bulbs was the second best treatment that retained carotenoid without much degradation next to 1% calcium treated bulbs. This is in line with the findings of Mercadante and Rodriguez-Amaya (1998) who had reported that ascorbic acid pretreatment in fresh cut could minimise the carotenoid loss due to its free radical scavenging activity (RSA), resulting in the prevention of total carotenoid oxidation.

Fig 5. Effects of pre-treatments on vitamin C (mg100g^{-1}) of jackfruit bulbs

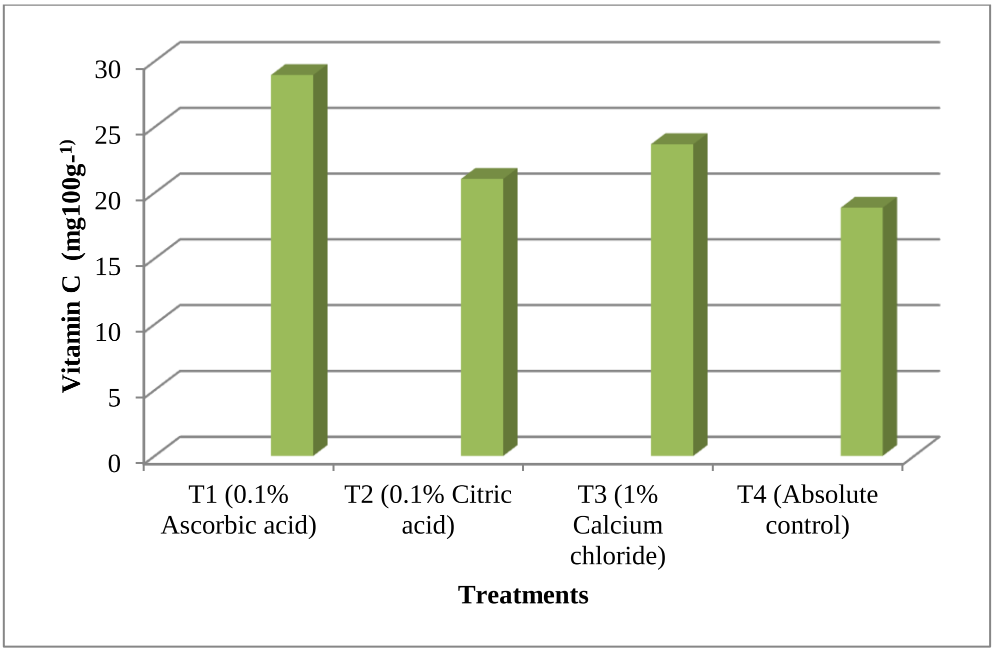
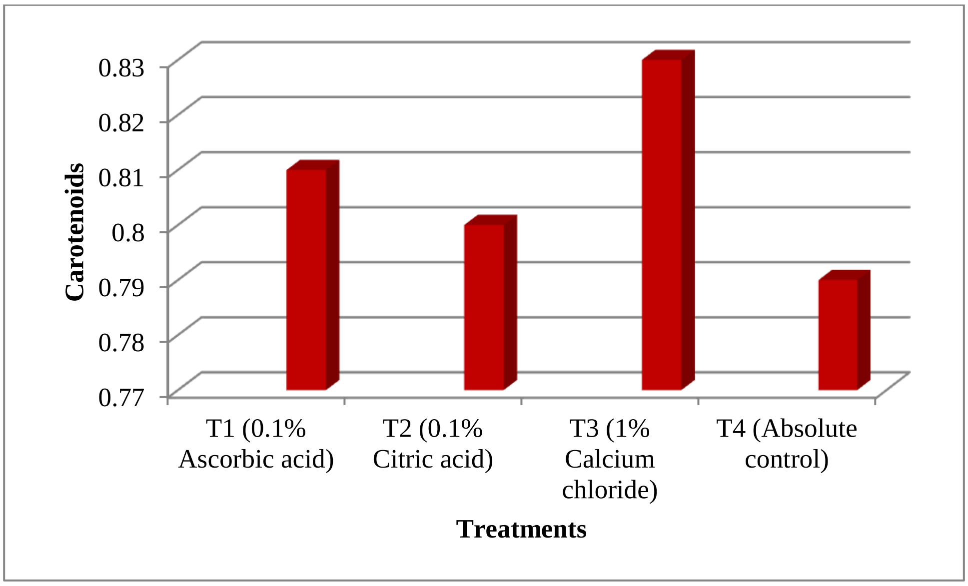


Fig 6. Effects of pre-treatments on total carotenoid content (mg100g^{-1}) of jackfruit bulbs



All jackfruit bulbs except those treated with 1% calcium chloride were discarded by 5th day of storage. It had recorded a vitamin C content of 21.05 mg100g^{-1}, carotenoid content of 0.76 mg100g^{-1} and 35.83 mg100g^{-1} of total phenols on 5th day of storage.

1% calcium chloride treated jackfruit bulbs were found to be superior to the bulbs treated with 0.1% ascorbic, 0.1% citric acid and the untreated control. Any fresh cut fruit should have high TSS and low acidity for better palatability. 1% calcium treated jackfruit bulbs recorded least PLW and percent leakage resulting in better texture and appearance. High carotenoid and vitamin C along with low phenol content made it attractive and nutritionally superior to other treatments. 0.1% ascorbic acid treated bulbs maintained these quality parameters next to 1% calcium chloride treated bulbs with highest vitamin C content. Hence 1% calcium chloride was selected as the best pre-treatment for minimally processed jackfruit bulbs and hence used for further part of the study.

5.3 Development of packaging system

Quality parameters are greatly influenced by the packaging system adopted. Packaging is an important factor which determines the shelf life, quality and acceptability of any product by the consumers. Packaging helps in the reduction of water loss, decay and microbial spoilage while maintaining the quality. Good packaging and low temperature storage condition are important for shelf life extension while considering minimally processed produce.

Good quality harvested jackfruits were ripened and surface sanitized using 100 ppm sodium hypochlorite solution, the best method selected from the first step of experiment. Good quality bulbs were extracted, seeds removed and pre-treated with 1% calcium chloride for 10 minutes, the best pre-treatment selected from the second step of the experiment. The pre-treated bulbs were packaged in four different packaging systems viz., laminated pouch, shrink wrapping, cling film wrapping and aluminium tray wrapped with cling film and stored under refrigerated (5-7^{0}C) conditions with the objective to develop an efficient packaging system for minimally processed jackfruit bulbs. The packaged bulbs were evaluated for physical, physiological and chemical quality parameters initially and at regular intervals till the end of shelf life

5.3.1 Physiological parameters

Jackfruit bulbs packaged in laminated pouch recorded maximum shelf life of 7 days followed by shrink wrapped bulbs with a shelf life of 6 days. Bulbs packed in aluminium tray wrapped with cling film and cling film wrapped bulbs recorded a shelf life of 5 and 4 days respectively.

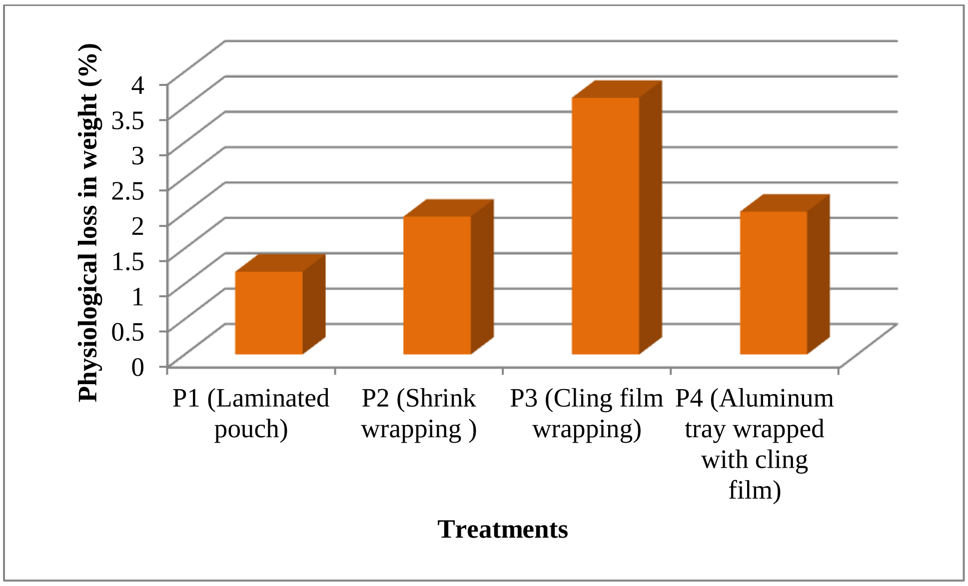
Jackfruit bulbs pretreated with 1% calcium chloride and packaged in laminated pouch recorded the least mean loss in weight (1.17) and percent leakage (65.90) after 4 days of storage.

Shrink wrapped bulbs was the second best with 1.95% PLW and 67.78% percent leakage (Figure 7). Highest mean loss in weight was observed on bulbs wrapped in cling film (3.63). Bulbs wrapped in cling film recorded the highest weight loss (3.63) and percent leakage (72.10) after 4 days of storage. Shrink wrapping has been identified as the better packaging material in reducing moisture losses (Thakur *et al*., 2017), reduction in weight loss (Miller *et al*., 1983, Nanda *et al*., 2001 and Thakur *et al*., 2017) resulting in extended shelf life (Nanda *et al*., 2001).

Physiological loss in weight increased from 1.57% on 2nd day of storage to 2.82% on 4th day of storage. The increase in loss in weight may be due to due to physiological processes like respiration. Similar increase in PLW was noticed by Alam *et al*. (2013) in papaya cubes irrespective of the packaging material. Percent leakage of jackfruit bulbs increased with increase in storage period. It was 61.92% at the time of storage, increased to 68.92%, 74.76% on 2nd and 4th days of storage respectively.

All jackfruit bulbs except those packed in laminated pouch and shrink wrapped bulbs were spoiled and had to be discarded by 6th day of storage. Low physiological loss in weight (4.00) and percent leakage (72.08) were recorded in bulbs packed in laminated pouch indicating better firmness and freshness followed by shrink wrapped bulbs (4.72) on 6th day of storage. A reduction in leakage was

Fig 7. Effect of packaging system on physiological loss in weight of jackfruit bulbs.



reported in sweet pepper by Bar-Yosef *et al*. (2009) packed with shrink film, which serves as a tight barrier to water evaporation.

5.3.2 Physical parameters.

1% calcium chloride treated bulbs packaged in laminated pouch recorded maximum score for colour, texture, appearance, flavor and taste than the other treatments. A gradual decrease in all sensory parameters was observed in jackfruit bulbs due to activity of enzymes resulting in quality loss and other physiological process like respiration, oxidation etc. Different packaging materials have been proved to protect sensory and microbial quality of perishable commodities This is in accordance with the findings of Gomez *et al.* (1980) who had reported better flavour, colour, and microbiological quality for mango slices packed in aluminium foil laminate pouches.

5.3.2 Chemical parameters

Lowest acidity (0.31%) and highest mean TSS content (18.92^{0}B) were noticed in bulbs packed in laminated pouch. Shrink wrapping was the second best package with 0.34 % acidity and highest TSS content (18.55^{0}B) after 4 days of storage period. Highest acidity (0.38%) and least TSS (18.35^{0}B) were observed on cling film wrapped jackfruit bulbs.

Acidity of the jackfruit bulbs was seen decreased from 0.40% at the time of storage to 0.30% on 4th days of storage period. This is in accordance with the findings of Nanda *et al*. (2001) who had noticed decrease in acidity of shrink wrapped pomegranate during its storage period. Similar reduction in titratable acidity was noticed with the advancement of storage period as observed by Taj *et al.* (2014) in minimally processed jackfruit bulbs. TSS content of the jackfruit bulbs increased with storage and it ranged from 18^{0}B at the time of storage to 19.08 ^{0}B on 4th days of storage period. The increased TSS could be attributed to the hydrolysis of starch and other polysaccharides to soluble form of sugar as reported by Alam *et al.* (2013)

All jackfruit bulbs except those packed in laminated pouch and shrink wrapped were discarded by 6th day of storage. Acidity percentage did not show any significant variation on 6th day of storage, whereas higher TSS (20.5^{0}B) was recorded by bulbs packed in laminated pouch compared to shrink wrapped bulbs (19.63^{0}B).

Highest total sugar (37.28%), reducing sugar (16.75%) and non-reducing sugar (20.53%) content were noticed in bulbs packed in laminated pouch. Shrink wrapped bulbs were the second best with 36.92% total sugar, 16.29% reducing sugar and non-reducing sugar (20.63%) after 4 days of storage. This result is in accordance with Pongener *et al*. (2010) who had reported the highest mean total sugars in shrink film packed fruits compared to control.

Bulbs wrapped in cling film recorded the lowest mean total sugar (35.57%) reducing sugar (15.51%) and non-reducing content (20.06%).after 4 days of storage..

All jackfruit bulbs except those packed in laminated pouch and the shrink wrapped bulbs were discarded by the 6th day of storage. High total sugar (41.51%) and reducing sugar content (19.24%) were recorded in bulbs packed in laminated pouch (21.06%) on 6th day of storage, whereas non reducing sugar showed no significant variation among treatments.

Total sugar content increased from 34.48% at the time of storage to 38.31% on 4th day of storage period. Increase in total sugar has been reported in guava fruits by Pal *et al.* (2004). Total sugar content significantly increased in fresh cut sweet potato during storage period irrespective of the packaging material (Erturk and. Picha, 2007)

Reducing sugar content of the jackfruit bulbs increased from 14.71% at the time of storage to 15.71% and 17.83% on 2nd and 4th days of storage respectively. This increase may be due to the hydrolysis of starch to sugars during storage and due to the conversion of sucrose into glucose and fructose. Non reducing was found decreased during the storage period due to hydrolysis of sucrose to fructose and glucose by invertase enzyme at low temperatures (Rocha *et al.,* 1995).

Increased TSS and sugar content with reduced acidity observed in bulbs packed in laminated pouches indicates increased bio chemical activity related to ripening during storage.

Highest vitamin C (27.43 mg100g^{-1}) and total carotenoid (0.83) content and were noticed in bulbs packed in laminated pouch due to the impermeability to oxygen. This is in accordance with the results of Thakur and Arya (1988) who had observed a similar higher retention of ascorbic acid and carotenoid content in mango pulp packed in foil laminate pouches during frozen storage.

Shrink wrapped bulbs had a higher vitamin C (26.39 mg100g^{-1}) and carotenoid content (0.82 mg100g^{-1}) after 4 days of storage. This is in accordance with the findings of Perli *et al*. (2019) who had reported retention of ascorbic acid in shrink wrapped papaya without much deterioration

Bulbs wrapped in cling film recorded the least vitamin C of 23.61 mg100g^{-1} and total carotenoid content (0.79 mg100g^{-1}).

All jackfruit bulbs except those packed in laminated pouch and the shrink wrapped bulbs were discarded by 6th day of storage. Though vitamin C showed no significant variation among treatments, a higher total carotenoid content (0.78 mg100g^{-1}) was observed in bulbs packed in laminated pouch on 6th day of storage. Dissolved oxygen present in the head space may be the reason for degradation as reported by Thakur and Arya (1988)

Vitamin C content decreased from 29.17 mg100g^{-1} at the time of storage to 23.70 mg100g^{-1} on 4th days of storage. Similar decreases in ascorbic acid content with storage period were noticed by Pilon *et al*. (2006) and Sahoo *et al*. (2015) during refrigerated storage.

Total carotenoid content decreased from 0.85 mg100g^{-1} at the time of storage to 0.78 mg100g^{-1} on 4th day of storage due to its oxidative deterioration as reported by Prathibha *et al*. (2019) in minimally processed jackfruit bulbs. Minimal processing techniques may lead to stimulation of enzymes such as lipoxygenase, resulting in the degradation of b-carotene (Klein, 1987).

The presence phenolic content in any foods has been associated with sensory and health promoting properties. Lowest total phenol content (39.50) was reported in bulbs packed in laminated pouch whereas bulbs wrapped in cling film recorded the highest total phenols (42.28 mg100g^{-1}) after 4 days of storage which was on par with the shrink wrapped bulbs (41.66 mg100g^{-1}).

Total phenols decreased with storage from 42.59 mg100g^{-1} at the time of storage to 39.12 mg100g^{-1} on 4th day of storage. Similar reduction in phenolic content was reported by Raseetha and Nadirah (2018) in fresh cut broccoli and cauliflower irrespective of packaging material during storage.

All the jackfruit bulbs except those packed in laminated pouch and shrink wrapped bulbs were discarded by 6 days of storage and total phenol content of bulbs under those two treatments showed no significance on 6th day of storage.

1% calcium treated bulbs packaged in laminated pouch was superior to other treatments with least physiological loss in weight and percent leakage resulting in maximum shelf life, maximum TSS content and least acidity and phenol content resulting in better taste along with maximum vitamin C and total carotenoid content. The bulbs also scored maximum score for sensory parameters like colour, texture, appearance, flavor and taste by the sensory panel.

The packaging material used in the present experiment was double layered laminated pouches with polypropylene (PP) and Low Density Poly propylene (LDPE). Lamination is the process in which two or more flexible packaging materials like films, papers or aluminum foils are joined together. Suitable combination of films in laminated packages helps to prevent the permeation of moisture and gases through the packages, thus protecting the commodity from spoilage. Both PP and LDPE used here have low water transmission rate and a comparatively higher gas transmission rate. As the product is a fresh cut commodity having active respiration or high metabolic activity the selected package should have at least one component with low gas transmission rate, particularly oxygen transmission rate. The package used might not have completely prevented entry of gases in to the packaging thus permitting continuation of respiration. Though there was no restriction in gas concentration, the selected treatment could enhance the shelf life of jack fruit bulb compared to other treatments. Analysis of physiological parameters during storage clearly showed that parameters gradually changed indicating product deterioration. Based on retention of quality parameters, laminated pouch was selected as the best packaging system for minimally processed jack fruit bulbs.

5.4 Assessment of acceptability

The strength of sensory evaluation allows providing a complete profile that is valid for product comparison, shelf-life monitoring, and the prediction of consumer acceptance. The quality of fresh-cut fruits and vegetables is primarily analyzed from sensorial, nutritional and safety aspects. Consumers are generally more sensitive to even small differences in sensory quality parameters.

Colour has been considered to have a key role in food acceptability, and may even influence taste thresholds, sweetness perception and pleasantness as reported by Clydesdale (1993). Textural properties of fresh cut fruits and vegetables is also an important quality attribute which is defined as a "sensory and functional manifestation of structural, mechanical and surface properties of food, detected through sense of vision, hearing, touch and kinesthetic" (Szczesniac, 2002).

Appearance is also an important factor in consumer perception of fresh cut fruits and vegetables. Consumers relate appearance of the produce to quality and also it should be appealing to the consumers.

Minimally processed jackfruit bulbs were prepared as per the standardized technology. Jackfruit were surface sanitized using 100 ppm sodium hypochlorite solution, good quality bulbs were pretreated with 1% calcium chloride and packaged in laminated pouch and acceptability of the prepared product was analyzed. Though all the sensory parameters showed a gradual decreasing trend towards the end of the storage period, the minimally processed jack fruit bulb had acceptable sensory scores for appearance (7.10), colour (6.96), texture (7.26), taste (6.90), flavour (6.60) and overall acceptability (7.43) even after 6th day of storage. If the product is subjected to vacuum packaging the quality of the product might have been enhanced due to complete prevention of oxygen into the packaging system.

Cost of production of the standardized protocol was carried out as per the current market rate and it was found that cost of production of 1 kg minimally processed jackfruit bulbs was Rs. 206.89/-.

Future line of work

The shelf life of the minimally processed jackfruit bulbs is to be tested under vacuum and modified atmospheric packaging conditions.

Summary

6. SUMMARY

The experiment entitled “Protocol development for minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs” was carried out in Department of Post Harvest Technology, College of Agriculture, Vellayani with the objective to standardize an efficient and economic protocol for development of minimally processed jackfruit bulbs with extended shelf life. The major findings of the experiment are summarized below.

The experiment was carried out as four different continuous experiments as, Evaluation of sanitizing agents, evaluation of pre-storage treatments, development of packaging system and assessment of acceptability

Good quality, fresh and optimum mature jackfruit cultivar Muttom varikka were harvested, ripened and subjected to four different sanitization treatments viz., 40^0C water, 100 ppm sodium hypochlorite, 120 ppm sodium hypochlorite and 2 ppm ozonized water for 15 minutes along with untreated jackfruit kept as absolute control in order to study the efficiency of different sanitizing solutions in controlling the total microbial load on the fruit surface.

All the surface sanitization treatments resulted in reduced total microbial load on the jackfruit surface compared to the untreated fruits. 120 ppm and 100pm sodium hypochlorite were equally effective in reducing both the bacterial and fungal load. Jackfruit sanitized using 2 ppm ozonized water recorded a lesser microbial load next to those treated with sodium hypochorite solution. Untreated jackfruit had maximum bacterial (4.923 log cfu/ cm^2) and fungal count (3.039 log cfu/ cm^2), which was on par with the fruits treated with 40^0C water.

Efficiency and economics are the two factors that must be considered while selection of the best treatment. Therefore lower concentration of sodium hypochlorite ie 100 ppm sodium hypochlorite was selected as the best treatment after considering the efficiency, economics and safety aspects and utilized for the second part of the experiment.

Pre-storage treatments are given in maintaining the quality of fresh cut products and also for its shelf life extension. Any treatment given should also not compromise its sensorial qualities like colour, texture, taste etc. In the second part of the study, ripe fruits were surface sanitized using 100 ppm sodium hypochlorite solution, the best sanitizing solution selected from part1 of the experiment and extracted good quality bulbs without seeds were dipped in three different pre-storage treatment solutions for 10 minutes viz., 0.1% ascorbic acid, 0.1% citric acid, 1% Calcium Chloride and untreated bulbs were kept as absolute control to analyse the efficiency of different pre -storage treatment solutions. The treated bulbs and the untreated ones were stored under refrigerated conditions after keeping in aluminium foil trays wrapped with cling film. Effects of different pre-storage treatments on physical, physiological and chemical quality parameters of the bulbs were analysed.

All the pre-storage treatments resulted in better physiological quality parameters in jackfruit bulbs than the untreated bulbs. Jackfruit bulbs treated with 1% calcium chloride recorded the highest shelf life (5.00 days) with lowest mean physiological loss in weight (2.03) and percent leakage (79.24) after 3 days of storage. During the initial 1st and 3rd days also, the physiological parameters were superior for calcium chloride treated bulbs.

Jackfruit bulbs treated with 0.1% ascorbic acid was the second best treatment with 4 days shelf life and had 2.65% PLW and 81.27 % percent leakage.

Untreated jackfruit bulbs recorded the highest mean loss in weight (5.12) and percent leakage (83.11) and had the lowest shelf life (3.00 days).

All the bulbs except the one treated with 1% calcium chloride were discarded by 5th day of storage. 1% calcium chloride treated bulbs had recorded mean loss in weight of 4.4% and percent leakage of 89.52% on 5th day of storage.

Physiological Loss in Weight increased from 2.27% on 1st day of storage to 4.21% on 3rd day of storage and percent leakage increased from 72.44% at the time of storage to 90.4% on 3rd day of storage.

Mean sensory scores for colour, texture, appearance, taste and flavor of jackfruit bulbs were similar for the treatments at the time of storage and significant differences were noticed among the treatments from third day onwards. All pretreated jackfruit bulbs recorded high sensory scores compared to the untreated bulbs.

The maintenance of texture by calcium chloride treated bulbs has been reflected in the high organoleptic scoring of the jackfruit bulbs and 1% calcium chloride treated bulbs recorded the highest mean sensory score for colour (7.96), texture (8.03), appearance (8.2), flavor (8.13) and taste (7.83) on 3rd day of storage. All the sensory parameters gradually decreased with the increase in storage period

All the pre-treated bulbs had shown a better chemical quality parameters compared to untreated bulbs.

Jackfruit bulbs pretreated with 1% calcium chloride recorded least mean acidity (0.36%) and highest TSS content (20.20) after 3 days of storage, making it more palatable recording maximum sensory score for taste and flavor. 0.1% citric acid treated bulbs recorded highest acidity (0.43) and lowest TSS content (19.53).

Acidity decreased from 0.45% at the time of storage to 0.36% on 5th day of storage, whereas TSS increased from 19.39^{0}B at the time of storage to 20.28^{0}B on 3rd days.

Untreated bulbs recorded the highest mean total sugar (34.29%) and reducing sugar content (14.99%) after three days of storage. This was on par with the bulbs treated with 1% calcium chloride, which recorded 34.14% of total sugar and 14.81% of reducing sugar after three days.

Non reducing sugar was significantly influenced by days of storage and interaction between days and treatment, whereas no significant variation was noticed among the treatments.

Total sugar content increased from 32.47% to 35.34% and reducing sugar increased from 13.26% to 15.47% from the time of storage to 3rd day of storage. Non reducing sugar decreased from 19.21% at the time of storage to 18.85% on first day of storage and then increased to 19.87% on 3rd day of storage.

Lowest total sugar (33.26%) and non-reducing sugar (13.98%) were reported by 0.1% citric acid treated bulbs after three days of storage which was on par with the bulbs treated with 0.1% ascorbic acid with 33.31% of total sugar and 13.99% of reducing sugar.

All jackfruit bulbs except those treated with 1% calcium chloride were discarded by 5th day of storage and it recorded 36.50%, 16.40% and 20.10% of total sugar, reducing sugar and non-reducing sugar respectively.

1% calcium chloride treated bulbs had high ascorbic acid content (23.69) next to 0.1% ascorbic acid treated bulbs (28.95) after 3 days of storage

Vitamin C of jackfruit bulbs decreased from 27.64 $mg100g^{-1}$ at the time of storage to 19.41 $mg100g^{-1}$ on 3rd day of storage.

Bulbs treated with 1% calcium chloride recorded the highest mean total carotenoid content (0.83) and lowest total phenols (39.77) after 3 days of storage indicating its superiority in maintaining the colour of the jackfruit bulbs thus received maximum sensory score for colour during the storage period.

Total carotenoid content of the jackfruit bulbs decreased from 0.86 $mg100g^{-1}$ at the time of storage to 0.76 $mg100g^{-1}$ on 3rd day of storage. Total phenol content decreased from 42.59 $mg100g^{-1}$ at the time of storage to 41.20 $mg100g^{-1}$ and 39.20 $mg100g^{-1}$ on 1st and 3rd day respectively.

0.1% ascorbic acid treated bulbs was the second best treatment that retained carotenoid without much degradation next to 1% calcium treated bulbs.

All the jackfruit bulbs except those treated with 1% calcium chloride were discarded by 5th day of storage. It had recorded a vitamin C content of 21.05 $mg100g^{-1}$ carotenoid content of
0.76 $mg100g^{-1}$ and 35.83 $mg100g^{-1}$ of total phenols on 5th day of storage.

Hence 1% calcium chloride was selected as the best pre-storage treatment for minimally processed jackfruit bulbs and hence used for further part of the study.

In the third part of the study, ripe jackfruits were surface sanitized using 100 ppm sodium hypochlorite solution, bulbs were pre-treated with 1% calcium chloride for 10 minutes and packaged in four different packaging systems viz., laminated pouch, shrink wrapping, cling film wrapping and aluminium tray wrapped with cling film and stored under refrigerated (5-7^0C) conditions with the objective to develop an efficient packaging system for minimally processed jackfruit bulbs. The packaged bulbs were evaluated for physical, physiological and chemical quality parameters initially and at regular intervals till the end of shelf life

Jackfruit bulbs packaged in laminated pouch recorded maximum shelf life of 7 days followed by shrink wrapped bulbs with a shelf life of 6 days. Bulbs packed in aluminium tray wrapped with cling film and cling film wrapped bulbs recorded a shelf life of 5 and 4 days respectively.

Jackfruit bulbs packaged in laminated pouch recorded the least mean loss in weight (1.17) and percent leakage (65.90) after 4 days of storage.

Shrink wrapped bulbs were the second best with 1.95% PLW and 67.78% percent leakage. Highest mean loss in weight was observed for bulbs wrapped in cling film (3.63). Bulbs wrapped in cling film recorded the highest weight loss (3.63) and percent leakage (72.10) after 4 days of storage.

Physiological loss in weight increased from 1.57% on 2nd day of storage to 2.82% on 4th day of storage and percent leakage increased from 61.92% at the time of storage to 74.76% on 4th days of storage.

All jackfruit bulbs except those packed in laminated pouch and shrink wrapped bulbs were spoiled and had to be discarded by 6th day of storage. Low physiological loss in weight (4.00) and percent leakage (72.08) were recorded in bulbs packed in laminated pouch indicating better firmness and freshness followed by shrink wrapped bulbs (4.72) on 6th day of storage.

1% calcium chloride treated bulbs packaged in laminated pouch recorded maximum score for colour, texture, appearance, flavor and taste than the other treatments. A gradual decrease in all sensory parameters was observed in jackfruit bulbs due to activity of enzymes resulting in quality loss and other physiological process like respiration, oxidation etc.

Lowest acidity (0.31%) and highest mean TSS content (18.92^{0}B) were noticed in bulbs packed in laminated pouch. Shrink wrapping was the second best package with 0.34 % acidity and highest TSS content (18.55^{0}B) after 4 days of storage period. Highest acidity (0.38%) and least TSS (18.35^{0}B) were observed in cling film wrapped jackfruit bulbs.

Acidity of the jackfruit bulbs was seen decreased from 0.40% at the time of storage to 0.30% on 4th day of storage period, whereas the corresponding increase in TSS content was from 18^{0}B to 19.08 ^{0}B.

All the jackfruit bulbs except those packed in laminated pouch and shrink wrapped were discarded by 6th day of storage. Acidity percentage did not show any significant variation on 6th day of storage, whereas higher TSS (20.5^{0}B) was recorded by bulbs packed in laminated pouch compared to shrink wrapped bulbs (19.63^{0}B).

Highest total sugar (37.28%), reducing sugar (16.75%) and non-reducing sugar (20.53%) content were noticed in bulbs packed in laminated pouch. Shrink wrapped bulbs were the second best with 36.92% total sugar, 16.29% reducing sugar and non-reducing sugar (20.63%) after 4 days of storage.

Bulbs wrapped in cling film recorded the lowest mean total sugar (35.57%) reducing sugar (15.51%) and non-reducing content (20.06%) after 4 days of storage..

All jackfruit bulbs except those packed in laminated pouch and the shrink wrapped bulbs were discarded by the 6th day of storage. High total sugar (41.51%) and reducing sugar content (19.24%) were recorded in bulbs packed in laminated pouch (21.06%) on 6th day of storage, whereas non reducing sugar showed no significant variation among treatments.

Total sugar content increased from 34.48% to 38.31% and reducing sugar content of the jackfruit bulbs increased from 14.71% at the time of storage to 17.83% on 4th day of storage.

Highest vitamin C (27.43 mg100g^{-1}) and total carotenoid (0.83) content were noticed in bulbs packed in laminated pouch and shrink wrapped bulbs had a comparatively lower vitamin C (26.39 mg100g^{-1}) and carotenoid content (0.82 mg100g^{-1}) after 4 days of storage.

Bulbs wrapped in cling film recorded the least vitamin C of 23.61 mg100g^{-1} and total carotenoid content of 0.79 mg100g^{-1}.

All jackfruit bulbs except those packed in laminated pouch and the shrink wrapped bulbs were discarded by 6th day of storage. Though vitamin C showed no significant variation among treatments, a higher total carotenoid content (0.78 mg100g^{-1}) was observed in bulbs packed in laminated pouch on 6th day of storage.

Vitamin C content decreased from 29.17 mg100g^{-1} at the time of storage to 23.70 mg100g^{-1} on 4th day of storage. The corresponding decrease in total carotenoid content was from 0.85 mg100g^{-1} to 0.78 mg100g^{-1}. Total phenols decreased with storage from 42.59 mg100g^{-1} at the time of storage to 39.12 mg100g^{-1} on 4th day of storage.

Lowest total phenol content (39.50) was reported in bulbs packed in laminated pouch whereas bulbs wrapped in cling film recorded the highest total phenols (42.28 mg100g^{-1}) after 4 days of storage which was on par with the shrink wrapped bulbs (41.66 mg100g^{-1}).

All the jackfruit bulbs except those packed in laminated pouch and shrink wrapped bulbs were discarded by 6 days of storage. The bulbs also scored maximum score for sensory parameters like colour, texture, appearance, flavor and taste by the sensory panel.

Minimally processed jackfruit bulbs were prepared as per the standardized technology and acceptability of the prepared product was analyzed. Though all the sensory parameters showed a gradual decreasing trend towards the end of the storage period, the minimally processed jack fruit bulb had acceptable sensory scores for appearance (7.10), colour (6.96), texture (7.26), taste (6.90), flavour (6.60) and overall acceptability (7.43) even after 6^{th} day of storage.

Cost of production of the standardized protocol was carried out as per the current market rate and it was found that cost of production of 1 kg minimally processed jackfruit bulbs was Rs. 206.89/-.

It was concluded that minimally processed ripe jackfruit cv. Muttom varikka bulbs of seven days shelf life could be prepared by surface sanitization of fruit using 100 ppm sodium hypochlorite for 15 minutes followed by pretreating the de-seeded bulbs with 1% calcium chloride for 10 minutes and refrigerated storage after packaging in laminated pouch of PP/LDPE.

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Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Score card for sensory evaluation of ripe Jackfruit bulbs

Sample: Ripe jackfruit bulbs

Instructions : You are given 4 samples of ripe jackfruit bulbs. Evaluate them and give scores for each criterion

Criteria	Samples				
	1	2	3	4	5
Appearance					
Flesh colour					
Flavour					
Taste					
Texture					
Overall acceptability					
Any other remarks					

<u>Score:</u>

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

Date

Name:

Signature:

Abstract

PROTOCOL DEVELOPMENT FOR MINIMALLY PROCESSED JACKFRUIT (*Artocarpus heterophyllus* L.) BULBS

by

GAYATHRI. G. S.

(2018-12-036)

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2020

ABSTRACT

The study entitled "Protocol development for minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs" was carried out in Department of Post-Harvest Technology, College of Agriculture, Vellayani with the objective to standardize an efficient and economic protocol for development of minimally processed jackfruit bulbs with extended shelf life. The work was carried out as four different continuous experiments, *viz*., evaluation of sanitizing agents, evaluation of pre-storage treatments, development of packaging system and assessment of acceptability.

Fresh, good quality optimum mature fruits of the jackfruit cultivar Muttom varikka were harvested, allowed to ripe and were subjected to four different sanitization treatments *viz*., immersion in water (40^0C), 100 ppm sodium hypochlorite solution, 120 ppm sodium hypochlorite solution and 2 ppm ozonized water for 15 minutes each. Untreated fruits were kept as absolute control to evaluate the efficacy of sanitization treatments in controlling total microbial load on the fruit surface.

All the sanitization treatments resulted in reduction in microbial load on the fruit surface. Sodium hypochlorite at both concentrations, 120 and 100 ppm, were equally effective in reducing both the bacterial and fungal load. Untreated fruits had the maximum microbial count, which was comparable with the fruits treated with water at 40^0C. Considering the efficiency and economics, the lower concentration of sodium hypochlorite, 100 ppm, was selected as the best surface sanitizing treatment and used for the second part of the experiment.

In the second part of the study, after surface sanitization of the fruits with 100 ppm sodium hypochlorite solution, bulbs were extracted and after removal of the seeds, dipped in three different pre-treatment solutions viz, 0.1% ascorbic acid, 0.1% citric acid, 1% calcium chloride for 10 minutes. Untreated bulbs were kept as absolute control and both treated and untreated bulbs were stored under refrigerated conditions in aluminium foil trays wrapped with cling film to analyse the efficacy of pre-storage treatment solutions.

All the pre-storage treatments resulted in better physiological, chemical and sensory quality parameters of the bulbs compared to the untreated ones. However,

all the bulbs except the ones treated with 1% calcium chloride solution had to be discarded by 5th day of storage owing to deterioration.

Pre-storage treatment of the bulbs with calcium chloride (1%) resulted in maximum shelf life (5.00 days), TSS (20.20^0B), ascorbic acid (23.69) and total carotenoid content (0.83), lowest physiological loss in weight (2.03), percent leakage (79.24), acidity (0.36%) and total phenol content (39.77), after three days of storage, with best sensory scores and hence selected as the best pre-treatment for minimally processed jackfruit bulbs.

In the third part of the study, fruits and bulbs that received the best treatments mentioned above were kept under four different packaging systems *viz*., laminated pouch, shrink wrapping, cling film wrapping and aluminium tray wrapped with cling film were compared under refrigerated ($5\text{-}7^0$C) conditions.

Jackfruit bulbs packaged in laminated pouches recorded the maximum shelf life (7 days), TSS (18.92^0B), total sugar (37.28%), reducing sugar (16.75%), non-reducing sugar (20.53%), vitamin C (27.43 $mg100g^{-1}$), total carotenoid (0.83) content with maximum sensory scores. They also had least PLW (1.17), percent leakage (65.90), acidity (0.31%) and phenol content (39.50).

Shrink wrapping was the second best in maintaining quality with 6 days shelf life, and bulbs wrapped in cling film showed the least quality parameters with a shelf life of 4 days only. All jackfruit bulbs except those packed in laminated pouch and shrink wrap were found to be spoiled and had to be discarded by 6th day of storage.

Minimally processed ripe jackfruit bulbs of cv. Muttom varikka can have a shelf life of seven days if surface sanitization of fruit are done using 100 ppm sodium hypochlorite for 15 minutes, followed by pretreating de-seeded bulbs with 1% calcium chloride for 10 minutes and stored under refrigerated conditions after packaging in laminated pouch of PP/LDPE.

Minimally processed jackfruit bulbs prepared as per the standardized technology above had acceptable sensory scores for appearance (7.10), colour (6.96), texture (7.26), taste (6.90), flavour (6.60) and overall acceptability (7.43) even at the end of shelf life period. Cost of production of 1 kg minimally processed jackfruit bulbs was estimated to be Rs. 206.89/-.

സംഗ്രഹം

വെള്ളായണി കാർഷിക കോളേജിലെ വിളവെടുപ്പാനന്തര സാങ്കേതിക വിദ്യാവിഭാഗത്തിൽ 2018-2020 കാലയളവിൽ മിനിമൽ പ്രോസസിങ് ചെയ്ത ചക്കച്ചുളകളുടെ സൂക്ഷിപ്പുകാലം വർദ്ധിപ്പിക്കുന്നതിനായി കാര്യക്ഷമമായ പ്രോട്ടോക്കോൾ വികസിപ്പിക്കുക എന്ന ലക്ഷ്യത്തോടെ ഒരു പഠനം നടത്തുകയുണ്ടായി.

യോജിച്ച ശുചിത്വലായനികൾ, പ്രീസ്റ്റോറേജ് ലായനികൾ, പാക്കേജിംഗ് എന്നിവയുടെ തിരഞ്ഞെടുക്കലും അതുവഴി ഉൽപ്പാദിപ്പിച്ച ചക്കചുളകളുടെ സ്വീകാര്യത വിലയിരുത്തലും എന്നിങ്ങനെ തുടർച്ചയായ നാല് വ്യത്യസ്ത പരീക്ഷണങ്ങൾ നടത്തി.

കൃത്യമായ മൂപ്പെത്തിയ മുട്ടംവരിക്ക എന്ന ഇനം ചക്ക വിളവെടുത്ത് പഴുപ്പിച്ചതിനുശേഷം നാല് വ്യത്യസ്ത ശുചിത്വലായനികളിൽ മുക്കിവച്ചു. 40°C ചൂടുവെള്ളം 100 പിപിഎം സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ലയനി 120 പിപിഎം സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ലയനി 2 പിപിഎം ഓസോണൈസ്ഡ് വെള്ളം എന്നിവയിൽ 15 മിനിറ്റ് നേരം മുക്കിവയ്ക്കുന്നതോടൊപ്പം യാതൊരു ലായനിയിലും മുക്കാത്ത ചക്കയെയും പഠനവിധേയമാക്കി.

എല്ലാ ശുചിത്വലായനികളും ചക്കയുടെ ഉപരിതലത്തിലെ സൂക്ഷ്മജീവികളുടെ തോത് കുറക്കുന്നതായി കണ്ടു. 120 പിപിഎം , 100 പിപിഎം എന്നീ രണ്ടു സാന്ദ്രതകളിലുള്ള സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ലായനികൾ ബാക്ടീരിയ, ഫംഗസ് എന്നിവയുടെ തോത് കുറക്കുന്നതിന് നല്ലരീതിയിൽ ഫലപ്രദമാണെന്ന് കണ്ടെത്തി. യാതൊരു പരിചരണവും കൂടാതെയുള്ള ചക്കയിൽ പരമാവധി സൂക്ഷ്മജീവികൾ കാണപ്പെട്ടു. കാര്യക്ഷമതയും സാമ്പത്തികവും കണക്കിലെടുത്ത് 100 പിപിഎം സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ലായനിയെ മികച്ച ഉപരിതല ശുചീകരണ ലായനിയായി തിരഞ്ഞെടുക്കുകയും പരീക്ഷണത്തിന്റെ രണ്ടാം ഭാഗത്തിനായി ഉപയോഗിക്കുകയും ചെയ്തു.

പഠനത്തിന്റെ രണ്ടാം ഭാഗത്ത് 100 പിപിഎം സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ലായനി ഉപയോഗിച്ച് ചക്കയുടെ പുറംതൊലി ശുചീകരിച്ചതിനുശേഷം ചുളകൾ വേർതിരിച്ച് വിത്തുകൾ നീക്കം ചെയ്തതിനുശേഷം 0.1% അസ്കോർബിക് ആസിഡ്, 0.1% സിട്രിക്ക് ആസിഡ്, 1% കാൽസ്യം ക്ലോറൈഡ് തുടങ്ങി മൂന്ന് വ്യത്യസ്ത പ്രീസ്റ്റോറേജ് ലായനികളിൽ 10 മിനിറ്റ് നേരം മുക്കിവച്ചു. അതിനുശേഷം ചക്കചുളയെ ക്ളിംഗ് ഫിലിം കൊണ്ട് പൊതിഞ്ഞ അലുമിനിയം ട്രേയിൽ പായ്ക്ക് ചെയ്ത് ഫ്രിഡ്ജിൽ സൂക്ഷിക്കുകയും പരിചരണലായനികളുടെ ഫലപ്രാപ്തി പഠിക്കുകയും ചെയ്തു. യാതൊരു പരിചരണവും നൽകാതെയുള്ള ചക്കചുളയെ കേവലനിയന്ത്രണമായി ഉപയോഗിച്ചു.

പ്രീസ്റ്റോറേജ് ലായനികളിൽ മുക്കിവച്ച ചക്കചുളകൾ മികച്ച ഗുണങ്ങൾ പ്രകടിപ്പിക്കുകയുണ്ടായി. 1% കാൽസ്യം ക്ലോറൈഡ് ലായനിയിൽ മുക്കിവച്ച ചുളകൾക്ക് 5 ദിവസത്തെ സൂക്ഷിപ്പുകാലം ലഭ്യമായി. മൂന്നു ദിവസത്തെ സംഭരണത്തിനുശേഷം 1% കാൽസ്യം ക്ലോറൈഡ് ലായനിയിൽ മുക്കിവച്ച ചുളകളിൽ ഏറ്റവും കുറവ് ഭാരനഷ്ടം (2.03), ഉയർന്ന ടി.എസ്.എസ് (20.20), അസ്കോർബിക് ആസിഡ്, (23.69), കരോട്ടിനോയിഡ് (0.83), കുറഞ്ഞ അമ്ലത്വം (0.36), ഫിനോൾ, (39.77) എന്നിവ കണ്ടെത്തി. കൂടാതെ മികച്ച സെൻസറി ഗുണങ്ങളും പ്രകടി

പ്പിച്ചു. അതിനാൽ 1% കാൽസ്യം ക്ലോറൈഡ് ലായനി എറ്റവും മികച്ച പ്രിസ്റ്റോറേജ് ലായനിയായി തിരഞ്ഞെടുത്തു.

പഠനത്തിന്റെ മൂന്നാം ഭാഗത്ത് മുകളിൽ സൂചിപ്പിച്ച മികച്ച പരിചരണങ്ങൾക്ക് വിധേയമായ ചക്കചുളയെ ലാമിനേറ്റഡ് പൗച്ച്, ഷ്രിങ്ക് റാപ്പിംഗ്, ക്ളിംഗ് ഫിലിം റാപ്പിംഗ്, ക്ളിംഗ് ഫിലിം പൊതിഞ്ഞ അലുമിനിയം ട്രേ എന്നിങ്ങനെ നാല് വ്യത്യസ്ത പാക്കേജിംഗ് സംവിധാനങ്ങളിൽ പായ്ക്ക് ചെയ്ത് ഫ്രിഡ്ജിൽ സൂക്ഷിച്ചു.

ലാമിനേറ്റഡ്പൗച്ചിൽ പായ്ക്ക് ചെയ്ത ചുളകൾക്ക് എറ്റവും ഉയർന്ന സൂക്ഷിപ്പുകാലം (7ദിവസം) ലഭിച്ചു. അതോടൊപ്പം എറ്റവും കുറവ് ഭാരനഷ്ടം (1.17), അമ്ലത്വം (0.31%), ഫിനോൾ, (39.50) എന്നിവയും ഉയർന്ന അസ്കോർബിക് ആസിഡ്, (27.43), കരോട്ടിനോയിഡ് (0.83), ടി.എസ്.എസ് (18.92) എന്നിവയും രേഖപ്പെടുത്തി.

6 ദിവസം സൂക്ഷിപ്പുകാലം ലഭിച്ച ഷ്രിങ്ക് റാപ്പിംഗ് മികച്ച രണ്ടാമത്തെ പാക്കേജിംഗ് സംവിധാനമായി തിരഞ്ഞെടുത്തു. എന്നാൽ ലാമിനേറ്റഡ് പൗച്ചിൽ പായ്ക്ക് ചെയ്തവയും ഷിങ്ക് റാപ്പിംഗ് പായ്ക്ക് ചെയ്തവയും ഒഴികെയുള്ള ചക്കചുളകളുടെ സൂക്ഷിപ്പുകാലം 6 ാം ദിവസം അവസാനിച്ചതായി കണ്ടെത്തി.

100 പിപിഎം സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ലായനിയിൽ ഉപരിതല ശുചീകരണം നടത്തിയ ചക്കയുടെ ചുളകൾ 1% കാൽസ്യം ക്ലോറൈഡ് ലായനിയിൽ 10 മിനിറ്റ് മുക്കിവച്ചശേഷം അവയെ ലാമിനേറ്റഡ് പൗച്ചിൽ പായ്ക്ക് ചെയ്ത് ഫ്രിഡ്ജിൽ സൂക്ഷിക്കുന്നതുവഴി ഏഴ് ദിവസത്തെ സൂക്ഷിപ്പുകാലം ലഭിക്കും. ഈപ്രകാരം മിനിമൽ പ്രോസസ് ചെയ്ത 1 കിലോഗ്രാം ചക്കചുളയുടെ ചിലവ് 206.89 രൂപയാണ്.