PORTION PACKAGING AND STORAGE OF JACKFRUIT

(*Artocarpus heterophyllus* Lam.)

by

GANA K.R.

(2016-12-024)

THESIS

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

2018

DECLARATION

I, hereby declare that this thesis entitled **"PORTION PACKAGING AND STORAGE OF JACKFRUIT (*Artocarpus heterophyllus* Lam.)"** 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, associate ship, fellowship or other similar title, of any other University or Society.

Vellayani,

Date: 13-6-2018

Gana

Gana K.R.

(2016 - 12-024)

CERTIFICATE

Certified that this thesis entitled **"PORTION PACKAGING AND STORAGE OF JACKFRUIT(*Artocarpus heterophyllus* Lam.)"** is a record of research work done independently by Ms. Gana K.R. 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.

Vellayani,

Date: 13-6-2018

Dr. Mini. C

(Major Advisor, Advisory Committee)

Professor and Head

Department of Post Harvest Technology

College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Gana K.R. (2016-12-024)** a candidate for the degree of Master of Science in Horticulture with major Post Harvest Technology, agree that the thesis entitled **"Portion packaging and storage of jackfruit (*Artocarpus heteropyllus* Lam.)"** may be submitted by **Ms. Gana K.R. (2016-12-024)**, in partial fulfilment of the requirement for the degree.

13/6/18

Dr. Mini C.
(Chairman, Advisory Committee)
Professor and Head
Department of Post Harvest Technology
College of Agriculture, Vellayani

Dr. P.R. Geethalekshmi
(Member, Advisory Committee)
Assistant Professor
Department of Post Harvest Technology
College of agriculture, Vellayani

13/6/18

Dr. Manju R.V.
(Member, Advisory Committee)
Professor
Department of Plant Physiology
College of Agriculture, Vellayani

Dr. Anith K.N.
(Member, Advisory Committee)
Professor
Department of Agrl. Microbiology
College of agriculture, Vellayani

13/06/2018

Dr. Sajeev M.S.
Principal scientist
Department of Crop Utilization
CTCRI, Sreekaraym, Thiruvananthapuram

13/06/2018

(EXTERNAL EXAMINER)
Dr. Philipose Joshua
Peedikayil
23 Kairali Nagar
Kanjirampara
Trivandrum 695030.

ACKNOWLEDGEMENT

And so comes the time to look back on the path traveled during the endeavor and to remember the faces and spirits behind the action with a sense of gratitude.

I have been amazingly fortunate to have such an advisor who gave me the freedom to explore on my own and at the same time the guidance to recover when my steps faltered. The words may fall in short to express my sincere and profound gratitude to my chairperson **Dr. Mini C**, Professor and Head, Department of Post Harvest Technology for her valuable guidance, critical comments, well-timed support, warm encouragement and worthy advices that I have experienced for the last two years. Thank you mam for your care and special love

I express my sincere and heartfelt gratitude to Dr. **Geethalekshmi P.R**, Assistant Professor, Department of Post Harvest Technology, for the timely advice, careful instructions, valuable suggestions and support provided during the course of work. I was very fortunate to get suggestions and advice from you.

I convey my sincere thanks to Dr. **Manju. R. V**, Professor, Department of Plant Physiology, for the valuable advice, suggestions and support during my study. I deem it my previlage in expressing my heartfelt great fulness to the member of my advisory committee **Dr.Anith K.N**, Professor, Department of Agrl. Microbiology for explicit instructions and valuable suggestions throughout my investigation. I would like to thank **Dr.M.S.Sajeev**, principal scientist Department of crop utilization for the valuable suggestions.

I express my gratitude to **Archana chechi and Baby chechi** for the timely support, care and love rendered during all stages of my research work.

I avail this opportunity to thank my dear seniors **Thushara chechi** and **Aparna akka** for their support, help, care, love and encouragement during my research work.

I am thankful to my dearest **Aparna akka** for her unconditional love, care, patience, and selfless support that I have received during the period. Thank you akka for being with me in all my tough and good moments. I express my heartfelt thanks to my batch mate **Athira** for the care, support and inspiration throughout these two years and also for the great times we relished together.

I express my sincere gratitude to my dear friends Niranjan, Tharani, Gokul and Pooja for their company, constant help, support and inspiration. I profoundly express my gratefulness to dear senior Harshitha akka, Manasa akka, Vishwa joythi akka, Theju akka and Asoondha chechi for the encouragement, valuable suggestions. I extend my gratitude to My juniors Keerthana, Swathi , Archana, Lakshmi, Pooja and Ahwirya for their support and love.

I am thankful to the KAU for providing all the facilities during my study. I would like to thank all teaching and non teaching staff of CoA, Vellayani for their direct or indirect help rendered during the course work I do acknowledge the help and support rendered by all seniors and juniors of CoA Vellayani.

Words are not enough to express my whole-hearted and affectionate gratitude to my Appa and Amma for their unbounding love, unparallel affection and constant encouragement throughout my career and without whose invaluable moral support, the thesis would not have seen the light of the day.

I bow to the lotus feet of the Almighty, whose grace had endowed me the inner strength and patience and blessed me with will power to complete this endeavour successfully.

Gana .K.R.

CONTENTS

LIST OF TABLES

69	Fungal count of mature koozha portions under refrigeration	121-121
70	Cost of production of vacuum packed jackfruit portions	121-121

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

LIST OF ABBREVATIONS

^0C	Degree Celsius
%	Per cent
Min	Minutes
ml	Milli litre
CD	Critical difference
CfFU	Colony forming unit
CRD	Completely Randomised Design
et al.	And co-workers
Fig.	Figure
g	Gram
i.e.	That is
KMS	Potassium metabisuphite
$KMnO_4$	Potassium permanganate
MAP	Modified Atmospheric Package
Mm	Milli molar
H	Hour
$\mu g\ g^{-1}$	Micro gram per gram
Mg	Milligram
ml^{-1}	Per millilitre
NS	Non significant
PLW	Physiological Loss in Weight
PP	Polypropylene
viz.,	Namely

TSS	Total Soluble Solids
OTR	Oxygen Transmission Rate
WTR	Water Transmission Rate

Introduction

1. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.), is a delicious tropical fruit of Indian origin and grows wild in the rain forests of Western Ghats of India. The fruit is rich in carbohydrates, proteins, potassium, calcium, iron and vitaminA, B & C, while the presence of isoflavones, antioxidants and phytonutrients in fruits indicates that jackfruit has anti-cancerous properties (APAARI, 2012).

The economic part of the fruit is bulb, which is used as dessert and processed in to various products which can be stored and used round the year. The green, unripe, immature fruits are used for preparing vegetable curry, pickle, chips and the seeds are processed into roasted nuts. In the state there are two commonly found types; 'Koozha' and 'Varikka'. The Koozha variety is not much in demand and householders find it difficult to dispose it off after it ripens and falls and creates unhygienic conditions. Kerala contributes 10.98% of total production with 190.14 thousand tones (NHB, 2015-16).

Production of fruits and vegetables is of significance only when they reach the consumer in good condition and at a reasonable price. Due to postharvest losses, there is a considerable gap between gross production and net availability of fruits to consumers at present and this loss has been attributed to several factors, among which lack of packaging and storage facilities and poor means of transportation are the major ones. Hence, there is an urgent need to adopt proper post harvest management practices including improved packaging techniques. But very little emphasis has been given to research on packaging of perishable commodities.

Packaging is an integral element in the marketing of fresh horticultural produce and it provides an essential link between the producer and the consumer. Packaging is one of the most commonly used post harvest practices that puts the produce into unitized volumes which are easy to handle while also protecting them from hazards of transportation and storage (Burdon 2001).

Jackfruit is available in plenty in Kerala during the month of April-August and its market system is highly unorganized. Selling fruits, cut portions or even bulbs of jackfruit under unhygienic conditions without any package through road side stalls and also by push cart vendors is very common in local and domestic Kerala markets. Kerala Government has recently declared jackfruit, the largest tree borne fruit with distinctive taste and aroma, as Kerala's official fruit. Hence the fruit has received the required attention recently and hence it is the most appropriate fruit to be studied considering its immense possibilities in the context of food security, climate change and global warming. . The 'Kerala jackfruit' is more organic and tasty as it is produced in a very natural way without using any chemical fertilizers or pesticides.

In spite of such a vast potential and usefulness, jackfruit has remained as an underutilized fruit species so far and more scientific research is needed to exploit it as a commercial crop. Developing appropriate packaging technology for shelf-life extension may facilitate quality sale and transportation from production site to remote location, thereby minimizing postharvest loss with great significance for food security, economic growth and welfare of the society. Hence a study on "Portion packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.)" was undertaken at the Department of Post Harvest Technology, College of Agriculture, Vellayani with the objective to standardize portion packaging and storage techniques for extending shelf life of jackfruit types.

Review of Literature

2. REVIEW OF LITERATURE

Jackfruit (*Artocarpus heterophyllus* Lam.) is the most significant fruit in the tropical world, which belongs to the genus *Artocarpus*. It is most widespread and useful fruit, cultivated since prehistoric times and has naturalized in tropics, particularly in Southeast Asia. It is an important crop of India, Bangladesh, Burma, China, Sri Lanka, Malaysia, Indonesia, Thailand and the Philippines. It is also grown in parts of Africa, Brazil, Surinam, the Caribbean, Florida, and Australia (Elevitch and Manner, 2006).

2.1. RAW MATERIAL SELECTION

The final quality of the product mainly depends on the correct choice of the raw material (Wiley, 1994). All types of fruits and vegetables may not be suitable for minimal processing. The selection of appropriate variety is most important to ensure good shelf life after minimal processing.

Under ambient condition rapid quality deterioration will occur in all minimally processed fruits and vegetables due to tissue damage at the time of processing. The processing steps may involve cutting, peeling, shredding, slicing, trimming etc. (Ahvenainen, 1996).

Jackfruit varieties can be differentiated based on many visual and organoleptic properties for fresh market and minimal processing. So far, no systematic study has been made on the suitability of different varieties for minimal processing of many of the popular fruits and vegetables (Mandhare, 2008).

2.2. PHYSIOLOGICAL CAHNGES DURING MINIMAL PROCESSING

The major tissue disruption and the release of enzymes occur during minimal processing (Lamikanra, 2002). Damaged tissue and lack of protective skin make minimally processed fruits and vegetables perishables. Implementation of integrated approaches involving proper cultivar selection, pre harvest and post harvest management, post harvest treatments and adoption of appropriate packaging techniques helps to minimize tissue senescence and deterioration of minimally processed fruits and vegetables (Kaur and Kapoor, 2000).

Natural protection layer of the fruit generally removed during minimal processing leads to enhanced susceptibility towards microbial spoilage (Watada and Qi, 1999).

Due to membrane and cell wall degradation water loss will enhance. Respiration leads to water loss and result in negative impact on aroma and flavor with reduced levels of vitamins, carbohydrates, and organic acids. Availability of sugars at the cut surface encourages microbial growth and spoilage (Ngarmsak,2010).

Minimally processed produce is known to be susceptible to contamination and subsequent survival or growth of microorganisms resulting in both safety concerns and relatively short shelf life (Parish *et al.*, 2001).

Wounding plant tissues creates more susceptibility to attack by pathogenic organisms and possibly becomes conducive to survival and growth of food poisoning microorganisms. Flavor and aroma production are directly influenced by wounding (Morettie *et al.*, 2002).

2.3. PACKAGING

Packaging aids in handling of fruits from the place of produce (field) to the final place of consumption (consumer's house) and also in protecting them from deterioration during this period and it ensures protection of fruits from physical, physiological and pathological decline (Neeraj and Bhatia, 2003).

Quality of chopped carrots were evaluated by placing them in polymeric film with perforations under refrigeration .Sieve and Pal, (2006) observed that shelf life of shredded carrots was increased to 14 days when it was packed under low density polyethylene (LDPE) of 100-guage thickness with perforations.

Okan *et al.* (2011) evaluated the effect of different packaging films on quality of "Napoleon" cherry. Weight loss was less in packaged commodity compared to control, and it was reported to be 0.81%, 0.39% and 24.08% for polypropylene tray/ cast polypropylene film, polyvinyl chloride, polyethylene tray/polyethylene terephthalate, polyethylene films and control respectively.

2.4. MODIFIED ATMOSHERE PACKAGING (MAP)

Gunes and Lee (1997) found that the Modified Atmospheric Packaging (MAP) plays an important role in delaying the process of physiological ageing, reduction of unwanted metabolic reactions like respiration or water loss and it also provides protection of commodities from the microbial contamination. Within the pack modified atmosphere (MA) can be created in two ways, i.e. the one which involves the pulling of a slight vacuum within the pack and then replacing the atmosphere with the desired gas mixture; active modification system and the other one is passive modification system which involve the modification of atmosphere through the respiration of the commodity within the pack. Most commonly used ones are reduced O_2 and elevated CO_2 levels. Besides O_2 and CO_2, nitrogen (N_2) is also used in MAP. Nitrogen is frequently used to relocate oxygen in MAP which aids in delaying oxidative browning and inhibiting aerobic microorganisms (Day, 2007).

Due to respiration of the commodity atmosphere inside the package is modified. Modified atmosphere packaging helps to get a low oxygen level, which is beneficial in maintaining product quality such as retarded browning and physiological disorders in cabbage and cut lettuce (Hicks and Hall, 1973).

Gorny *et al.* (2000) found that MAP is capable of lengthening shelf life of several intact and fresh- cut horticultural products.

Shelf life of fresh cut or minimally processed fruits and vegetables are increased by modified atmosphere packaging technique. Freshness state of the product is prolonged due to modification of air around the product. The gaseous composition inside the package depends on product type, packaging material and storage condition (Church and Parsons, 1995). Limbanyen *et al.*, (1998) reported that a modified atmosphere of 10% oxygen and 10% carbon dioxide slowed browning and softening of fresh cut mangoes compared to the control (ambient).

The measures to slow down the process of ripening and senescence are by retarding the rate of respiration, transpiration and ethylene evolution provided by the modified atmospheric packaging (MAP). MAP also demonstrates its function in reduced microbial contamination thus MAP consequently ensures better quality retention for the period of storage, transport and marketing (Mattheis and Fellman, 2000).

In a study related to qualitative alterations in broccoli (*Brassica oleracea italica*) under MAP in perforated polymeric film, Rai *et al.* (2008) reported that perforated PP film packages having two holes, each of 0.3 mm in diameter and having a film area of 0.1 m^2 helps to store broccoli for four days through the maintenance of chlorophyll and ascorbic acid in MAP.

The quality of fresh-cut tomato slices during cold storage under various MAP conditions was studied by Hong and Gross (2001). The results revealed that at 5 °C MAP affords good quality of tomato slices with a shelf life of two weeks or more. LDPE packaging was enough for fresh cut cabbage storage (Rinaldi *et al.*, 2010).

At 5°C during storage of shredded lettuce for ten days Heimdal *et al.*, (1995) found that modified vacuum packaging (MVP) inhibited enzymatic browning when packed in flexible 80 μm polyethylene bags evacuated to a pressure of 46 k Pa. Packing with the micro-perforation shows the way to retain the product quality in case of fresh weight, firmness, sugar: acid ratio and thus aids in reduction of deterioration and provides prolonged shelf life (Kale and Kadavu, 2003).

Roshita *et al.* (2005) reported that the shelf life of minimally processed shredded cabbage can be extended up to three weeks with least colour change; less weight loss and deterioration in sensory properties by use of polypropylene.

2.5. VACUUM PACKAGING

Wiley (2009) stated that Vacuum packaging refers to "packaging in containers (rigid or flexible), from which substantially all air has been removed prior to final sealing of the package". It is in fact a form of "Modified Atmosphere", as normal ambient air is detached from the package. Vacuum packaging could be a substitute to accomplish an inhibition of the advancement of deterioration of food stuffs. Papaya fruits were pre-treated with wax, oil, purafil packets, tissue paper wrapping along with the control and packed in 150 gauge thick polyethylene film bags under vacuum. Another set of these samples were maintained without vacuum. Shelf-life of the papaya fruits was found to be increased in vacuum packaging up to 1- 4 weeks. Quality of the papaya fruits with minimum changes was maintained by pre-treatment with waxing followed by purafil and oil application.

Vacuum packaging prevented enzymatic browning reaction on the surface of apple slices. However, this beneficial effect on apple slice color was offset by a negative effect on firmness. Results obtained by use of both the calcium treated and the calcium + erythorbic acid treated samples showed that apple slices packaged under vacuum were softer and rate of softening was also faster than those packaged without vacuum (Lee and Smith, 1995). It was observed that apple slices packaged at low vacuum were significantly firmer than apple slices packaged at high vacuum at the end of three weeks storage. It was concluded that vacuum packaging helped to prevent discoloration but contributed to softening when Jonagold apple slices were packaged under vacuum at two different levels.

2.6. QUALITY PARAMETERS IN MINIMAL PROCESSING

2.6.1. Ascorbic acid

Limbo and Piergiovanni (2006) reported that high oxygen partial pressure prevented the enzymatic browning of minimally processed potatoes in combination with citric acid and ascorbic acid.

The physiological stress which imposed upon fresh-cut commodity affects the ascorbic acid content significantly. Saxena *et al.* (2009) reported that the visual quality of the produce could be maintained by use of ascorbic acid through restricted browning. Ascorbic acid content in pretreated samples increased by 3 fold when ascorbic acid content was added during dip pretreatment. It has an important role as a phytochemical, owing to its functionality as antioxidants in addition to its vitamin C activity.

2.6.2. Reducing sugars

Sakane *et al.* (1990) found that browning of shredded cabbage can be reduced by dipping them in 0.25% sucrose fatty acid esters. The reducing sugar content continued intact or slightly enhanced under refrigeration conditions where as sucrose content decreased in comparison with ambient storage.

Mandhare (2008) reported that the flavor of carrots was influenced by reducing sugars and is the chief component causative to the carrot taste. In his study, the reducing sugar content of fresh carrot samples was 50.15 mg per 100 g. Glucose and fructose (reducing sugars) actually decreased during the storage of minimally processed carrot samples and it was further reduced down to 2.75- 2.65 mg at the end of refrigerated storage. The carrot cubes when treated with varied preservatives like ascorbic acid, citric acid and potassium metabisulfite and packed in low density polyethylene and polypropylene films they retained more reducing sugars compared to the control.

Majumdar *et al.* (2010) found increase in the content of reducing sugars in bottle gourd-basil leaves juice and decrease of the non-reducing sugars during storage. The changes were accredited to sucrose inversion in the incidence of acidic environment.

2.6.3. Titratable acidity

Increase in organic acids was observed during sensory evaluation of minimally processed and stored carrots (Kakiomenou *et al.* ,1996). During storage, decrease in the texture values were noticed which is characterized by softening of the tissue.

Piga *et al.* (2000) reported sharp increase in titratable acidity when cactus pears stored at 15$_o$ C shows drastic reduction in the pH value from day 4 of storage.

Ferrer *et al.* (2002) stated that increase in the titratable acidity and decrease in pH of minimally processed mango and pineapple fruits occur when citric acid was added in pre-treatment dip.

Benedetti *et al.* (2002) found that titratable acidity content of carrot and green pepper was not affected by the storage period. A decrease in citric acid from 0.08 to 0.06 mg per 100g was observed in green pepper, decline in malic acid was observed in grated carrots; both were packed under modified atmosphere (10% O2 and 40% CO2) for 10 days at 10$_o$C temperature. Pilon *et al.* (2006) reported that titratable acidity was not affected by the storage period.

Saxena *et al.* (2008) reported that the change in ripening index (o B/acid ratio) of minimally processed jackfruits bulbs stored under modified atmosphere packaging indicated an increase in soluble solids and reduction in titratable acidity due to the ripening process during storage. After 35 days of storage, control samples recorded nearly 1.8–2.5 fold higher ripening index of the initial value while pre-treated samples were observed with a restricted rise of 1.4–2.1 fold of the initial value in different modified atmosphere packaging techniques adopted. Significant changes were observed between the modified atmosphere packaging techniques used in terms of ripening index. After 14 days pretreated and 3 kPa O_2 + 5 kPa CO_2 gas flushed polyethylene bag samples were found to be more effective in restricting the increase in ripening index which was accredited for lowering respiratory activity and retarding metabolic activity of the samples. Control MAP samples showed rapid loss in firmness and other detrimental changes from 7^{th} day onwards. The increase in oBrix/acid ratio in the pre-cut jackfruit bulbs was reported to be due to degradation of available starch during storage into simple sugars which might be the reason for decreased acidity and increased sweetness of bulbs.

2.6.4. TSS

During fresh cut apple storage, Rocha *et al.* (1995) found increase in the total soluble solids and decline in acidity due to ripening process as indicated by change in ripening index (oBrix/acid ratio) in fresh apple.

The pH value of fresh carrot samples was observed to be 4.3 and this increased in the range of 4.7-5.8 at the end of the 6th day of ambient storage. In the minimally processed carrots, the average value of pH ranged from 4.9 to 5.9 at the end of 21st day of refrigerated storage. The rate of increase of pH in the experiment during the refrigerated storage was lower than that of ambient storage. Further it was seen that the pH value was less in carrot cube samples in LDPE pouch than in PP. The TSS value decreased up to 4.1 oBrix (PP) at ambient storage from the fresh carrot sample (4.7 ^{o}Brix) at refrigerated storage, the rate of decrease was slower. At the end of 21st day of refrigerated storage, TSS value was found to be in the range of 4.8-5.1 ^{o} Brix (Mandhare, 2008).

2.7. STORAGE TEMPERATURE

Quality of minimally processed products is affected by storage temperature, regardless of the use of packages. To achieve reasonable shelf life products should be stored at less than 5-8°C and make sure of microbiological safety (Rolle and Chism, 1992). Minimally processed products are perishable in nature compared to intact products because they have been subjected to various physical stress, such as peeling, cutting, slicing, trimming, and/or coring, and removal of the protective epidermal cells. Minimally processed products should be kept under low temperature storage compared to intact product. Fresh cut can be safely stored at 0^{o}C, shipped and stored at 5°C. Elevated storage temperature leads to the product deterioration because Q_{10} of biological reactions ranges from 3 to 4 and possibly as high as 7 within this temperature regime (Schlimme, 1995). High temperature will results in high respiration products. In the 0-10°C storage temperature range, the Q_{10} of several fresh-cuts was higher than the whole product. The Q_{10} was greater in the 10-20°C temperature range than in the 0-10°C range for 11 of the 15 fresh-cut commodities studied. At 10-20^{o}C, there was high Q_{10} of several fresh-cut products which was due to the rapid deterioration at 20°C. The high Q_{10} values, particularly in the 10-20°C range indicated the importance of handling and storing both intact and fresh-cut products at near 0°C if the product was not sensitive to chilling injury (Watada *et al.*, 1996). Pathogens grow well at 10^{o}C or above in fresh cut products.

When vacuum packaging or modified atmosphere packaging is used for fresh cut storage plays a very important role (Francis and O'Beirne, 1997). All the post harvest operations like processing, transportation, display and intermediate storage all should be done at the same low temperature if possible between 2-4°C for produce not responsive to chilling injury.

Marrero and Kader (2006) reported that respiration rate of the product directly depends on storage temperature of fresh cut pineapples. The end of shelf life was indicated by a marked increase in respiration rate followed by visual signs of microbial spoilage. This stage was reached after 4 days at 10$_{o}$C, 8 days at 7.5$_{o}$C, 12 days at 5$_{o}$C and more than 15 days at 2.2$_{o}$C and 0$_{o}$C.

Shelf life of the minimally processed fresh cut vegetables was increased by storing them at 7°C, slowed down the microorganisms growth rate, but was selective for psychotropic microorganisms (Pilon *et al.,* 2006). Maintaining the quality and minimization of post harvest loss can be achieved by storing the fresh cuts at proper storage temperature and relative humidity. Above the minimum safe temperature for mango as a chilling-sensitive commodity, every 10°C increase in temperature accelerate deterioration and the rate of loss in nutritional quality by 2 to 3 folds (Kader, 2008).

2.8. ACCEPTABILTY STUDIES BY SENSORY ANALYSIS

The consequence of calcium chloride and calcium lactate dips were evaluated by Luna-Guzman and Barrett (2000) in sensorial assessment of freshcut cantaloupe.

Vandekinderen *et al.* (2008) found that the sensory quality of cooked leek significantly changes when treated with sodium hypochlorite @ 200 mg L$_{-1}$ or peroxy acetic acid @ 250 mg L$_{-1}$ in contrast with water washing. Manolopoulou and Varzakas (2011) stated that in retention of color and in increasing the overall acceptance and organoleptic quality of fresh cut cabbage, soaking with citric acid plays an important role and it reduces the browning of cut surface and also protects from formation of black specks.

2.8. COST ECONOMICS

Mandhare (2008) calculated cost economics of minimally processed carrots by considering all variable and fixed costs in their study wand and reported that the cost: benefit ratio for low density polyethylene (LDPE) package (1:1.38) was more than 1:1.28 for polypropylene (PP). According to Taj (2013), the cost: benefit ratio for vacuum packaging of the minimally processed jackfruit bulbs was calculated to be 1.0: 3.82.

Materials and Methods

3. MATERIALS AND METHODS

The experiment entitled "Portion packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.)" was conducted at Department of Post Harvest Technology, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, during the year 2016-2018 with the objective to standardize portion packaging and storage techniques for extending shelf life of jackfruit (*Artocarpus heterophyllus* Lam.) types.

The materials used and the methodologies adopted during investigation is detailed in this chapter. The experiment was conducted as two separate parts.

3.1. Effect of portion packaging and storage on shelf life

3.2. Quality evaluation of selected treatment

The most suitable portion packaging and storage conditions were standardized independently for *mature varikka* , *ripe varikka* and *mature koozha*.

3.1 EFFECT OF PORTION PACKAGING AND STORAGE ON SHELF LIFE

Good quality jackfruits of uniform size and maturity, free from pests, diseases and mechanical damages were harvested from Instructional Farm, Vellayani. Harvested fruits were washed, outer spiny rind removed, cut into pieces or portions of approximately 200-250 g weight , pretreated with 0.5% solution of potassium metabisulphite (KMS) and citric acid, drained to remove excess moisture (Plate 1) and then subjected to the following seven different packaging systems.

T_1: Polypropylene film with 5 % ventilation

T_2: Cling film wrapping

T_3: Shrink wrapping (polyolefin film of 15 μ)

T_4: Vacuum packaging in laminated pouches

T_5: Modified Atmospheric Packaging (MAP) in laminated pouches with $KMnO_4$

T_6: Modified Atmospheric Packaging (MAP) in laminated pouches with silica gel

T_7: Unwrapped (control)

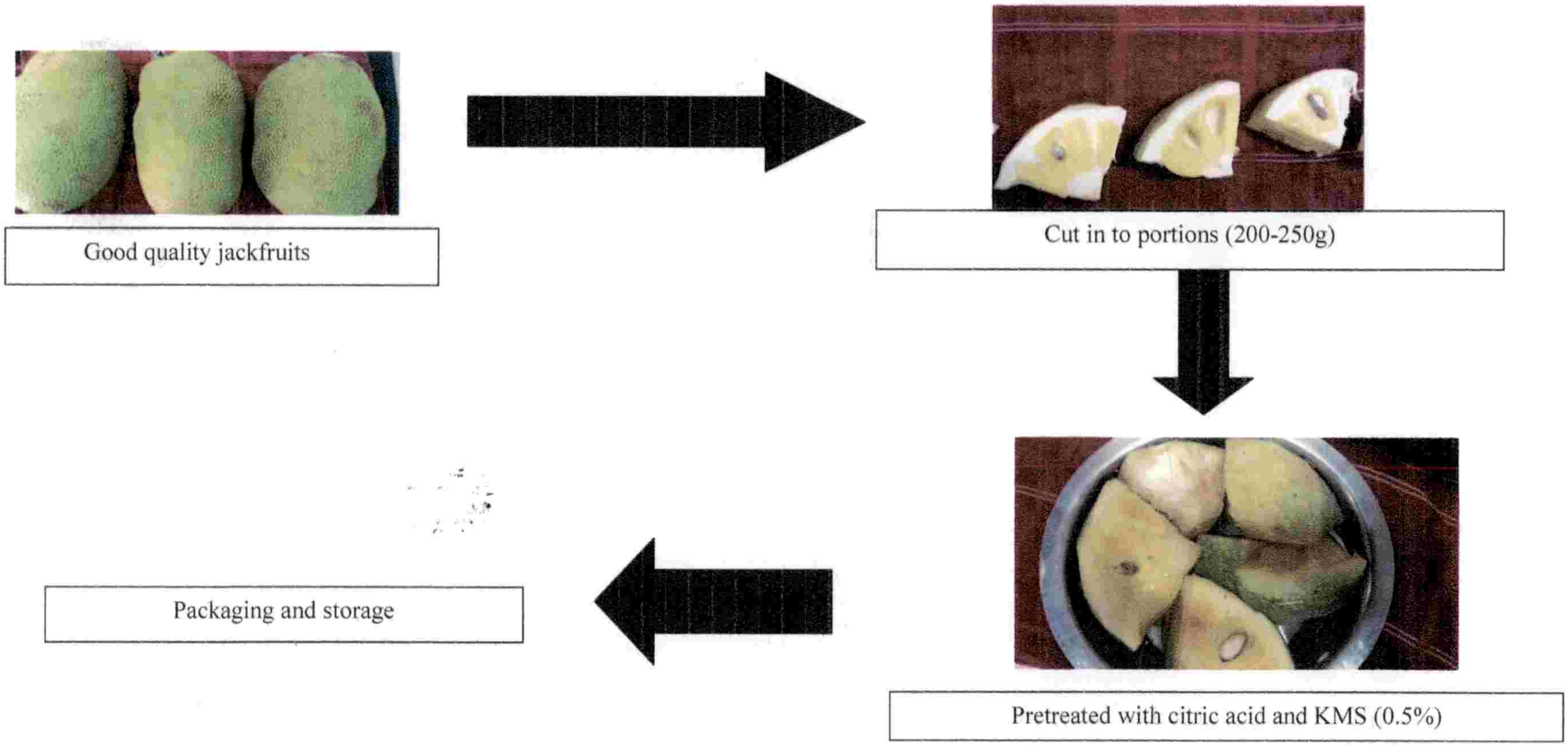

Plate 1.Flow chart of preparation of jackfruit for portion packaging and storage

3.1.1 Packaging systems

T_1: Polypropylene film with 5 % ventilation

Pretreated and surface drained jackfruit portions were packed in 150 gauge polypropylene cover with 5% ventilation and sealed by using heat sealing machine (Seapack machine with 240 AC volts and 380 WATTS)

T_2: Cling film wrapping

The pretreated surface drained jackfruit portions were cling wrapped with food grade LDPE film of 15 micron thickness using cling film wrapper (Plate 2).

T_3: Shrink wrapping (polyolefin film of 15 μ)

The pretreated and surface drained jackfruit portions were packed using shrink-wrapping machine (SEVANA'S QS4020DSTV) (Plate 3). Shrink wrapping machine consists of a tunnel, through which the produce moves and a L- sealer, which is used to seal the produce.

Jackfruit portions were initially placed in heat shrinkable PVC polyolefin film of 15 μ, sealed loosely with the help of L – sealer of the machine. The sealed portions move through the tunnel of the machine, where the package tightly shrinks around the portions.

Preliminary setting of the machine was adjusted as detailed below.

Shrink Time - 1.5 sec

Shrink Temperature -180^0 C

Plate 2. Cling wrapped jackfruit portions

Plate 3. Shrink wrapped jackfruit portions

T_4: Vacuum packaging in laminated pouches

The pretreated and surface drained jackfruit portions were vacuum packed in transparent laminated pouches (PP/LDPE) using a laboratory model vacuum packaging machine (SEVANA'S SEVOL V VACUUM PACKING MACHINE QS 400 MG (MC) (Plate 4).

Vacuum packaging machine consists of a programmable pump that creates desired percentage of vacuum inside the product chamber. The product chamber has a thermal film sealer as well as a gas flushing nozzle which can fill the product chamber with selected gas inside the product package if desired. However, in this study, no internal gas flushing was done.

Preliminary settings of the machine were adjusted as detailed below.

Mode – 4 (Vacuum pack): Vacuum – 700 mm Hg
Flush 1 – 600 mm Hg (vacuum pack)
Flush 2 – 760 mm Hg
Flush 3 – 760 mm Hg
Sealing time – 2.5 seconds
Cooling time - 9 seconds

Jackruit portions were placed in laminated pouches (PP/LDPE) and kept inside the product chamber of vacuum packaging machine in such a way that the opening of pouch is covered by the gas flushing nozzle and the sealing bars could seal the pouches properly. When the acrylic lid was closed and gently pressed, vacuum pump evacuated the air inside the chamber. The chamber was flushed with programmed level of selected gas, in this case, the air. Immediately, the sealing of the pouch was activated and initiated. Evacuated package collapsed around the product and the pouch opening was hermetically sealed by a heat impulse transmitted by the bar resistance. The sealing bar is made up of two resistances, one to cut the left over pouch material, and the other for hermetic sealing.

Plate 4. Vacuum packed jackfruit portions

Plate 5. Jackfruit portions under MAP in laminated pouches with $KMnO_4$

After sealing and cooling, the lid of product chamber opened automatically and the packaged sample was taken out.

T_5: MAP in laminated pouches with $KMnO_4$

Pretreated and surface drained jackfruit portions were placed in laminated pouches (PP/LDPE) of 180 cm^2. Ethylene scrubber, KMnO4 was packed in muslin cloth sachets of 42 cm^2 @ 8% and the KMnO4 sachet was placed inside the larger laminated pouches in such a way that the contact between jackfruit portions and KMnO4 was avoided (Plate 5). The laminated pouches with KMnO4 scahets were sealed using heat sealing machine (Seapack machine with 240 AC volts and 380 WATTS) so as to form Modified Atmospheric Packaging (MAP).

T_6: MAP in laminated pouches with silica gel

Pretreated and surface drained jackfruit portions were placed in laminated pouches (PP/LDPE) of 180 cm^2. The moisture scavenger, silica gel was packed in muslin cloth sachets of 42 cm^2 @ 8% and the silica gel sachet was placed inside the larger laminated pouches in such a way that the contact between jackfruit portions and silica gel was avoided (Plate 6). The laminated pouches with silica gel were sealed using heat sealing machine (Seapack machine with 240 AC volts and 380 WATTS) so as to form Modified Atmospheric Packaging.

T_7: Unwrapped (control)

Pretreated and drained jackfruit portions were kept without any packaging (Plate 7).

All the above seven treatments were subjected to two different storage systems

S_1-Refrigerated storage

S_2- Ambient storage

Plate 6. Jackfruit portions under MAP in laminated pouches with Silica gel

Plate 7. Unwrapped jackfruit portions

Packaging treatments: 7

Storage atmosphere-2

Total number of treatments- 14

Replication: 3

Design: CRD

The same sets of treatments were imposed on *varikka* type at mature and ripe stage and *koozha* type at mature stage.

The most efficient packaging and storage systems capable of maintaining quality and shelf life were selected independently for three types of fruit portions.

The following physiological, organoleptic and marketability parameters of the portion packaged jackfruit samples were recorded on alternate days till the end of shelf life.

3.1.2. Physiological parameters

The following physiological parameters were recorded once in two days continuously till the end of shelf life.

3.1.2.1. Physiological loss in weight (%)

Physiological loss in weight was determined on initial weight basis by weighing the fruit samples at two days interval, using a laboratory level weighing balance having 0.01g accuracy, using the following formula and expressed as percentage (Srivastava and Tandon,1968).

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

3.1.2.2. Shelf life (days)

Shelf life of jackfruit portions was assessed as number of days from harvest till it remained fresh. Freshness assessment was based on the physical appearance of the fruit portions as judged by the retention of quality, freshness, color and glossy appearance without any desiccation, level of pathogenic decay, color variation and juiciness of the bulbs (Nanda *et al.*, 2000).

3.1.3. Marketability

Marketability of the jackfruit portions was subjectively assessed according to the procedure described by Mohammed *et al* (1999).

The descriptive quality attributes were determined by observing the level of decay, colour, surface defects, and shrivelling.

A 1–9 rating with, 1 = unusable, 3 = unsalable, 5 = fair, 7 = good, and 9 = excellent, was used to evaluate the fruit quality. Fruits receiving a rating of 5 and above were considered marketable, while those rated less than 5 were considered unmarketable. The number of marketable fruits was used as a measure to calculate the percentage of marketable fruits during storage, by using the following formula and expressed as percentage.

$$\text{Marketability} = \frac{\text{Number of fruits marketable}}{\text{Total number of fruits}} \times 100$$

3.1.4. Organoleptic parameters

The physical parameters like color, texture, appearance, flavor and taste of the jackfruit bulbs extracted from pretreated portions were evaluated on alternative days of storage by conducting sensory evaluation performed by a 10 member semi - trained panel. The panel constituted the research students and staff members of College of Agriculture Vellayani. The panel were asked to score the bulbs for different sensory attributes on a numerical scoring method (Amerine *et al.*, 1965) using a nine point hedonic scale (Annexure-1). Samples were ranked for quality parameters from higher to lower in descending order of acceptability, as shown below, which was briefly described to the panel members before evaluation.

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

3.1.5. Statistical analysis

Data generated from the experiments were analyzed statistically using Completely Randomized Design (CRD). In organoleptic parameters, preference scores were analyzed using Kruskall – Wallis by chi square test.

Based on the physiological, organoleptic parameters and marketability, the best portion packaging and storage system capable of quality retention of jackfruit portions was selected for the three different jackfruit types independently.

3.2 QUALITY EVALUATION OF SELECTED TREATMENT

The packaging and storage system capable of maintaining quality and shelf life of jackfruit portions was selected from the first part.

This part was also planned as three independent experiments for, mature varikka, ripe varikka and mature koozha.

The harvested jackfruits were cleaned, spiny rind removed, cut into portions, pretreated, surface drained and subjected to the best packaging and storage system selected from the part 1.

The treatments were evaluated for quality parameters before and after subjecting the jack fruit portions to the best packaging and storage system selected from part 1 of the experiment and compared with the control.

P_1- Packaging and storage system selected from part 1 of the study

P_2- Unwrapped jack portion (control)

Total treatments: 2

Replication: 7

Design: CRD

3.2.1. Physiological parameters

Jackfruit portions were evaluated for the following physiological parameters before and after subjecting them to the best packaging and storage system selected from part 1 of the experiment and compared with the control.

3.2.1.1. Shelf life (days)

Shelf life of the jackfruit portions was recorded as described in 3.1.3.2

3.2.1.2. Physiological loss in weight (%)

Physiological loss in weight of the jackfruit portions was calculated as described in 3.1.2.1

3.2.1.3. O_2 and CO_2 evolution rate

O_2 and CO_2 evolution rate of the packaged jackfruit portions (P_1) were measured by noting the change in concentration of O_2 and CO_2 gases inside the package, over the storage period by using Checkpoint Portable Gas Analyzer (Plate 8) and expressed in percentage.

A septum seal sticker was placed on the stored jack fruit portions and the needle of the machine was allowed to pierce through it. The gas inside the package was allowed to come out through the needle and was analyzed directly by the sensor.

3.2.2. Chemical quality parameters

Bulbs of the jackfruit portions were evaluated for the following chemical quality parameters before and after subjecting the portions to the best packaging and storage system selected from part 1 of the experiment and compared with the control.

3.2.2.1.TSS (°B)

Total Soluble Solids (TSS) of the jack fruit bulbs was recorded directly using Erma Hand refractometer (range 0-32^0 brix) and expressed in degree brix (°B).

3.2.2.2. Sugars (%)

3.2.2.2a. Reducing sugar

The titrimetric method of Lane and Eynon as described by Ranganna (1986) was adopted for the estimation of reducing sugar.

Twenty five gram of the jack fruit bulb was blended in 100ml distilled water with mortar & pestle, taken into 250 ml volumetric flask and was made up to 100 ml with water. Neutralized the solution with 1 N NaOH, 2 ml neutral lead acetate solution was added and kept for 10 minutes after shaking. Potassium oxalate (2 ml) was added to remove excess lead acetate; solution was filtered and made up to required volume to form clarified sample solution.

Fehlings A and B solution (5 ml each) were pipetted into a 250 ml conical flask and 50 ml water was added. The burette was filled with the clarified sample and the sugar solution was added into the boiling Fehling solution drop by drop. When the blue colour of the Fehling solution changed, three drops of methylene blue indicator was added and the titration was completed after adding sugar solution till a brick red colour developed. Percentage of reducing sugar was calculated according to the following formula

$$\text{Reducing sugar} = \frac{\text{Glucose Eq. (0.05) x Total volume made up (ml)} \quad \text{x } 100}{\text{Titre value (ml) x Weight of the pulp (g)}}$$

3.2.2.2b. Total Sugar (%)

Twenty five ml clarified sample solution was pipetted into 250 ml conical flask. Citric acid (5 g) and 50 ml distilled water were added into it. The solution was boiled for 10 minutes to complete the inversion, cooled, neutralized with 1N NaOH using phenolphthalein indicator and made up to required volume. Fehling's A and B (5 ml each) solutions were pipetted into a 250 ml conical flask and 50 ml water was added. The burette was filled with the clarified sample and the sugar solution was added into the boiling Fehling solution drop by drop. When blue colour of the Fehling solution changed, three drops of methylene blue indicator was added and the titration was completed after adding sugar solution till a brick red colour developed. Total sugar content was expressed as per cent in terms of invert sugar according to the following formula (Ranganna, 1986).

Total sugar (%) =

$$\frac{\text{Glucose Eq. (0.05) x Total vol. made up (ml) x Vol. made up after inversion (ml)} \quad \text{x } 100}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (ml)}}$$

3.2.2.2c.Non reducing sugar

Estimated by subtracting reducing sugar by total sugar.

3.2.2.3. Vitamin C (mg $100g^{-1}$)

Ascorbic acid content in jack fruit bulb of the portions was estimated by 2,6- dichloro phenol indophenol (DCPIP) dye method Sadasivam and Manickam (1992) and expressed as mg $100g^{-1}$. Five gram sample (5 g) was weighed, ground in a mortar and pestle with 4% oxalic acid and made up to a known volume (100 ml) and centrifuged. The supernatant was collected and 5 ml of the aliquot was pipetted into a conical flask to which 10 ml of 4 % oxalic acid was added. This was titrated against 2,6- dichloro phenol indophenol dye solution, until the appearance of pink colour (V_2 ml) persisted for few minutes. The amount of ascorbic acid was calculated as follows:

$$\text{Vitamin C (mg } 100g^{-1}) = \frac{\text{Titre value X Dye factor X Volume made up (ml)} \quad x\ 100}{\text{Aliquot. of extract taken (ml) X Wt. of sample (g)}}$$

Dye factor = 0.5/ V_1 ml

3.2.2.4.Total carotenoids (mg $100g^{-1}$)

Carotenoids of the jackfruit bulbs were estimated (Saini *et al.*, 2001) and expressed as mg $100g^{-1}$

Five gram of jackfruit bulb was ground using mortar and pestle by adding 20 ml of 80% acetone to get a fine pulp. The extract was centrifuged (5000 rpm for 5 min) and supernatant solution was transferred to 100 ml volumetric flask. The remaining residue was ground again with 20 ml of 80% acetone, centrifuged and supernatant solution was transferred to the same flask . Process was repeated with residue until it became colourless. Mortar and pestle were washed thoroughly with 80% acetone and washed acetone was collected in the same flask. Finally volume was made up to 100 ml with 80% acetone and absorbance was read at 480 nm and 510 nm against solvent (80%) blank. The Total carotenoids was calculated as follows:

$$\text{Total carotenoids (mg } 100g^{-1}) = \frac{7.6 \times OD_{480} - 1.49 \times OD_{510} \times V}{W \times 1000}$$

3.2.2.5. Titrable acidity (%)

The method described by Ranganna (1986) was followed to measure titrable acidity of the jackfruit bulbs collected from portions.

3.2.2.6. Total Phenol (mg $100g^{-1}$)

Total phenol content of the jackfruit bulbs were estimated using the method described by Sadasivam and Manickam (1992).

One gram of the jackfruit bulb was weighed and ground in a mortar and pestle with 10 times volume of 80% ethanol. The homogenate was centrifuged at 10,000 rpm for 20 minutes, supernatant was evaporated to dryness and the residue was dissolved in 5 ml distilled water. 0.5 ml of the aliquot was pipetted out in test tubes, made up the volume to 3 ml with distilled water and 0.5 ml Folin- Ciocalteau reagent was added. Two millilitre of 20 percent Na_2CO_3 was added to the test tubes after 3 minutes and mixed it thoroughly. The test tubes were placed in boiling water for one minute, cooled and the absorbance was measured at 765 nm against the reagent blank. Standard curve using different concentrations of Gallic acid was recorded and phenol content was expressed as mg phenols g^{-1} sample of jackfruit.

3.2.3.Marketability

Marketability of the jackfruit portions was estimated (Mohammed *et. al.*,1999) as described in 3.1.3.

3.2.3. Organoleptic quality (hedonic rating)

Organoleptic quality of the jack fruit bulbs extracted from portions was estimated as described in 3.1.4.

3.2.5. Physical parameters

3.2.5.1. Colour

Colour of the jackfruit bulbs extracted from stored jackfruit portions was estimated as per Jagdeesh *et al.*,(2006), which was based on the principle that the intensity of bulb colour, as revealed visually, is directly related to the amount of carotenoids found.
The range of carotenoid content in bulbs was correlated to the colour as follows

0.363-0.477mg $100g^{-1}$ carotenoid	-	Cream colour bulbs
0.497-0.678 mg $100g^{-1}$ carotenoid	-	Yellow colour bulbs
and		
0.683-0.879 mg $100g^{-1}$ carotenoid	-	Deep yellow color bulbs

3.2.5.2. Texture

The firmness of the jackfruit bulbs extracted from stored portions was measured using a texture analyzer TA.HD plus (Stable Microsystems, England) (Plate 9) using compression mode. The machine was calibrated using the following test conditions.

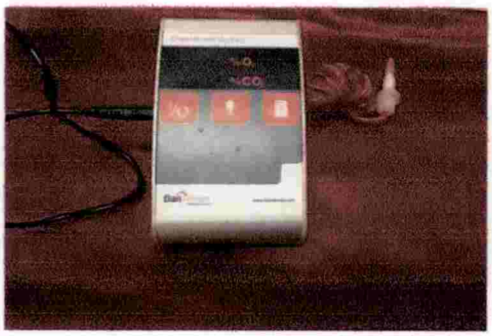

Plate 8. Gas analyzer

Plate 9. Texture analyzer

Mode – measure force in compression

Pretest speed – 1.5 mm/sec

Test speed - 1.5mm/sec

Post test speed –10mm/sec

Distance – 5mm

Trigger force – 0.049 N

Data acquisition -200 pps

After calibration of the equipment the jackfruit bulb was positioned centrally on the blank plate of the plat form. The compression test was carried out using 2mm cylindrical stainless steel (P/2 dia cylinder stainless steel) probe to plot a corresponding force deformation curve.

3.2.6. Microbial load

Bulbs of the stored jackfruit portions were subjected to quantitative assay of the micro flora by serial dilution spread plate techniques (Somasegaran and Hoben, 1985). Nutrient agar and Rose Bengal agar medium were used for the enumeration of bacterial and fungal population of jackfruit bulbs respectively.

Jackfruit bulb piece of one cm^2 area, collected from stored portions was suspended in 100 ml distilled water and shaken thoroughly for 2minutes to get 10^{-1} dilution. 100 μl of the supernatant was accurately pipetted out into eppendroff tube containing 900 μl of sterile distilled water to get 10^{-2} dilution. This procedure was repeated up to get 10^{-6} dilution.

100μl each of 10^{-2}, 10^{-4}& 10^{-6} was used for the enumeration of total bacterial count and 10^{-2}, 10^{-3}& 10^{-4} for total fungal count. Bacterial count was noted for three days continuously from the next day of inoculation whereas fungal count was taken from three days after inoculation.

Number of microorganisms (bacteria and fungi) per cm^2 was counted and results expressed as colony forming units (cfu/g of sample) as per the following formula.

$$\text{No. of colony forming units per ml of samples} = \frac{\text{Total no. of colony formed X dilution factor}}{\text{Aliquot taken}}$$

3.2.7. Cost of production.

Cost of production of the selected packaging and storage system required for 1 kg jackfruit portions (4 portions each with 250 g.) in an established processing unit was calculated based on the current market price, taking into account all aspects of fixed and variable costs involved in the investigation.

3.2.7. Statistical analysis

Data generated from the experiments were analyzed statistically using Completely Randomized Design (CRD). In physical parameters, preferences scores were analyzed using Kruskall – Wallis by chi square test (Dunn, 1964).

Results

4. RESULTS

The experimental data collected from the study on "Portion packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.)" were analyzed and the results are presented in this chapter under the following headings.

4.1. Effect of portion packaging and storage on shelf life

4.2. Quality evaluation of selected treatment

4.1. EFFECT OF PORTION PACKAGING AND STORAGE ON SHELF LIFE

As the experiment was conducted independently for three different jackfruit types viz., mature varikka , ripe varikka and mature koozha, the results are also presented here separately for different jackfruit types of different maturity.

Jackfruit types were harvested, cleaned, green spiny rind removed, cut in to portions, pretreated with 0.5% KMS and citric acid, surface drained and subjected to seven different packaging conditions and stored under ambient and refrigerated storage conditions.

The pre treated portion packed jackfruit types viz., mature varikka , ripe varikka and mature koozha were evaluated for physiological, organoleptic and marketability parameters and the data relating to these parameters as presented below.

4.1.1. Mature Varikka

4.1.1.1. Physiological Parameters

Effect of packaging and storage treatments on physiological parameters of portion packed mature varikka jackfruit portions at two days intervals is shown below.

4.1.1.1.1. Shelf Life (days)

The effect of packaging systems on shelf life of mature varikka jackfruit portions stored under refrigeration is shown in Table 1. There was significant difference in shelf life among the seven treatments. The vacuum packed (T_4) mature varikka jackfruit portions showed the highest shelf life of 20.33 days. This was followed by portions under Modified Atmospheric Packaging (MAP) in laminated pouches with silica gel (T_6) with a shelf life of 18.33 days which was on par with shrink wrapped (T_3) portions with shelf life of 18.00 days . Least shelf life (2.33 days) was recorded by unwrapped jackfruit portions.

The effect of packaging on shelf life of mature varikka jackfruit portions stored under ambient condition is shown in Table 2. There was significant difference in shelf life among the seven treatments. The vacuum packed (T_4) mature varikka jackfruit portions had the highest shelf life of 3.00 days and least shelf life was recorded by unwrapped jackfruit portions (0.33 days).

4.1.1.1.2. Physiological loss in weight (%)

Effect of packaging on physiological loss in weight (PLW) of mature varikka jackfruit portions stored under refrigeration is shown in Table 3.

Mean physiological loss in weight was least (1.08) for the portions under vacuum packaging in laminated pouches followed by portions packed under MAP in laminated pouches with silica gel (1.59). Highest (16.97) weight loss was recorded by the unwrapped portions under refrigerated storage.

Effect of packaging on physiological loss in weight of mature varikka jackfruit portions stored under ambient condition is shown in Table 4. Under ambient condition PLW was least (0.21) for the jackfruit portions under vacuum packaging in

Table 1. Effect of packaging on shelf life (days) of mature varikka portions under refrigeration

Treatment	Shelf life (days)
Polypropylene film (T_1)	10.66
Cling film wrapping (T_2)	13.33
Shrink wrapping (T_3)	18.00
Vacuum packaging (T_4)	20.33
MAP with $KMnO_4$ (T_5)	13.33
MAP with silica gel (T_6)	18.33
Unwrapped (T_7)	2.33
C.D.(0.05)	1.33

Table 2. Effect of packaging on shelf life (days) of mature varikka portions under ambient storage

Treatment	Shelf life (days)
Polypropylene film (T_1)	1.00
Cling film wrapping (T_2)	1.33
Shrink wrapping (T_3)	1.67
Vacuum packaging (T_4)	3.00
MAP with $KMnO_4$ (T_5)	1.67
MAP with silica gel (T_6)	2.00
Unwrapped (T_7)	0.33
C.D.	0.72

Table 3. Effect of packaging on Physiological Loss in Weight (%) of mature varikka portions under refrigeration

PLW (%)										
Treatments	Days after storage									
	2	4	6	8	10	12	14	16	18	20	Mean
Polypropylene film (T_1)	0.35	1.25	2.75	4.01	6.20	7.65	9.64	11.27	12.44	13.55	6.28
Cling film wrapping (T_2)	0.33	1.69	3.06	4.59	6.66	8.17	10.28	11.74	12.95	14.02	6.68
Shrink wrapping (T_3)	0.38	0.77	1.04	1.40	1.77	2.28	2.68	3.03	3.14	4.28	1.94
Vacuum packaging (T_4)	0.24	0.44	0.70	0.85	1.12	1.27	1.52	1.68	1.93	2.11	1.08
MAP with $KMnO_4$ (T_5)	0.56	2.70	5.03	7.57	9.93	12.44	14.83	17.28	19.12	22.73	10.20
MAP with silica gel (T_6)	0.29	0.73	1.02	1.30	1.51	1.89	2.20	2.53	2.81	3.17	1.59
Unwrapped(T_7)	1.36	5.04	8.66	12.27	15.86	19.47	25.33	26.54	28.56	29.34	16.94
Mean	0.50	1.80	3.18	4.57	6.15	7.59	9.50	11.12	12.27	13.54	
CD - 0.05	Treatments(T) – 0.054				Days(D) -0.067			T x D -0.178			

Table 4. Effect of packaging on Physiological Loss in Weight (%) of mature varikka portions under ambient storage

PLW (%)		
Treatments	Days after storage	
	2	Mean
Polypropylene film (T_1)	2.30	1.10
Cling film wrapping (T_2)	1.38	0.69
Shrink wrapping (T_3)	1.14	0.57
Vacuum packaging (T_4)	0.42	0.21
MAP with $KMnO_4$ (T_5)	1.48	0.74
MAP with silica gel (T_6)	0.86	0.43
Unwrapped(T_7)	3.75	1.87
Mean	1.58	-
CD(0.05) Treatments 0.201	Days - 0.108	T x D- 0.285

laminated pouches which was on par with the portions packed under MAP in laminated pouches with silica gel (0.43). Highest (1.87) weight loss was recorded by the unwrapped portions kept under ambient storage condition.

4.1.1.2. Marketability

The effect of packaging on marketability of mature varikka jackfruit portions is shown in Table 5. The vacuum packed portions had high mean marketability of 94.54%. Unwrapped fruit portions lost marketability within six days of storage and it had mean marketability of 13.63.

As the ambient storage portions spoilt within three days, marketability could be made only for portions under refrigeration.

4.1.1.2. Organoleptic parameters

Effect of packaging and storage on organoleptic parameters of mature varikka jackfruit portions, as judged by sensory scoring for appearance, color, flavor, taste, texture, and overall acceptability is shown in Tables 6a – 6f.

Rank for appearance was maximum (163.5) for portions kept under vacuum packaging followed by samples packed under MAP in laminated pouches with silica gel (111.45). Least (15.50) mean rank value for appearance was for unwrapped portions at the 20th day of storage (Table 6a).

Mean rank value for color was maximum (164.5) for portions packed under vacuum packaging in laminated pouches at 20th day of storage followed by portions packed under MAP laminated pouches with silica gel (97.5). Unwrapped jackfruit portions had least (15.5) mean value for color(Table 6b).

Table 5. Effect of packaging on Marketability(%) of mature varikka jackfruit portions under refrigeration

Marketability (%)											
Treatments	At the time storage	Days after storage									
		2	4	6	8	10	12	14	16	18	20	Mean
Polypropylene film (T_1)	100.00	90.00	80.00	73.33	70.00	63.33	56.66	50.00	33.33	30.00	26.66	61.21
Cling film wrapping (T_2)	100.00	80.00	80.00	73.33	60.00	60.00	46.66	46.66	36.66	16.66	10.00	55.45
Shrink wrapping (T_3)	100.00	90.00	86.66	80.00	76.66	70.00	66.66	56.66	50.00	36.66	36.66	68.18
Vacuum packaging (T_4)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	90.00	90.00	80.00	80.00	94.54
MAP with $KMnO_4$ (T_5)	100.00	86.66	76.66	60.00	50.00	50.00	40.00	40.00	36.66	30.00	30.00	54.54
MAP with silica gel (T_6)	100.00	100.00	100.00	90.00	90.00	80.00	73.33	66.66	60.00	56.67	46.66	78.48
Unwrapped(T_7)	100.00	30.00	20.00	0.00	-	-	-	-	-	-	-	13.63
Mean	100.00	82.38	77.61	68.09	63.81	60.47	54.76	50.00	43.81	35.71	32.85	
CD (0.05)	Treatments - 1.53	Days - 1.92	T x D – 5.09									

Table 6(a). Effect of packaging on appearance of mature varikka portions under refrigeration

Treatments	Appearance																					
	Days after storage																					
	At the day of storage		2		4		6		8		10		12		14		16		18		20	
	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS
T_1	105.5	9	81.65	6.9	81.65	6.9	80.65	6.9	61.1	6.5	60.1	6.5	47.6	5.5	46.6	5.5	45.5	4.2	40.5	4.1	40.5	4.1
T_2	105.5	9	95.75	7.0	94.75	7.0	94.75	7.0	93.5	6.7	93.5	6.7	84.8	5.6	84.8	5.6	84.00	4.3	80.5	4.2	80.5	4.2
T_3	105.5	9	131.00	8.2	131.00	8.2	130.00	8.2	123.8	7.8	122.8	7.8	123.8	7.4	120.8	7.4	111.00	6.1	98.56	5.9	98.56	5.9
T_4	105.5	9	191.00	8.9	191.00	8.9	191.00	8.9	165.5	8.6	165.5	8.6	165.5	8.6	165.5	8.6	164.5	8.4	164.5	8.3	163.5	8
T_5	105.5	9	74.60	5.6	73.3	5.6	50.75	5.2	49.75	5.2	19.87	4.86	19.5	4.1	17.5	3.2	17.5	3.2	15.5	2.9	15.5	2.9
T_6	105.5	9	149.00	8.3	148.00	8.3	147.00	8.3	132.23	7.9	130.23	7.9	128.5	7.5	128.5	7.5	112.67	6.2	111.45	6.1	111.45	6.1
T_7	105.5	9	15.5	2.9																		
KW value	NA		174.31		173.5		171.32		156.73		154.56		147.79		147.12		146.68		145.75		143.45	
χ^2 (0.05)	12.59				11.07																	

R - Rank M S – Mean score

Table 6(b). Effect of packaging on color of mature varikka portions under refrigeration

Treatments	Colour																					
	Days after storage																					
	At the day of storage		2		4		6		8		10		12		14		16		18		20	
	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS
T_1	105.5	9	53.5	7.5	53.5	7.5	49.60	7.2	45.60	6.9	45.6	6.9	40.6	6.5	37.6	6.0	35.6	5.7	30.80	5.1	30.80	5.1
T_2	105.5	9	62.5	7.3	62.5	7.3	62.1	7.3	62.1	7.3	58.09	7.1	58.09	7.1	45.5	6.2	45.5	5.8	40.5	5.3	40.5	5.3
T_3	105.5	9	114.96	8.3	114.96	8.3	114.96	8.3	113.96	8.1	110.9	7.9	110.96	7.9	100.8	7.2	100.8	7.2	95.5	6.5	95.5	6.5
T_4	105.5	9	165.5	8.9	165.5	8.9	165.5	8.9	165.5	8.9	165.5	8.8	165.5	8.6	164.5	8.4	164.5	8.3	164.5	8.1	164.5	7.5
T_5	105.5	9	24.30	5.5	24.30	5.5	18.5	5.1	18.5	5.1	17.5	4.5	16.5	4.1	16.5	4.0	16.5	3.9	15.5	3.2	15.5	3.2
T_6	105.5	9	123.6	8.4	123.6	8.4	122.7	8.3	122.7	8.3	121.1	8.2	121.1	7.6	118.5	7.2	115.5	6.9	105.5	6.7	97.5	6.7
T_7	105.5	9	15.5	3.1	-		-		-		-		-		-		-		–		-	
KW value	NA		160.28		160.28		158.22		157.78		152.63		151.54		147.79		146.89		143.90		142.78	
χ^2 (0.05)	12.59				11.07																	

R - Rank M S – Mean score

Table 6(c). Effect of packaging on flavor of mature varikka portions under refrigeration

Treatments	Flavor – Days after storage: At the day of storage R	MS	2 R	MS	4 R	MS	6 R	MS	8 R	MS	10 R	MS	12 R	MS	14 R	MS	16 R	MS	18 R	MS	20 R	MS
T_1	105.5	9	81.65	7.5	81.65	7.5	81.65	6.9	78.9	6.9	77.9	6.8	76.5	6.3	69.5	5.4	68.5	5.4	45.5	4.9	44.5	4.9
T_2	105.5	9	95.75	7.8	95.75	7.8	95.75	7.0	94.65	7.0	94.45	6.9	84.6	6.5	81.5	5.9	80.0	5.7	74.00	5.1	74.00	5.1
T_3	105.5	9	131.00	8.4	130.5	8.4	116.00	8.2	114.75	8.2	114.75	8.2	113.67	7.1	94.5	6.5	93.5	6.1	91.00	5.9	91.00	5.9
T_4	105.5	9	191.0	8.9	191.0	8.9	191.0	8.9	175.7	8.9	175.7	8.9	167.5	8.5	165.5	8.5	165.5	8.5	163.2	7.9	163.2	7.9
T_5	105.5	9	74.60	5.6	73.3	5.6	50.75	5.2	49.75	5.2	19.87	4.86	19.5	4.1	17.5	3.2	17.5	3.2	15.5	2.9	15.5	2.9
T_6	105.5	9	149.00	8.5	148.12	8.5	136.00	8.3	134.56	8.3	133.25	8.2	130.78	7.5	97.5	6.3	96.5	6.2	92.67	5.2	92.5	5.2
T_7	105.5	9	15.5	2.9	-																	
KW value	NA		192.84		191.75		184.12		183.0		174.31		173.25		165.188		163.15		143.90		142.98	
χ^2(0.05)	12.59				11.07																	

R - Rank M S – Mean score

Table 6(d). Effect of packaging on taste of mature varikka portions under refrigeration

Treatments	Taste – Days after storage: At the day of storage R	MS	2 R	MS	4 R	MS	6 R	MS	8 R	MS	10 R	MS	12 R	MS	14 R	MS	16 R	MS	18 R	MS	20 R	MS
T_1	105.5	9	53.5	7.5	53.5	7.5	49.60	7.2	45.60	6.9	45.6	6.9	40.6	6.5	37.6	6.0	35.6	5.7	30.80	5.1	30.80	5.1
T_2	105.5	9	62.5	7.3	62.5	7.3	62.1	7.3	62.1	7.3	58.09	7.1	58.09	7.1	45.5	6.2	45.5	5.8	40.5	5.3	40.5	5.3
T_3	105.5	9	114.96	8.3	114.96	8.3	114.96	8.3	113.96	8.1	110.9	7.9	110.96	7.9	100.8	7.2	100.8	7.2	95.5	6.5	95.5	6.5
T_4	105.5	9	165.5	8.9	165.5	8.9	165.5	8.9	165.5	8.9	165.5	8.8	165.5	8.6	163.5	8.4	163.5	8.3	161.5	8.1	158.3	7.5
T_5	105.5	9	24.30	5.5	24.30	5.5	18.5	5.1	18.5	5.1	17.5	4.5	16.5	4.1	16.5	4.0	16.5	3.9	15.5	3.2	15.5	3.2
T_6	105.5	9	123.6	8.4	123.6	8.4	122.7	8.3	122.7	8.3	121.1	8.2	121.1	7.6	118.5	7.2	115.5	6.9	105.5	6.7	105.5	6.7
T_7	105.5	9	15.5	3.1	-		-		-		-		-		-		-		--		-	
KW value	NA		160.28		160.28		158.22		157.78		152.63		151.54		147.79		146.89		143.90		142.78	
χ^2(0.05)	12.59				11.07																	

R - Rank M S – Mean score

Table 6(e.).Effect of packaging on texture of mature varikka portions under refrigeration

Treatments	Texture: Days after storage: At the day of storage		2		4		6		8		10		12		14		16		18		20	
	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS
T_1	105.5	9	65.00	7.8	65.00	7.8	65.00	7.8	64.5	7.5	63.45	7.1	63.4	7.1	56.45	6.1	40.6	5.9	30.80	4.6	30.08	4.6
T_2	105.5	9	69.05	8	69.05	8	68.68	7.9	67.56	7.7	65.35	7.4	65.05	7.3	65.5	6.4	58.09	6.1	40.5	4.8	40.5	4.8
T_3	105.5	9	115.45	8.2	115.45	8.2	114.54	8.2	113.5	8.1	112.0	7.9	112.0	7.4	111.5	7.2	110.96	6.5	95.5	5.9	94.5	5.8
T_4	105.5	9	166.5	9	166.5	9	166.5	8.9	165.5	8.8	165.5	8.8	165.5	8.8	164.5	8.6	165.5	8.1	161.5	7.9	161.5	7.9
T_5	105.5	9	19.87	5.1	19.5	5.0	17.5	4.5	17.5	4.4	17.5	4.3	17.5	4.2	16.5	3.9	16.5	3.5	15.5	3.1	15.5	3.1
T_6	105.5	9	118.21	8.4	118.21	8.4	117.5	8.3	116.0	8.2	115.45	8.0	114.0	7.5	113.89	7.3	121.1	6.6	105.5	6.1	105.5	6.1
T_7	105.5	9	15.5	2.9																		
KW value	NA		156.095		156.095		155.70		154.5		153.93		152.93		151.65		146.68		145.75		143.90	
χ^2 (0.05)	12.59				11.07																	

R - Rank M S – Mean score

Table 6(f). Effect of packaging on overall acceptability of mature varikka portions under refrigeration

Treatments	Overall acceptability: Days after storage: At the day of storage		2		4		6		8		10		12		14		16		18		20	
	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS
T_1	105.5	9	73.10	7.2	71.2	7.1	64.7	6.4	54.7	6.4	50.3	5.5	49.9	5.5	49.5	5.0	48.5	4.9	48.5	4.9	48.5	4.9
T_2	105.5	9	96.95	7.8	94.95	7.8	74.2	6.6	73.2	6.6	70.2	6.3	69.2	6.3	63.2	6.0	62.5	5.9	62.5	5.9	62.5	5.9
T_3	105.5	9	154.25	8.2	152.2	8.2	112.7	7.4	110.7	7.4	100.0	7.0	101.0	7.0	100.0	6.8	98.54	6.5	98.54	6.5	98.54	6.5
T_4	105.5	9	179.00	8.9	179.0	8.9	167.5	8.8	167.5	8.8	166.5	8.5	166.4	8.5	165.4	8.4	164.5	8.4	163.5	8.2	162.5	8
T_5	105.5	9	53.30	5.3	50.2	5.2	17.5	4.7	16.5	4.7	16.5	3.5	16.5	3.5	16.5	3.5	16.5	3.5	15.5	3.1	15.5	3.1
T_6	105.5	9	159.20	8.4	154.23	8.3	112.7	7.4	111.7	7.4	108.65	7.2	103.65	7.2	101.12	6.9	101.2	6.9	98.45	6.5	98.45	6.5
T_7	105.5	9	15.5	3.1																		
KW value	NA		184.13		180.24		165.188		162.188		165.02		161.02		160.26		158.45		157.43		156.45	
χ^2 (0.05)	12.59				11.07																	

R - Rank M S – Mean score

Maximum (163.2) mean rank value for flavor was for portioned jackfruit under vacuum packaging followed by portions packed under MAP in laminated pouches with silica gel (92.5) and shrink wrapped samples (91.00)(Table 6c.).

Highest (158.3) mean rank value for taste was for portioned jackfruit under vacuum packaging followed by sample packed under MAP in laminated pouches with silica gel (105.5). Unwrapped jackfruit had Least (15.5) mean value for taste (Table 6d).

Maximum (161.5) mean rank value for texture was for portioned jackfruit under vacuum packaging followed by portions packed under MAP in laminated pouches with silica gel (105.5). Least (15.50) mean value for texture was for unwrapped portioned jackfruit (Table 6e).

Maximum (162.5) mean rank value for overall acceptability was for portioned jackfruit under vacuum packaging followed by portions packed under MAP in laminated pouches with silica gel (92.45) and shrink wrapped samples (91.54). Unwrapped portions had least (15.5) mean rank value for overall acceptability (Table 6f).

As the ambient stored portions were spoilt within three days of storage organoleptic analysis could be made only for refrigerated portions.

4.1.2. Ripe varikka

4.1.2.1. Physiological Parameters

Effect of packaging and storage on physiological parameters of ripe varikka jackfruit portions at two days interval is shown below.

Table 7. Effect of packaging on shelf life (days) of ripe varikka portions under refrigeration

Treatment	Shelf life (days)
Polypropylene film (T_1)	5.66
Cling film wrapping (T_2)	6.66
Shrink wrapping (T_3)	8.66
Vacuum packaging (T_4)	12.33
MAP with $KMnO_4$ (T_5)	7.33
MAP with silica gel (T_6)	9.66
Unwrapped(T_7)	1.33
C.D(0.05)	1.02

Table 8. Effect of packaging on shelf life (days) of ripe varikka portions under ambient storage

Treatment	Shelf life (days)
Polypropylene film (T_1)	1.00
Cling film wrapping (T_2)	1..00
Shrink wrapping (T_3)	1.33
Vacuum packaging (T_4)	1.67
MAP with $KMnO_4$ (T_5)	1.33
MAP with silica gel (T_6)	1.33
Unwrapped(T_7)	0.00
C.D.	NS

Table 9. Effect of packaging on Physiological Loss in Weight (%) of ripe varikka portions under refrigeration

	PLW(%)						
	Days after storage						
Treatments	2	4	6	8	10	12	Mean
Polypropylene film (T_1)	0.30	1.93	3.47	5.06	6.61	8.26	3.66
Cling film wrapping (T_2)	0.299	2.78	5.02	7.41	9.85	12.17	15.35
Shrink wrapping (T_3)	0.59	1.34	2.10	2.89	3.55	4.53	2.14
Vacuum packaging (T_4)	0.32	0.47	0.84	1.12	2.30	2.50	1.08
MAP with $KMnO_4$ (T_5)	0.40	3.13	5.86	9.31	12.53	15.96	6.74
MAP with silica gel (T_6)	0.50	0.82	1.39	1.68	2.75	3.83	1.57
Unwrapped(T_7)	1.00	8.73	19.33	21.90	24.68	29.67	15.23
Mean	0.49	2.73	5.43	7.05	8.90	11.18	-
CD(0.05) Treatments - 0.12 Days – 0.12 T x D – 0.31							

4.1.2.1.2. Shelf Life (days)

The effect of packaging on shelf life of ripe varikka portions stored under refrigeration is shown in Table 7. There was significant difference in shelf life among the seven treatments. The ripe varikka jackfruit portions under vacuum packaging (T4) in laminated pouches showed the highest shelf life of 12.33 days. This was followed by portions packed under MAP in laminated pouches with silica gel (T6) having a shelf life of 9.66 days which was on par with portions packed under shrink wrapping (8.66 days). Least shelf life was recorded by unwrapped jackfruit portions with 1.33 days shelf life.

The effect of packaging on shelf life of ripe varikka portions stored under ambient storage condition is shown in Table 8. There was no significant difference among the treatments. However vacuum packed (T4) ripe varikka portions showed a considerably high shelf life (1.66 days)

4.1.2.1.2. Physiological Loss in Weight (%)

Effect of packaging on physiological loss in weight of ripe varikka jackfruit portions stored under refrigerated and ambient storage condition is shown in Table 9 and 10 respectively.

Mean physiological loss in weight was least (1.08%) for ripe varikka jackfruit portions under vacuum packaging in laminated pouches followed by the portions packed under MAP in laminated pouches with the silica gel sachets (1.57%). Highest (15.23%) weight loss was recorded by the unwrapped portions under refrigerated condition.

Under ambient storage physiological loss in weight was least (0.21%) for vacuum packed ripe varikka jackfruit portions and highest (1.10%) weight loss was

Table10. Effect of packaging on Physiological Loss in Weight (%) of ripe varikka jackfruit under ambient storage

PLW (%)			
Treatments	At the day of storage	Days after storage	
		2	Mean
Polypropylene film (T_1)	0.00	0.95	0.47
Cling film wrapping (T_2)	0.00	0.97	0.48
Shrink wrapping (T_3)	0.00	0.08	0.41
Vacuum packaging (T_4)	0.00	0.43	0.21
MAP with $KMnO_4$ (T_5)	0.00	1.03	0.51
MAP with silica gel (T_6)	0.00	0.80	0.40
Unwrapped (T_7)	0.00	2.20	1.10
Mean	0.00	1.03	
CD (0.05) Treatments – 0.12		Days – 0.06	T x D – 0.16

Table 11. Effect of packagingon marketability of ripe varikka portions under refrigeration

Treatments	Marketability (%)							
	At the time of storage	Days after storage						
		2	4	6	8	10	12	Mean
Polypropylene film (T_1)	100.00	63.33	50.00	46.66	40.00	26.66	20.00	49.52
Cling film wrapping (T_2)	100.00	60.00	46.66	40.00	30.00	16.66	10.00	43.33
Shrink wrapping (T_3)	100.00	80.00	76.66	70.00	66.66	56.66	50.00	71.42
Vacuum packaging (T_4)	100.00	100.00	80.00	73.33	70.00	70.00	70.00	80.47
MAP with $KMnO_4$ (T_5)	100.00	60.00	50.00	43.33	40.00	30.00	30.00	50.47
MAP with silica gel (T_6)	100.00	80.00	76.66	70.00	66.66	60.00	50.00	71.90
Unwrapped(T_7)	100.00	20.00	0.00	0.00	0.00	0.00	0.00	17.14
Mean	100.00	66.19	54.28	49.04	44.76	37.14	32.85	
CD(0.05) Treatments – 1.95			Days – 1.95		T x D – 5.18			

recorded by the unwrapped portions. The portioned jackfruits under ambient storage was spoilt within 2 days.

4.1.2.2. Marketability

The effect of packaging on marketability of ripe varikka jackfruit portions under refrigeration is shown in Table 11. Ripe varikka portions packed under vacuum in laminated pouches had highest mean marketability (80.47%). Portions packed under MAP in laminated pouches with silica gel and shrink wrapped fruit portions had marketablility of 71.90% and 71.42% respectively. The unwrapped portions had least marketability (17.14%).

As the ambient storage portions were spoilt within a day, evaluation of marketability could be made only for refrigerated portions.

4.1.2.3. Organoleptic parameters

Effect of packaging and storage on organoleptic parameters of ripe varikka jackfruit portions, as judged by sensory scoring for appearance, color, flavor taste, texture, and overall acceptability is shown in Table 12a- 12f.

Appearance was maximum (159.9) for samples under vacuum packaging followed by samples packed under MAP in laminated pouches with silica gel (120.4) and shrik wrapped portions (102.1) on 12 days after storage (Table 12a).

Portions under vacuum packaging in laminated pouches had maximum (159.8) mean rank value for color followed by portions packed under MAP in laminated pouches with silica gel (138.2) on 12 days after storage (Table 12b).

Maximum (165.5) mean rank value for flavor was obtained for portioned jackfruit under vacuum packaging. This was followed by portions packed under

Table 12(a). Effect of packaging on appearance of ripe varikka portions under refrigeration

Treatments	Appearance													
	Days after storage													
	At the day of storage		2		4		6		8		10		12	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	61.6	6.3	61.6	6.3	58.24	6.1	58.24	6.1	59.0	4.4	50.4	4.2
T_2	105.5	9	71.40	6.5	71.40	6.5	62.4	6.2	62.4	6.2	69.8	4.5	60.12	4.3
T_3	105.5	9	108.00	7.2	108.00	7.2	105.63	7.0	105.63	7.0	104.0	4.7	102.1	5.2
T_4	105.5	9	166.5	8.9	166.5	8.9	163.95	8.7	163.95	8.7	158.4	7.6	159.9	6.8
T_5	105.5	9	26.0	4.7	26.0	4.7	25.0	4.7	20.0	3.5	20.0	3.5	33.18	2.3
T_6	105.5	9	125.00	7.6	125.00	7.6	133.40	7.2	133.40	7.2	123.0	4.8	120.4	5.0
T_7	105.5	9	15.00	2.1	-		-		-		-		-	
KW value	NA		161.989		161.00		160.02		160.00		151.10		146.88	
χ^2 (0.05)	12.59				11.07									

R – Rank M S - Mean score

Table 12(b). Effect of packaging on color of ripe varikka portions under refrigeration

Treatments	Colour													
	Days after storage													
	At the day of storage		2		4		6		8		10		12	
	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score
T_1	105.5	9	65.0	7.1	60.2	7.0	60.0	6.2	70.4	6.1	70.6	5.9	46.9	3
T_2	105.5	9	54.8	7.4	67.6	7.3	67.4	5.9	53.6	5.8	53.9	6.2	62.7	3.6
T_3	105.5	9	120.5	8	112.0	8	112.0	7.2	114.2	7.2	114.2	7.2	108.5	5.5
T_4	105.5	9	165.5	9	161.0	9	161.0	8.2	154.6	8.2	154.6	8.2	159.8	7.4
T_5	105.5	9	21.75	3.9	21.75	4.0	16.00	3.8	16.00	3.8	15.5	3.2	15.7	2.9
T_6	105.5	9	120.5	8.3	126.7	8.3	126.7	7.7	129.1	7.5	134.1	7.7	138.2	6.6
T_7	105.5	9	15.5	2.8	-	-	-	-	-	-	-	-	-	
KW value	NA		169.98		164.41		163.32		163.20		162.55		162.00	
χ2 (0.05)	12.59				11.07									

R – Rank M S - Mean score

Table 12(c). Effect of packaging on flavor of ripe varikka portionsunder refrigeration

Flavor														
Treatments	Days after storage													
	At the day of storage		2		4		6		8		10		12	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	55.8	5.5	55.8	5.5	54.9	5.5	55.8	5.5	61.2	4.7	51.88	3.1
T_2	105.5	9	66.2	5.6	66.2	5.6	70.3	5.5	61.2	4.7	61.2	4.7	78.9	2.8
T_3	105.5	9	114.0	6.6	114.0	6.6	114.0	6.6	100.5	5.9	100.5	5.9	96.13	4.4
T_4	105.5	9	165.5	8.5	165.5	8.5	166.5	8.5	165.5	8.5	165.5	8.5	165.5	6.6
T_5	105.5	9	115.5	6.7	115.5	6.7	115.5	6.7	100.5	5.9	100.5	5.9	98.98	3.6
T_6	105.5	9	26.0	4.7	26.0	4.7	25.0	4.7	20.0	3.5	20.0	3.5	33.18	2.3
T_7	105.5	9	15.5	3.3	-		-		-		-		-	
KW value	NA		149.677		149.677		147.112		146.14		146.14		132.52	
χ^2 (0.05)	12.59				11.07									

R – Rank M S - Mean score

76

50

Table 12(d). Effect of packaging on taste of ripe varikka portions under refrigeration

Treatments	Taste													
	Days after storage													
	At the day of storage		2		4		6		8		10		12	
	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score
T_1	105.5	9	64.7	6.4	64.7	6.4	60.2	6.2	60.2	6.2	59.0	4.4	58.4	3.8
T_2	105.5	9	74.2	6.6	74.2	6.5	70.2	6.3	70.0	6.3	69.8	4.5	69.2	3.9
T_3	105.5	9	112.7	7.4	112.7	7.4	100.0	7.2	100.0	7.2	100.0	4.7	110.2	4.5
T_4	105.5	9	163.1	8.8	163.1	8.8	160.2	8.5	160.2	8.5	158.4	7.6	160.1	6.9
T_5	105.5	9	112.7	7.4	112.7	7.4	110.0	7.3	109.0	7.3	100.0	4.8	69.0	3.9
T_6	105.5	9	17.5	4.7	17.5	4.7	16.5	4.0	16.5	4.0	15.5	3.2	15.5	3.2
T_7	105.5	9	16.4	3.1	-		-		-		-		-	
KW value	NA		164.622		164.622		158.517		158.42		151.107		141.304	
χ^2 (0.05)	12.59				11.07									

R – Rank M S - Mean score

Table 12(e). Effect of packaging on texture of ripe varikka portions under refrigeration

Texture														
Treatments	Days after storage													
	At the day of storage		2		4		6		8		10		12	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	61.6	6.3	61.6	6.3	58.24	6.1	58.24	6.1	59.0	4.4	50.4	4.2
T_2	105.5	9	71.40	6.5	71.40	6.5	62.4	6.2	62.4	6.2	69.8	4.5	60.12	4.3
T_3	105.5	9	108.00	7.2	108.00	7.2	105.63	7.0	105.63	7.0	100.0	4.7	102.1	5.2
T_4	105.5	9	166.5	8.9	166.5	8.9	163.95	8.7	163.95	8.7	158.4	7.6	159.9	6.8
T_5	105.5	9	21.75	3.9	21.75	4.0	16.00	3.8	16.00	3.8	15.5	3.2	15.7	2.9
T_6	105.5	9	125.00	7.6	125.00	7.6	133.40	7.2	133.40	7.2	100.0	4.8	100.4	5.0
T_7	105.5	9	15.5	2.1	-		-		-		-		-	
KW value	NA		161.989		161.00		160.02		160.00		151.10		146.88	
χ^2 (0.05)	12.59				11.07									

R – Rank M S - Mean score

Table 12(f). Effect of packaging on overall acceptability of ripe varikka portions under refrigeration

Treatments	Overall acceptability													
	Days after storage													
	At the day of storage		2		4		6		8		10		12	
	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score
T_1	105.5	9	75.20	7.0	75.20	7.0	62.6	6.5	62.6	6.5	61.6	6.3	58.24	6.1
T_2	105.5	9	80.00	7.5	80.00	7.5	75.5	6.7	75.5	6.7	71.40	6.5	62.4	6.2
T_3	105.5	9	114.5	8.6	114.5	8.6	100.5	7.4	108.5	7.4	103.00	7.2	100.63	7.0
T_4	105.5	9	191.00	9.0	191.00	9.0	165.5	8.8	166.5	8.9	165.5	8.8	163.95	8.7
T_5	105.5	9	161.6	8.8	161.6	8.8	119.6	7.6	125.6	7.6	119.00	7.6	118.40	7.2
T_6	105.5	9	100.7	7.7	100.7	7.7	29.75	4.2	29.75	4.2	21.75	3.9	16.00	3.8
T_7	105.5	9	15.5	3.8	-		-		-		-		-	
KW value	NA		183.55		183.54		162.95		162.94		161.989		160.02	
$\chi2$ (0.05)	12.59				11.07									

R – Rank M S - Mean score

MAP in laminated pouches with silica gel (96.98) and shrink wrapped portions (96.13)(Table 12c).

Maximum mean rank value for taste(160.1) was for portioned jackfruit under vacuum packaging in laminated pouches followed by portions packed under MAP in laminated pouches with silica gel (110.0) on 12^{th} day of storage (Table 12d).

Maximum (159.9) mean rank value for texture was for portioned jackfruit under vacuum packaging followed by portions packed under MAP in laminated pouches with silica gel (102.1)(Table 12e).

Maximum (163.95) mean rank value for overall acceptability was for jackfruit portion under vacuum packaging fallowed by portions packed under MAP in laminated pouches with silica gel (118.40) and shrink wrapped portions (100.63)on 12 days after storage (Table 12f). Unwrapped ripe varikka jackfruit portions had least (15.5) mean rank value for color, taste, texture, flavor, appearance and overall acceptability at 2 days after storage. As the ambient storage portions were spoilt within a day, organoleptic analysis could be made only for refrigerated portions.

4.1.3. Mature Koozha

4.1.3.1. Physiological Parameters

Effect of packaging and storage on physiological parameters of mature koozha jackfruit portions at two days intervals is shown below.

4.1.3.1.1. Shelf Life (days)

The effect of packaging on shelf life of mature koozha jackfruit portions stored under refrigeration is shown in Table 13. There was significant difference in shelf life among the seven treatments. Mature koozha portions under vacuum packaging in laminated pouches had highest shelf life of 15.33 days which was

Table:13: Effect of packaging on shelf life (days) of mature koozha portions under refrigeration

Treatment	Shelf life (days)
Polypropylene film (T_1)	6.67
Cling film wrapping (T_2)	7.66
Shrink wrapping (T_3)	10.33
Vacuum packaging (T_4)	15.33
MAP with $KMnO_4$ (T_5)	10.00
MAP with silica gel (T_6)	12.33
Unwrapped(T_7)	1.66
C.D(0.05)	1.15

Table 14. Effect of packaging on shelf life (days) of mature koozha portions under ambient storage

Treatment	Shelf life(days)
Polypropylene film (T_1)	1.000
Cling film wrapping (T_2)	1.000
Shrink wrapping (T_3)	1.333
Vacuum packaging (T_4)	2.000
MAP with $KMnO_4$ (T_5)	1.333
MAP with silica gel (T_6)	1.333
Unwrapped(T_7)	0.000
C.D(0.05)	0.772

Table 15. Effect of packaging on Physiological Loss in Weight (%) of mature koozha portions under refrigeration

Treatments	PLW (%) Days after storage							
	2	4	6	8	10	12	15	Mean
Polypropylene film (T_1)	0.26	2.14	3.79	5.35	6.94	8.57	10.07	4.6
Cling film wrapping (T_2)	0.31	2.58	4.89	7.32	9.85	12.20	15.06	6.5
Shrink wrapping (T_3)	0.30	0.79	1.50	2.02	3.02	3.35	4.50	1.9
Vacuum packaging (T_4)	0.29	0.65	0.90	1.23	1.48	2.04	2.43	1.1
MAP with $KMnO_4$ (T_5)	0.28	3.54	6.61	9.97	13.07	15.05	18.55	8.3
MAP with silica gel (T_6)	0.29	0.70	1.08	1.51	1.86	2.32	2.80	1.3
Unwrapped(T_7)	4.63	9.01	13.75	17.59	20.23	25.05	29.56	15.0
Mean	0.91	2.77	4.65	6.41	8.07	9.80	11.92	
CD(0.05)	Treatments - 0.05			Days – 0.05		T x D – 0.15		

Table 16. Effect of packaging on Physiological Loss in Weight (%) of mature koozha portions under ambient storage

PLW (%)		
Treatments	Days after storage	
	2	Mean
Polypropylene film (T_1)	1.29	0.94
Cling film wrapping (T_2)	1.62	0.83
Shrink wrapping (T_3)	1.47	0.73
Vacuum packaging (T_4)	0.86	0.43
MAP with $KMnO_4$ (T_5)	1.40	0.70
MAP with silica gel (T_6)	2.50	1.25
Unwrapped(T_7)	4.27	2.31
Mean	1.92	
CD (0.05) Treatments – 0.326	Days – 0.176 T x D – 0.465	

followed by portions packed under MAP in laminated pouches with silica gel (T6) having shelf life of 12.33 days. Least shelf life was recorded by unwrapped jackfruit portions with 1.66 days of shelf life.

The effect of packaging on shelf life of mature koozha portions stored under ambient condition is shown in Table 14. There was significant difference in shelf life among the seven treatments. The vacuum packed (T4) mature koozha portions had highest shelf life of 2.00 days. Unwrapped jackfruit portions was spoilt within a day with least shelf life(0.00 days).

4.1.3.1.2. Physiological Loss in Weight (%)

Effect of packaging on physiological loss in weight (PLW) of mature koozha jackfruit portions stored under refrigerated condition is shown in Table 15. Mean physiological loss in weight was least (1.10%) for mature koozha portions under vacuum packaging in laminated pouches. This was followed by portions packed under MAP in laminated pouches with silica gel (1.30%) sachet. Highest mean weight loss (15.00%) was recorded by the unwrapped portions under refrigeration.

Effect of packaging on physiological loss in weight of mature koozha jackfruit portions stored under ambient condition is shown in Table 16. Under ambient condition Physiological loss in weight was least (0.43%) for mature koozha jackfruit portions packed under vacuum in laminate pouches which was on par with the portions packed under MAP in laminated pouches with silica gel (0.70%) and shrink wrapped portions (0.73%). Highest (2.31) mean weight loss was recorded by the unwrapped portions.

4.1.3.2. Marketability

Table 17. Effect of packaging on Marketability (%) of mature koozha portions under refrigeration

Treatment	Marketability (%)								
	At the time of storage	Days after storage							
		2	4	6	8	10	12	15	Mean
Polypropylene film (T_1)	100.00	76.66	70.00	53.33	43.33	40.00	30.00	20.00	54.16
Cling film wrapping (T_2)	100.00	66.66	60.00	43.33	40.00	33.33	23.33	20.00	48.33
Shrink wrapping (T_3)	100.00	80.00	80.00	70.00	60.00	56.66	43.33	33.33	66.66
Vacuum packaging (T_4)	100.00	100.00	100.00	100.00	80.00	80.00	80.00	70.00	88.75
MAP with $KMnO_4$ (T_5)	100.00	63.33	60.00	53.33	53.33	43.33	26.66	23.33	52.91
MAP with silica gel (T_6)	100.00	83.3	83.33	73.3	60.0	60.00	50.00	40.0	67.5
Unwrapped(T_7)	100.00	23.33	0.00	0.00	0.00	0.00	0.00	0.00	15.41
Mean	100.00	70.47	64.76	56.19	48.09	44.76	36.19	29.52	
CD(0.05)	Treatments– 1.976			Days – 2.113			T x D - 5.589		

The effect of packaging treatments on marketability of mature koozha jackfruit portions shown in Table 17. The vacuum packed (T4) jackfruit portions had highest marketability of 88.75%. This was followed by jackfruit portions packed under MAP in laminated pouches with silica gel (T6) having 67.50% marketability. The unwrapped portions (T7) had lowest marketability of 15.41%. As ambient stored portions were spoilt within a day, observation on marketability could be recorded only for refrigerated portions.

4.1.2.3. Organoleptic parameters

Effect of packaging and storage on organoleptic parameters of mature koozha jackfruit portions, as judged by sensory scoring for appearance, color, flavor, taste, texture, and overall acceptability is shown in Table 18a – 18f.

Mean rank value for appearance was maximum (163.20) for mature koozha jackfruit portions under vacuum packaging in laminated pouches on 15th day of storage followed by portions packed under MAP in laminated pouches with silica gel (112.67) and shrink wrapped portions (111.00). Unwrapped portions had least (15.50) mean rank value for appearance (Table 18a) .

Vacuum packed portions in laminated pouches had maximum (161.3) mean rank value for colour and least (15.5) mean rank value for color was recorded by the unwrapped jackfruit portions (Table 18b). Maximum (165.5) mean rank value for flavor was for the portions under vacuum packaging in laminated pouches on 15th day of storage followed by portions packed under MAP in laminated pouches with silica gel (98.5) and shrink wrapped samples (94.5)(Table 18c).

Maximum (161.5) mean rank value for taste was recorded by the jackfruit portions under vacuum packaging followed by portions packed under MAP in

Table 18(a). Effect of packaging on appearance of mature koozha portions under refrigeration

Treatments	Appearance															
	Days after storage															
	At the day of storage		2		4		6		8		10		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	81.65	6.9	81.65	6.9	61.1	6.5	60.1	6.5	47.6	5.5	46.6	5.5	45.5	4.2
T_2	105.5	9	95.75	7.0	94.75	7.0	93.5	6.7	93.5	6.7	84.8	5.6	84.8	5.6	84.00	4.3
T_3	105.5	9	131.00	8.2	131.00	8.2	123.8	7.8	122.8	7.8	123.8	7.4	120.8	7.4	111.00	6.1
T_4	105.5	9	191.00	8.9	191.00	8.9	165.5	8.6	165.5	8.6	165.5	7.9	164.5	7.9	163.20	6.9
T_5	105.5	9	62.90	6.4	62.90	6.4	28.7	5.1	26.7	5.1	15.5	3.9	15.5	3.9	15.5	3.2
T_6	105.5	9	149.00	8.3	148.00	8.3	132.23	7.9	130.23	7.9	128.5	7.5	128.5	7.5	112.67	6.2
T_7	105.5	9	15.5	2.9	-		-		-		-		-		-	
KW value	NA		174.31		171.32		156.73		154.67		147.79		147.12		146.68	
$\chi 2$ (0.05)	12.59				11.07											

R – Rank M S – Mean Score

Table 18(b). Effect of packaging on color of maturekoozha portions under refrigeration

colour																
Treatments	Days after storage															
	At the day of storage		2		4		6		8		10		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	73.10	7.2	71.2	7.1	64.7	6.4	54.7	6.4	50.3	5.5	49.9	5.5	49.5	5.0
T_2	105.5	9	96.95	7.8	94.95	7.8	74.2	6.6	73.2	6.6	70.2	6.3	69.2	6.3	63.2	6.0
T_3	105.5	9	154.25	8.2	152.2	8.2	112.7	7.4	110.7	7.4	100.0	7.0	101.0	7.0	100.0	6.8
T_4	105.5	9	179.00	8.9	179.0	8.9	163.1	8.8	162.1	8.8	162.2	8.5	162.2	8.5	161.3	7.1
T_5	105.5	9	50.75	5.6	49.75	5.6	44.0	4.9	16.5	3.5	15.5	3.2	15.5	3.2	15.5	2.8
T_6	105.5	9	159.20	8.4	154.23	8.3	112.7	7.4	111.7	7.4	108.65	7.2	103.65	7.2	101.12	6.9
T_7	105.5	9	15.5	3.2	-		-		-		-		-		-	
KW values	NA		184.68		181.21		164.622		162.61		160.07		159.07		158.22	
$\chi 2$ (0.05)	12.59				11.07											

R – Rank M S – Mean Score

Table 18(c). Effect of packaging on flavor of maturekoozha portions under refrigeration

Flavor																
Treatments	Days after storage															
	At the day of storage		2		4		6		8		10		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	89.15	6.9	89.15	6.9	81.65	6.9	81.65	6.9	80.15	6.5	80.15	6.5	70.5	4.2
T_2	105.5	9	99.35	6.8	99.35	6.8	95.75	7.0	95.75	7.0	91.25	6.6	91.25	6.6	81.5	4.3
T_3	105.5	9	116.9	7.4	116.9	7.4	116.00	8.2	116.00	8.2	104.5	7.2	104.5	7.2	94.5	5.1
T_4	105.5	9	194.15	8.9	194.15	8.9	191.00	8.9	191.00	8.9	165.5	8.5	165.5	8.5	165.5	6.9
T_5	105.5	9	62.90	6.4	62.90	6.4	28.7	5.1	26.7	5.1	15.5	3.9	15.5	3.9	15.5	3.2
T_6	105.5	9	160.55	7.8	160.55	7.8	159.00	8.3	159.00	8.3	106.3	7.4	106.3	7.4	98.5	5.2
T_7	105.5	9	15.5	3.1	-		-		-		-		-		-	
KW value	NA		184.13		184.13		174.31		173.33		165.188		164.188		163.16	
χ^2 (0.05)	12.59				11.07											

R – Rank M S – Mean Score

Table 18(d). Effect of packaging on taste of mature koozha portions under refrigeration

Taste																
Treatments	Days after storage															
	At the day of storage		2		4		6		8		10		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	80.9	7.5	78.9	7.5	70.5	7.2	68.5	7.2	53.00	5.6	50.00	5.6	37.80	4.2
T_2	105.5	9	102.65	7.8	101.65	7.8	95.5	7.5	89.5	7.5	75.5	5.8	72.5	5.8	64.9	4.5
T_3	105.5	9	143.75	8.4	141.75	8.4	139.5	8.2	134.5	8.2	123.5	6.9	119.5	6.9	105.5	5.2
T_4	105.5	9	190.7	8.9	175.7	8.9	165.5	8.8	165.5	8.8	165.5	8.5	165.5	8.5	161.5	6.8
T_5	105.5	9	154.25	8.5	154.25	8.5	117.5	8.3	115.5	8.3	117.5	6.5	117.5	6.5	116.5	5.1
T_6	105.5	9	50.75	5.6	49.75	5.6	44.0	4.9	16.5	3.5	15.5	3.2	15.5	3.2	15.5	2.8
T_7	105.5	9	15.5	2.9	-		-		-		-		-		-	
KW value	NA		192.84		184.12		163.16		161.18		160.79		159.79		143.90	
χ^2 (0.05)	12.59				11.07											

R – Rank M S – Mean Score

Table 18(e). Effect of packaging on texture of mature koozha portions under refrigeration

Treatments	Texture															
	Days after storage															
	At the day of storage		2		4		6		8		10		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	89.15	6.9	85.15	6.8	80.15	6.5	78.15	6.5	66.5	5.4	64.5	5.4	38.6	4.2
T_2	105.5	9	99.35	6.8	94.35	6.9	91.25	6.6	84.25	6.6	70.5	5.6	69.5	5.6	67.4	4.8
T_3	105.5	9	116.9	7.4	113.9	7.4	104.5	7.2	104.5	7.2	100.5	6.9	98.5	6.9	89.15	5.1
T_4	105.5	9	194.15	8.9	194.15	8.9	165.5	8.5	165.5	8.5	163.95	7.9	163.95	7.9	161.00	6.9
T_5	105.5	9	160.55	7.8	158.55	7.8	106.3	7.4	102.3	7.4	105.2	7.0	103.2	7.0	102.00	5.2
T_6	105.5	9	62.90	6.4	62.90	6.4	28.7	5.1	26.7	5.1	15.5	3.9	15.5	3.9	15.5	3.2
T_7	105.5	9	15.5	3.1	-											
KW value	NA		184.13		180.24		165.188		162.188		165.02		161.02		160.26	
$\chi2$ (0.05)	12.59				11.07											

R – Rank M S – Mean Score

Table 18(f). Effect of packaging on overall acceptability of mature koozha portions under refrigeration

Treatments	overall acceptability															
	Days after storage															
	At the day of storage		2		4		6		8		10		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
T_1	105.5	9	81.65	6.9	80.65	6.8	80.15	6.5	70.5	6.2	69.5	6.2	47.6	5.5	45.5	4.2
T_2	105.5	9	95.75	7.0	95.75	7.0	91.25	6.6	81.5	6.4	81.5	6.4	80.8	5.6	74.00	4.3
T_3	105.5	9	131.00	8.2	130.12	8.2	104.5	7.2	94.5	7.0	94.5	7.0	92.5	6.9	91.00	6.1
T_4	105.5	9	191.00	8.9	190.00	8.9	165.5	8.5	165.5	8.4	165.5	8.4	164.5	8.3	163.20	8
T_5	105.5	9	149.00	8.3	148.00	8.3	106.3	7.4	98.5	7.1	97.5	7.1	95.5	6.8	92.67	6.2
T_6	105.5	9	74.60	5.2	74.60	5.2	28.7	5.1	15.5	4.2	15.5	4.2	15.5	3.2	15.5	2.9
T_7	105.5	9	15.5	2.9	-		-		-		-		-		-	
KW value	NA		174.31		172.32		165.188		163.16		162.12		147.79		146.68	
χ^2 (0.05)	12.59				11.07											

R – Rank M S – Mean Score

laminated pouches with silica gel (116.5). Least (15.5) mean rank value for taste was recorded by the unwrapped jackfruit portions (Table 18d).

Maximum mean rank value for texture (161.00) was for mature koozha mature portions under vacuum packaging in laminated pouches followed by samples packed under MAP in laminated pouches with silica gel (102.00). Least (15.50) mean rank value for texture was for unwrapped portioned jackfruit (Table 18e).

Maximum (163.20) mean rank value for overall acceptability was for portioned jackfruit under vacuum packaging followed by portions packed under MAP in laminated pouches with silica gel sachet (92.67) and shrink wrapped portions (91.00). Least (15.5) mean rank value was for unwrapped jackfruit portions (Table 18f). As the ambient stored fruits were spoilt within a day, organoleptic analysis could made only for refrigerated portions

Based on the effectiveness of packaging and storage treatments in maintaining physiological parameters, oraganoleptic quality and marketability, vacuum packaging in laminated pouches of PP/LDPE under refrigeration was selected as the best packaging and storage treatment for further study.

4.2. QUALITY EVALUATION OF SELECTED TREATMENT

Harvested jackfruit were cleaned, outer spiny rind removed, cut into portions, pretreated with KMS (0.5%) and citric acid (0.5%) solution, surface drained and subjected to vacuum packaging in laminated pouches of PP/LDPE and stored under refrigeration (Selected from Part 1). The stored jackfruit portions were evaluated for quality parameters at three days interval and compared with unwrapped portions kept under refrigeration.

As the experiment was conducted independently for the three jack fruit types viz., mature varikka, ripe varikka and mature koozha, the results are also presented independently for the three types.

4.2.1. Mature varikka

4.2.1.1. Physiological Parameters

Physiological parameter of mature varikka jackfruit portions recorded at three days intervals is shown below.

4.2.1.1.1. Shelf life (days)

Shelf life of both mature varikka portions stored under refrigeration is shown in Table 19. Shelf life was high (21.00 days) for vacuum packed mature varikka portions stored under refrigeration in laminated pouches and low shelf life (4.28 days) was recorded by the unwrapped jackfruit portions.

4.2.1.1.2. Physiological Loss in Weight (%)

Physiological loss in weight of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions (Table 20a). As the unwrapped portions were spoilt after 3 days of storage, they were discarded and comparison between the treatments for physiological loss in weight could be made only up to 3 days.

Mean physiological loss in weight was less (0.18) for vacuum packed mature varikka portions and high (0.32) weight loss was recorded by the unwrapped portions under refrigeration (Table 20a.)

Physiological loss in weight of portions under vacuum packaging and refrigeration was recorded till the end of shelf life. Physiological loss in weight of vacuum packed portions under refrigeration gradually increased from 0.45% on 6^{th} day to 2.34% on 21^{st} day of storage (Table 20b.).

Table 19. Shelf life (days) of maturevarikka portions

Treatment	Shelf life(days)
Vacuum packed portions under refrigeration	21.00
Unwrapped portions under refrigeration	4.28
C.D.	9.26

Table 20(a). Physiological loss in weight (%) mature varikka portions till 3 days of storage

PLW %		
Treatments	Days after storage	
	3	Mean
Vacuum packaging	0.37	0.37
Unwrapped	0.96	0.96
Mean	1.33	
CD(0.05) Treatments –0.062 Days -0.062 T x D- 0.107		

Table 20(b). Physiological loss in weight (%)of vacuum packed mature varikka portions during storage

Days after storage	PLW (%)*
6	0.68
9	0.98
12	1.24
15	1.56
18	2.01
21	2.34

*Average of seven replicated values

Table 21. O_2 and CO_2 (%) evaluation rate of mature varikka portions

	O_2 and CO_2 evaluation rate (%)															
Treatments			3		6		9		12		15		18		21	
	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
Vacuum packed portions under refrigeration	4%	2%	4%	2%	3%	4%	3%	4%	2.5%	4%	2%	5%	1%	6%	1%	6%

4.2.1.1.3. O_2 and CO_2 evolution rate

Oxygen and carbon dioxide rate of mature varikka jackfruit portions under vacuum packaging and refrigerated storage is shown in Table 21. At the time of storage oxygen concentration was 2% and CO_2 concentration was 4%. By the end of shelf life (21st day) oxygen concentration was decreased to 1% and CO_2 rate increased to 6%.

4.2.1.2. Chemical parameters

Chemical parameters of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was recorded compared with unwrapped portions up to three days. As the unwrapped portions were spoilt after 3 days of storage (4.28 days) , they were discarded and comparison between the treatments for chemical parameters could be made only up to 3 days.

Chemical parameters of portions under vacuum packaging and refrigeration was recorded till the end of their shelf life.

4.2.1.2.1. TSS

TSS of the portions packed and stored using the selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days and shown in Table 22a. TSS of portions under vacuum packaging and refrigeration was recorded till 21st day, the end of shelf life (Table 22b.).

TSS was less (9.47) for vacuum packed mature varikka portions and high (13.13) TSS was recorded by the unwrapped portions under refrigeration (Table 22a.) on 3rd day of storage.

Table:22(a): TSS (ºB)of mature varikka portions till 3 days of storage

TSS (ºB)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	8.40	10.54	9.47
Unwrapped portions under refrigeration	8.40	17.87	13.13
Mean	8.40	14.20	
CD(0.05)	Treatments - 0.048	Days -0.058	T x D- 0.082

Table:22(b): TSS (ºB)of vacuum packed mature varikka portions during storage

Days after storage	TSS (ºB)*
6	11.82
9	11.82
12	13.65
15	18.54
18	21.34
21	22.53

*Average of seven replicated values

Table:23(a): Reducing sugars (%)of mature varikka portions till 3 days of storage

Reducing sugars (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	9.50	9.60	9.55
Unwrapped portions under refrigeration	9.50	9.87	9.68
Mean	9.50	9.73	
CD(0.05)	Treatments - 0.016	Days -0.019	T x D- 0.028

Table:23(b): Reducing sugars (%)of vacuum packed mature varikka portions during storage

Days after storage	Reducing sugars (%)*
6	10.15
9	10.48
12	10.60
15	10.82
18	11.17
21	11.48

*Average of seven replicated values

TSS of vacuum packed portions under refrigeration gradually increased from 11.82 °B on 6th day to 22.53 °B on 21st day of storage (Table 22b.).

4.2.1.2.2. Sugars (reducing, non-reducing &total) (%)

4.2.1.2.2.1. Reducing sugar

Reducing sugar of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days and shown in Table 23a. Reducing sugar of portions under vacuum packaging and refrigeration was recorded till 21st day, the end of shelf life (Table 23b).

Reducing sugar was less (9.47 %) for vacuum packed mature varikka portions and high (13.13%) reducing sugar was recorded by the unwrapped portions under refrigeration (Table 23a.) on 3rd day of storage.

Reducing sugar of vacuum packed portions under refrigeration gradually increased from 10.15% on 6th day to 11.48% on 21st day of storage (Table 23b.).

4.2.1.2.2.2. Non reducing sugar(%)

Non reducing sugar of the portions packed and stored using selected treatment of vacuum packaging under refrigeration was compared with unwrapped portions up to three days and shown in Table 24a. Non reducing sugar of portions under vacuum packaging and refrigeration was recorded till 21st day, the end of shelf life (Table 24b.).

Non reducing sugar was less (16.65%) for vacuum packed mature varikka portions and high (17.16%) non reducing sugar was recorded by the unwrapped portions under refrigeration (Table 24a.) on 3rd day of storage.

Table:24(a):Non Reducing sugars (%)of mature varikka portions till 3 days of storage

Non Reducing sugars (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	16.62	16.69	16.65
Unwrapped portions under refrigeration	16.62	17.71	17.16
Mean	16.62	17.20	
CD(0.05) Treatments - 0.017 Days -0.021 T x D- 0.029			

Table:24(b):Non Reducing sugars (%)of vacuum packed mature varikka portions during storage

Days after storage	Non Reducing sugars (%)*
6	16.69
9	16.69
12	16.69
15	16.98
18	16.98
21	16.98
*Average of seven replicated values	

Table:25(a):Total sugars (%)of mature varikka portions till 3 days of storage

Total sugars (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	26.12	26.27	26.19
Unwrapped portions under refrigeration	26.12	27.60	26.86
Mean	26.12	26.93	
CD(0.05) Treatments - 0.019 Days -0.023 T x D- 0.033			

Table:25(b):Total sugars (%)of vacuum packed mature varikka portions during storage

Days after storage	Total sugars (%)*
6	26.50
9	26.50
12	26.81
15	27.06
18	27.30
21	27.42
*Average of seven replicated values	

Table:26(a): Vitamin C(mg $100g^{-1}$)of mature varikka portions till 3 days of storage

Vitamin C(mg $100g^{-1}$)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	5.53	5.18	5.35
Unwrapped portions under refrigeration	5.53	4.90	5.21
Mean	5.53	5.04	
CD(0.05) Treatments - 0.008 Days -0.010 T x D- 0.014			

Table:26(b): Vitamin C(mg $100g^{-1}$)of vacuum packed mature varikka portions during storage

Days after storage	Vitamin C(mg $100g^{-1}$)*
6	4.52
9	4.43
12	4.15
15	3.87
18	3.11
21	2.58
*Average of seven replicated values	

Table:27(a): Total carotenoids (mg $100g^{-1}$)of mature varikka portions till 3 days of storage

Total carotenoids (mg $100g^{-1}$)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	0.35	0.37	0.36
Unwrapped portions under refrigeration	0.35	0.38	0.36
Mean	0.35	0.37	
CD(0.05) Treatments - 0.000 Days -0.000 T x D- 0.001			

Table:27(b):Total carotenoids (mg $100g^{-1}$)of vacuum packed mature varikka portions during storage

Days after storage	Total carotenoids (mg $100g^{-1}$)*
6	0.32
9	0.32
12	0.38
15	0.39
18	0.40
21	0.40
*Average of seven replicated values	

Non reducing sugar of vacuum packed portions under refrigeration gradually increased from 16.69% on 6^{th} day to 16.98% on 21^{st} day of storage (Table 24b.).

4.2.1.2.2.3. Total sugar(%)

Total sugar of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days and shown in Table 25a. Total sugar of portions under vacuum packaging and refrigeration was recorded till 21^{st} day, the end of shelf life (Table 25b).

Total sugar was less (26.19%) for vacuum packed mature varikka portions and high (26.89%) total sugar was recorded by the unwrapped portions under refrigeration (Table 25a.) on 3^{rd} day of storage.

Total sugar of vacuum packed portions under refrigeration gradually increased from 26.52% on 6^{th} day to 27.42% on 21^{st} day of storage (Table 25b.).

4.2.1.2.3. Vitamin C (mg $100g^{-1}$)

Vitamin C content of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days and shown in Table 26a. Vitamin C content of portions under vacuum packaging and refrigeration was recorded till 21^{st} day, the end of shelf life (Table 26b.).

Vitamin C content was high (5.35 mg $100g^{-1}$) for vacuum packed mature varikka portions and low (5.21 mg $100g^{-1}$) vitamin C was recorded by the unwrapped portions under refrigeration (Table 26a.) on 3^{rd} day of storage.

Table:28(a):Titrableacidity (%)of mature varikka portions till 3 days of storage

Titrable acidity (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	0.008	0.008	0.008
Unwrapped portions under refrigeration	0.008	0.007	0.007
Mean	0.008	0.007	
CD(0.05)	Treatments - 0.000	Days -0.000	T x D- 0.000

Table:28(b):Titrableacidity(%)of vacuum packed mature varikka portions during storage

Days after storage	Titrable acidity (%)*
6	0.005
9	0.005
12	0.004
15	0.004
18	0.002
21	0.001
*Average of seven replicated values	

Table:29(a):Total Phenol (mg $100g^{-1}$)of mature varikka portions till 3 days of storage

Total Phenol (mg $100g^{-1}$)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	60.29	60.29	60.29
Unwrapped portions under refrigeration	60.29	61.23	60.76
Mean	60.29	60.76	
CD(0.05)	Treatments - 0.000	Days -0.000	T x D- 0.000

Table:29(b):Total Phenol (mg $100g^{-1}$) of vacuum packed mature varikka portions during storage

Days after storage	Total Phenol (mg $100g^{-1}$)*
6	60.29
9	60.29
12	60.29
15	59.78
18	59.21
21	58.50
*Average of seven replicated values	

Vitamin C content of vacuum packed portions under refrigeration gradually decreased from 4.52 mg $100g^{-1}$ on 6^{th} day to 2.58 mg $100g^{-1}$ on 21^{st} day of storage (Table 26b.).

4.2.1.2.4. Total carotenoids (mg $100g^{-1}$)

Total carotenoids of the bulbs extracted from portions packed and stored using selected treatment (vacuum packaging under refrigeration) could be compared with unwrapped portions only up to three days. There was no significant difference between the treatments for total carotenoid content (Table 27a.) on 3^{rd} day of storage.

Total carotenoid content of portions under vacuum packaging and refrigeration was recorded till 21^{st} day, the end of shelf life (Table 27b.). Total carotenoids content of vacuum packed portions under refrigeration gradually increased from 0.32mg $100g^{-1}$on 6^{th} day to 0.40 mg $100g^{-1}$on 21^{st} day of storage (Table 27b.).

4.2.1.2.5. Titrable acidity (%)

Titrable acidity of both mature varikka portions stored under refrigeration up to 3^{rd} day of storage is shown in Table 28a. Titrable acidity was high (0.008%) for mature varikka portions under vacuum packaging in laminated pouches and low acidity (0.007%) was recorded by the unwrapped portions.

Titrable acidity content of vacuum packed portions gradually decreased from 0.005% on 6^{th} day to 0.001% on 21^{st} day of storage (Table 28b).

Table:30(a):Marketability (%) of mature varikka portions till 3 days of storage

Marketability (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	100.00	100.00	100.00
Unwrapped portions under refrigeration	100.00	0.00	50.00
Mean	100.00	50.00	
CD(0.05) Treatments – 1.371 Days -1.680 T x D- 2.375			

Table:30(b): Marketability (%) of vacuum packed mature varikka portions during storage

Days after storage	Marketability (%)*
6	100.00
9	100.00
12	96.00
15	90.00
18	85.00
21	80.00
*Average of seven replicated values	

Table:31(a):Appearance of mature varikka portions

Treatments	Days after storage															
	At the day of storage		3		6		9		12		15		17		20	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packaging	30.5	9	45.5	9	45.5	9	15.00	9	15.0	8.9	15.0	8.5	15.0	8.5	15.0	8.5
Unwrapped	30.5	9	15.5	3.2	--											
KW value	NA		53.393		47.55		0.0000		0.000		0.0000		0.0000		0.000	
χ^2 **(0.05)**	1.79															

R – Rank
M S –Mean score

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

Total phenol content of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days and shown in Table 29a. Total phenol of portions under vacuum packaging and refrigeration was recorded till 21st day, the end of shelf life (Table 29b.).

Total phenol was low (60.29 mg 100g^{-1}) for vacuum packed mature varikka portions and high (60.76 mg 100g^{-1}) total phenol was recorded by the unwrapped portions under refrigeration (Table 29a.) on 3rd day of storage.

Total phenol content of vacuum packed portions under refrigeration gradually decreased from 60.29mg 100g^{-1}on 6th day to 58.50 mg 100g^{-1}on 21st day of storage (Table 29b.).

4.2.1.3. Marketability

As the unwrapped portions were spoilt by the 3rd day of storage, comparison between the treatments for marketability parameters could be made only up to 3rd day of storage.

Mature varikka jackfruit portions kept in refrigerated storage under vacuum packaging in laminated pouches had 100% marketability, whereas unwrapped portions had 50% marketability on 3rd day of storage (Table 30a).

Marketability of jackfruit portions under vacuum packaging in laminated pouches was gradually decreased from 100% on 6th day to 80 % on 21st day of storage (Table 30b.).

4.2.1.4. Organoleptic quality (hedonic rating)

Organoleptic evaluation of mature varikka jackfruit portions, subjected to selected treatments as well as untreated portions are shown in Tables 31 a to 31f.

Mature varikka portions subjected to vacuum packaging and refrigeration had mean score of 8.0 for appearance and taste , 7.5 for flavor, 8.4 for texture and 8.5 for overall acceptability on 21^{st} day of storage,

The unwrapped portion kept under refrigeration had a mean score of 2.9 for all parameters by the end of 6^{th} day of storage.

4.2.1.5. Physical parameters

Physical parameters like colour and texture of the jackfruit portions under vacuum packaging and refrigeration were compared with unwrapped portions. As the unwrapped portions were spoilt after three days of storage, comparison between the treatments for physical parameters could be made only up to three days. Physical parameters of portions under vacuum packaging and refrigeration was recorded till 21^{st} day, the end of shelf life.

4.2.1.5.1. Colour

Colour of mature vacuum packed varikka portions stored under refrigeration had a cream colour with 0.370 mg $100g^{-1}$ carotenoid content and unwrapped portions was also cream color with 0.477 mg $100g^{-1}$ carotenoid content at the 6^{th} days after storage. Colour of vacuum packed varikka portions stored under refrigeration was cream in colour with 0.409 mg $100g^{-1}$ carotenoid content at the 21^{st} day after storage(Table 32).

Table:31(b):Colourof mature varikka portions

Treatments	Days after storage															
	At the day of storage		3		6		9		12		15		17		20	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packaging	30.5	9	45.5	9	45.5	9	15.00	9	15.0	8.5	15.0	8.5	15.0	8.5	15.00	8.5
Unwrapped	30.5	9	15.50	2.9	15.50	2.5	--									
KW value	NA		63.393		56.55		0.0000		0.000		0.0000		0.0000		0.000	
χ^2 **(0.05)**	1.79															

R – Rank
M S –Mean score

Table:31(c): Flavor of mature varikka portions

Treatments	Days after storage															
	At the day of storage		3		6		9		12		15		17		20	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packaging	30.5	9	45.5	9	45.5	9	15.00	9	15.0	8.9	15.0	8.5	15.0	8.5	15.0	7.5
Unwrapped	30.5	9	15.5	3.2	--											
KW value	NA		53.393		47.55		0.0000		0.000		0.0000		0.0000		0.000	
χ^2 **(0.05)**	1.79															

R – Rank
M S –Mean score

Table:31(d): Taste of mature varikka portions

Treatments	Days after storage															
	At the day of storage		3		6		9		12		15		17		20	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packaging	30.5	9	45.5	9	45.5	9	15.0	9	15.0	8.9	15.0	8.5	15.0	8.5	15.0	8.5
Unwrapped	30.5	9	15.50	3.2	-											
KW value	NA		53.393		47.55		0.0000		0.000		0.0000		0.0000		0.000	
χ^2 **(0.05)**	1.79															

R – Rank
M S –Mean score

Table:31(e): Texture of mature varikka portions

Treatments	Days after storage															
	At the day of storage		3		6		9		12		15		17		20	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packaging	30.5	9	45.5	9	45.5	9	15.0	9	15.0	8.9	15.00	8.5	15.0	8.5	15.0	8.4
Unwrapped	30.5	9	15.5	3.2	--											
KW value	NA		53.393		47.55		0.0000		0.000		0.0000		0.0000		0.000	
χ^2 **(0.05)**	1.79															

R– Rank   MS-Mean score

Table:31(f): Overall acceptabilityof mature varikka portions

Treatments	Overall acceptability															
	Days after storage															
	At the day of storage		3		6		9		12		15		17		20	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packaging	30.5	9	45.5	9	45.5	9	15.00	9	15.0	8.9	15.0	8.8	15.0	8.6	15.0	8.5
Unwrapped	30.5	9	15.5	3.2	15.50	2.9	--									
KW value	NA		53.393		47.55		0.0000		0.000		0.0000		0.0000		0.000	
χ^2 **(0.05)**	1.79															

R – Rank
M S –Mean score

Table:32: Colourof mature varikka portions

treatments	At the time of storage		Days after storage													
			3		6		9		12		15		17		21	
	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C
Vacuum	0.370	Cream	0.370	Cream	0.370	cream	0.370	Cream	0.378	Cream	0.378	cream	0.409	cream	0.409	cream
Control	0.370	Cream	0.477	Cream	-	-	-		-		-		-		-	

C – carotenoid content
BC- bulb colour

110
84

4.2.1.5.2. Texture

Texture, expressed as flesh firmness, of mature vacuum packed varikka portions stored under refrigeration had high firmness with 3.30 N and unwrapped portions had less texture value of 2.18N at the 3rd day of storage. Firmness of vacuum packed varikka portions stored under refrigeration gradually decreased from 2.79N on 6th day to 1.56N on 21st day of storage (Table 33).

4.2.1.6. Microbial load

Microbial load in the vacuum packaged jackfruit portions stored under refrigeration were compared with unwrapped portions. As the unwrapped portions were spoilt after three days of storage, comparison between the treatments for microbial load could be made only up to three days. Microbial load in the portions under vacuum packaging and refrigeration was recorded till 21st day, the end of shelf life.

Bacterial load was less (0.89 x 10^4 cfu/g) in refrigerated mature varikka portions under vacuum packaging in laminated pouches and it was high (4.38 x 10^4 cfu/g) in unwrapped jackfruit portions on 3rd day of storage (Table 34a). Bacterial count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased from 1.21 x 10^4 cfu/g on 6th day to 2.34 x 10^4 cfu/g on 21st day of storage (Table 34b).

Fungal count was less (1.28 x 10^3cfu/g) in refrigerated mature varikka portions under vacuum packaging in laminated pouches and the it was high (8.98 x 10^3cfu/g) in unwrapped jackfruit portions on 3rd day of storage (Table 34a). Fungal count of portions under vacuum packaging in laminated pouches and kept under

Table:33(a): Texture (N) of mature varikka portions till 3 days of storage

Texture (N)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	3.65	2.95	3.3
Unwrapped portions under refrigeration	3.65	0.71	2.18
Mean	3.65	1.83	
CD(0.05) Treatments – 0.00 Days -0.00 T x D- 0.00			

Table:33(b): Texture (N) of vacuum packed mature varikka portions during storage

Days after storage	Texture (N) *
6	2.79
9	2.78
12	2.77
15	2.76
18	2.69
21	1.56
*Average of seven replicated values	

Table:34(a): Bacterial count of mature varikka portions till 3 days of storage

Bacterial count x 10^4 cfu/g		
Treatments	Days after storage	
	3	Mean
Vacuum packed portions under refrigeration	0.89	0.89
Unwrapped portions under refrigeration	4.38	4.38
Mean	2.86	
CD(0.05) Treatments –0.258 Days –0.339T x D- 0.521		

Table:34(b): Bacterial count of vacuum packed mature varikka portions during storage

Days after storage	Bacterial count x 10^4 cfu/g*
6	1.21
9	1.28
12	1.54
15	1.98
18	2.13
21	2.34
*Average of seven replicated values	

Table:35(a): Fungal count of mature varikka portions till 3 days of storage

Fungal count x 10^3 cfu/g		
Treatments	Days after storage	
	3	Mean
Vacuum packed portions under refrigeration	1.28	1.28
Unwrapped portions under refrigeration	9.89	9.89
Mean	5.58	
CD(0.05) Treatments –0.689 Days -0.689 T x D- 0.864		

Table:35(b): Fungal count of vacuum packed mature varikka portions during storage

Days after storage	Fungal count x 10^3 cfu/g*
6	1.47
9	1.78
12	1.99
15	2.65
18	2.78
21	3.42
*Average of seven replicated values	

refrigeration gradually increased from 1.47 x 10^3cfu/g on 6^{th} day to 3.42 x 10^3 cfu/g on 21^{st} day of storage (Table 35b).

4.2.2. Ripe varikka

4.2.2.1. Physiological Parameters

Physiological parameters of ripe varikka jackfruit portions were recorded at three days intervals and shown below.

4.2.2.1.1. Shelf life (days)

Shelf life of both ripe varikka portions stored under refrigeration is shown in Table 36. Shelf life was high (12.28 days) for vacuum packed ripe varikka portions stored under refrigeration in laminated pouches and low shelf life (1.71 days) was recorded by the unwrapped jackfruit portions (Table 36).

4.2.1.1.2. Physiological loss in weight (PLW)

Physiological loss in weight of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to two days. As the unwrapped portions were spoilt after two days of storage (1.71 days), they were discarded and comparison between the treatments for physiological loss in weight could be made only up to two days. Mean physiological loss in weight was less (0.14) for vacuum packed ripe varikka portions and high (0.47) weight loss was recorded by the unwrapped portions under refrigeration (Table 37 a).

Table: 36. Shelf life (days) of ripe varikka jackfruit portions

Treatment	Shelf life(days)
Vacuum packaged portions	12.28
Unwrapped portions	1.71
C.D.	0.575

Table:37(a) Physiological Loss in Weight (%) of ripe varikka portions till 2 days of storage

Physiological Loss in Weight (%)		
Treatments	Days after storage	
	2	Mean
Vacuum packaging	0.14	0.14
Unwrapped	0.47	0.47
Mean	0.59	
CD(0.05) Treatments –0.028 Days -0.034 T x D- 0.048		

Table:37(b): Physiological Loss in Weight (%) of vacuum packed ripe varikka portions during storage

Days after storage	Physiological Loss in Weight (%)*
3	0.69
6	0.69
9	0.98
12	1.52
*Average of seven replicated values	

Table 38. O_2 and CO_2 evolution rate ripe varikka portions

O_2 and CO_2 (%)										
Treatment	At the time of storage		Days after storage							
			3		6		9		12	
Vacuum packed portions under refrigeration	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
	2	6	1	8	1	8	0.8	9	0.8	9

Physiological loss in weight of portions under vacuum packaging and refrigeration was recorded till the end of shelf life. Physiological loss in weight of vacuum packed portions under refrigeration gradually increased from 0.69% on 4th day to 1.52% on 12th day of storage (Table 37b.).

4.2.2.1.3. O_2 and CO_2 evolution rate

Oxygen and CO_2 rate of ripe varikka jackfruit portions under vacuum packaging and refrigerated storage is shown in Table 38. At the time of storage oxygen concentration was 2% and CO_2 concentration was 6%. At the end of shelf life (12th day) O_2 concentration was decreased to 0.8% and CO_2 rate increased to 9%.

4.2.2.2. Chemical parameters

Chemical parameters of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) were recorded compared with unwrapped portions up to two days. As the unwrapped portions were spoilt after two days of storage, they were discarded and comparison between the treatments for chemical parameters could be made only up to two days.

Chemical parameters of portions under vacuum packaging and refrigeration was recorded till the end of their shelf life.

4.2.2.2.1. TSS

TSS of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to two days. TSS was less (24.75°B) for vacuum packed ripe varikka portions and high (26.15 °B) TSS was recorded by the unwrapped portions under refrigeration (Table 39a.) on 2nd day of storage.

Table39(a).TSS (ºB)of ripe varikka portions till 2 days of storage

TSS (ºB)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	24.60	24.90	24.75
Unwrapped portions under refrigeration	24.60	27.70	26.15
Mean	24.60	26.30	
CD(0.05) Treatments – 0.002 Days -0.002 T x D- 0.003			

Table:39(b): TSS (ºB)of vacuum packed ripe varikka portions during storage

Days after storage	TSS (ºB)*
3	25.14
6	25.14
9	25.44
12	25.61
*Average of seven replicated values	

Table:40(a):Reducing sugar(%)of ripe varikka portions till 2 days of storage

Reducing sugar(%)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	19.50	20.70	20.10
Unwrapped portions under refrigeration	19.50	23.45	21.47
Mean	19.50	22.07	
CD(0.05) Treatments – 0.021 Days -0.021 T x D- 0.030			

Table:40(b): Reducing sugar(%)of vacuum packed ripe varikka portions during storage

Days after storage	Reducing sugar(%)*
3	21.98
6	21.98
9	23.21
12	24.73
*Average of seven replicated values	

Table:41(a): Non Reducing sugar(%)of ripe varikka portions till 2 days of storage

Non Reducing sugar(%)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	21.72	20.54	21.13
Unwrapped portions under refrigeration	21.72	22.30	22.01
Mean	21.72	21.42	
CD(0.05) Treatments – 0.002 Days -0.002 T x D- 0.003			

Table:41(b): Non Reducing sugar(%)of vacuum packed ripe varikka portions during storage

Days after storage	Non Reducing sugar(%)*
6	20.54
9	19.99
12	19.78
*Average of seven replicated values	

Table:42(a): Total sugar(%)of ripe varikka portions till 3 days of storage

Total sugar(%)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	41.20	41.40	41.30
Unwrapped portions under refrigeration	41.20	43.00	42.10
Mean	41.20	42.20	
CD(0.05) Treatments – 0.010 Days -0.010 T x D- 0.014			

Table:42(b):Total sugar(%)of vacuum packed ripe varikka portions during storage

Days after storage	Total sugar (%)*
3	41.61
6	41.61
9	41.82
12	41.94
*Average of seven replicated values	

TSS of portions under vacuum packaging and refrigeration was recorded till 12st day, the end of shelf life. TSS of vacuum packed portions under refrigeration gradually increased from 25.11 °B on 3rd day to 25.61 °B on 12st day of storage (Table 39b.).

4.2.2.2.2. Sugars (reducing, non-reducing &total) (%)

4.2.2.2.2.1. Reducing sugar

Reducing sugar of the vacuum packed portions stored under refrigeration was compared with unwrapped portions up to two days. Reducing sugar was less (20.10 %) for vacuum packed ripe varikka portions and high (21.47%) reducing sugar was recorded by the unwrapped portions under refrigeration (Table 40a.) on 2nd day of storage.

Reducing sugar of portions under vacuum packaging and refrigeration was recorded till 12th day, the end of shelf life. Reducing sugar of vacuum packed portions under refrigeration gradually increased from 21.98% on 3rd day to 24.73% on 12th day of storage (Table 40b.).

4.2.2.2.2.2. Non reducing sugar

Non reducing sugar of the portions subjected to the selected treatment of vacuum packaging under refrigeration was compared with unwrapped portions up to two days and shown in Table 41a. Non reducing sugar of portions under vacuum packaging and refrigeration was recorded till 12th day, the end of shelf life (Table 41b.).

Non reducing sugar was less (21.13%) for vacuum packed ripe varikka portions and high (22.01%) non reducing sugar was recorded by the unwrapped portions under refrigeration (Table 41a.) on 2nd day of storage. Non reducing sugar of vacuum

Table 43(a). Vitamin C (mg $100gm^{-1}$)of ripe varikka portions till 2 days of storage

Vitamin C (mg $100gm^{-1}$)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	8.60	8.11	8.35
Unwrapped portions under refrigeration	8.60	7.88	8.24
Mean	8.60	8.00	
CD(0.05) Treatments – 0.006 Days -0.006T x D- 0.008			

Table 43(b). Vitamin C (mg $100gm^{-1}$)of vacuum packed ripe varikka portions during storage

Days after storage	Vitamin C (mg $100gm^{-1}$)*
3	7.52
6	7.52
9	6.86
12	5.97
*Average of seven replicated values	

Table44(a). Total carotenoids(mg $100gm^{-1}$)of ripe varikka portions till 2 days of storage

Total carotenoids(mg $100gm^{-1}$)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	0.71	0.74	0.72
Unwrapped portions under refrigeration	0.71	0.76	0.74
Mean	0.71	0.75	
CD(0.05) Treatments – 0.000 Days -0.000T x D- 0.000			

Table 44(b).Total carotenoids(mg $100gm^{-1}$)of vacuum packed ripe varikka portions during storage

Days after storage	Total carotenoids(mg $100gm^{-1}$)*
3	0.77
6	0.77
9	0.85
12	0.86
*Average of seven replicated values	

packed portions under refrigeration gradually decreased from 20.54% on 3rd day to 19.78% on 12th day of storage (Table 41b.).

4.2.2.2.2.3. Total sugars

Total sugar of the vacuum packed portions stored under refrigeration (selected treatment) was compared with unwrapped portions up to two days. Total sugar was less (41.30%) for vacuum packed ripe varikka portions and high (42.10%) total sugar was recorded by the unwrapped portions under refrigeration (Table 42a.) on 2nd day of storage.

Total sugar of portions under vacuum packaging and refrigeration was recorded till 12th day, the end of shelf life. Total sugar of vacuum packed portions under refrigeration gradually increased from 41.62% on 3rd day to 41.94% on 21st day of storage (Table 42b.).

4.2.1.2.3. Vitamin C

Vitamin C content of the refrigerated vacuum packed portions (selected treatment) was compared with unwrapped portions up to two days. Vitamin C content was high (8.35 mg $100g^{-1}$) for vacuum packed ripe varikka portions and low (8.24 mg $100g^{-1}$) vitamin C was recorded by the unwrapped portions under refrigeration (Table 43a.) on 2nd day of storage.

Vitamin C content of portions under vacuum packaging and refrigeration was recorded till 12th day, the end of shelf life (Table 43b.). Vitamin C content of vacuum packed portions under refrigeration gradually decreased from 7.52 mg $100g^{-1}$ on 3rd day to 5.97 mg $100g^{-1}$ on 12th day of storage (Table 43b.).

4.2.2.2.4. Total carotenoids

Total carotenoids of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to two days. Ripe varikka jackfruit portions under vacuum packaging in laminated pouches had less total carotenoid value of 0.72 mg/100gm and unwrapped sample had high total carotenoids value of 0.74 mg/100gm (Table 44a) on 2nd day of storage.

Total carotenoid content of portions under vacuum packaging and refrigeration was recorded till 12th day, the end of shelf life. Total carotenoids content of vacuum packed portions under refrigeration gradually increased from 0.77mg $100g^{-1}$on 3rd day to 0.86 mg $100g^{-1}$on 12th day of storage (Table 44b.).

4.2.2.2.5. Titrable acidity (%)

There was no significant difference in titrable acidity between vacuum packed and unwrapped ripe varikka jackfruit portions up to 2nd day of storage (Table 45a). Titrable acidity content of vacuum packed portions gradually decreased from 0.063% on 3rd day to 0.062% on 12th day of storage (Table 45b).

4.2.2.2.5. Total phenol

Total phenol of the portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to two days. Total phenol was low (40.00 mg $100g^{-1}$) for vacuum packed ripe varikka portions and high (41.56 mg $100g^{-1}$) total phenol was recorded by the unwrapped portions under refrigeration (Table 46a.) on 2nd day of storage.

Table 45(a).Titrable acidity (%)of ripe varikka portions till 2 days of storage

Titrable acidity (%)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	0.07	0.07	0.07
Unwrapped portions under refrigeration	0.07	0.07	0.07
Mean	0.07	0.07	-
CD(0.05) Treatments – 0.000 Days -0.000T x D- 0.000			

Table 45(b) Titrable acidity (%)of vacuum packed ripe varikka portions during storage

Days after storage	Titrable acidity (%)*
3	0.06
6	0.06
9	0.06
12	0.06
*Average of seven replicated values	

Table 46(a).Total phenol(mg $100g^{-1}$)of ripe varikka portions till 2 days of storage

Total phenol(mg $100g^{-1}$)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	40.00	40.00	40.00
Unwrapped portions under refrigeration	40.00	41.56	40.78
Mean	40.00	40.78	
CD(0.05) Treatments – 0.001 Days -0.002T x D- 0.012			

Table 46(b).Total phenol(mg $100g^{-1}$)of vacuum packed ripe varikka portions during storage

Days after storage	Total phenol(mg $100g^{-1}$)*
3	39.67
6	39.67
9	39.12
12	38.42
*Average of seven replicated values	

Total phenol of portions under vacuum packaging and refrigeration was recorded till 12th, the end of shelf life. Total phenol content of vacuum packed portions under refrigeration gradually decreased from 39.67mg 100g^{-1}on 3rd day to 38.42 mg 100g^{-1}on 12th day of storage (Table 46b.).

4.2.2.3. Marketability

As the unwrapped portions were spoilt by the 2nd day of storage, comparison between the treatments for marketability parameters could be made only up to 2nd day of storage.

Ripe varikka jackfruit portions kept in refrigerated storage under vacuum packaging in laminated pouches had 95.71% marketability, whereas unwrapped portions had 51.42% marketability on 2nd day of storage (Table 47a). Marketability of jackfruit portions under vacuum packaging in laminated pouches was gradually decreased from 85.45% on 3rd day to 70.0 % on 12th day of storage (Table 47b.).

4.2.2.4. Organoleptic quality (hedonic rating)

Organoleptic evaluation of ripe varikka jackfruit portions, subjected to selected treatments as well as untreated portions are shown in Tables 48a to 48f.

Ripe varikka portions subjected to vacuum packaging and refrigeration had mean score of 7.9 for appearance, flavor and texture, 8.2 for colour and 8.0 for taste and overall acceptability on 12th day of storage. The unwrapped portion kept under refrigeration had a mean score of 3.2 for all parameters by the end of 2nd day of storage.

4.2.2.5. Physical parameters

Physical parameters like colour and texture of the ripe varikka vacuum packaged jackfruit portions under refrigeration (selected treatment) were compared

Table 47(a) . Marketability (%) of ripe varikka portions till 2 days of storage

Marketability (%)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	100.00	91.42	95.71
Unwrapped portions under refrigeration	100.00	2.85	51.42
Mean			
CD(0.05) Treatments – 2.422 Days -2.422T x D- 3.425			

Table 47(b). Marketability (%) of vacuum packed ripe varikka portions during storage

Days after storage	Marketability (%)
6	84.56
9	75.98
12	70.01
*Average of seven replicated values	

Table 48(a).Appearance of ripe varikka portions

Appearance										
Treatments	Days after storage									
	At the day of storage		3		6		9		12	
	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.00	8.2
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-					
KW value	NA		54.62		0.00		0.00		0.00	
χ^2 (0.05)	1.79									

R - Rank M S- Mean score

Table 48(b).Colourof ripe varikka portions

Treatments	Colour									
	Days after storage									
	At the day of storage		3		6		9		12	
	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.00	8.2
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-					
KW value	NA		54.62		0.00		0.00		0.00	
χ^2 **(0.05)**	1.79									

R - Rank

M S- Mean score

Table 48(c). Flavor of ripe varikka portions

Treatments	Flavor									
	Days after storage									
	At the day of storage		3		6		9		12	
	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.4	15.00	8
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-					
KW value	NA		54.62		0.00		0.00		0.00	
χ^2 **(0.05)**	1.79									

R - Rank

M S- Mean score

Table 48(d). Taste of ripe varikka portions

Treatments	Taste									
	Days after storage									
	At the day of storage		3		6		9		12	
	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	8.6	15.00	8.4	15.00	8
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-					
KW value	NA		54.62		0.00		0.00		0.00	
χ^2 **(0.05)**	1.79									

R - Rank
M S- Mean score

Table 48(e). Texture of ripe varikka portions

Treatments	Texture									
	Days after storage									
	At the day of storage		3		6		9		12	
	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	8.6	15.00	8	15.00	7.9
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-					
KW value	NA		54.62		0.00		0.00		0.00	
χ^2 **(0.05)**	1.79									

R - Rank
M S- Mean score

Table 48(f).Overall acceptabilityof ripe varikka portions

Treatments	Taste									
	Days after storage									
	At the day of storage		3		6		9		12	
	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	8.6	15.00	8.5	15.00	8
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-					
KW value	NA		54.62		0.00		0.00		0.00	
χ^2 **(0.05)**	1.79									

R - Rank
M S- Mean score

Table 49. Colourof ripe varikka portions

Treatments	At the time of storage		Days after storage							
			3		6		9		12	
Vacuum packed portions under refrigeration	C(mg 100g^{-1})	B C	C(mg 100g^{-1})	B C	C(mg 100g^{-1})	B C	C(mg 100g^{-1})	B C	C(mg 100g^{-1})	B C
Unwrapped portions under refrigeration	0.67	yellow	0.67	Yellow	0.67	Deep yellow	0.67	Deep yellow	0.69	Deep yellow
	0.67	Deep yellow	0.70	Deep yellow	-		-		-	

C – Carotenoid content
BC-Bulb colour

with unwrapped portions. As the unwrapped portions were spoilt after two days of storage, comparison between the treatments for physical parameters could be made only up to two days. Physical parameters of ripe varikka portions under vacuum packaging and refrigeration were recorded till 12th day, the end of shelf life.

4.2.2.5.1. Colour

Colour of ripe vacuum packed varikka portions stored under refrigeration had a yellow colour with 0.67 mg $100g^{-1}$ carotenoid content and unwrapped portions was deep yellow colored with 0.70 mg $100g^{-1}$ carotenoid content on the 2nd day after storage. Colour of vacuum packed ripe varikka portions stored under refrigeration was deep yellow in colour with 0.69mg $100g^{-1}$ carotenoid content at the 12th day after storage(Table 49).

4.2.2.5.2. Texture

Texture, expressed as flesh firmness, of ripe vacuum packed varikka portions stored under refrigeration had high firmness with 1.02N and unwrapped portions had low texture value of 0.62N on the 2nd day of storage (Table 50 a). Firmness of vacuum packed varikka portions stored under refrigeration gradually decreased from 0.94N on 3rd day to 0.85 N on 12th day of storage (Table 50b).

4.2.2.6. Microbial load

Microbial load of the vacuum packed ripe varikka jackfruit portions stored under refrigeration were compared with unwrapped portions. As the unwrapped portions were spoilt after two days of storage, comparison between the treatments for microbial load could be made only up to two days. Microbial load of portions under vacuum packaging and refrigeration was recorded till 12th day, the end of shelf life.

Table50(a).Texture(N) of ripe varikka portions till 2 days of storage

Texture(N)			
Treatments	At the time of storage	Days after storage	
		2	Mean
Vacuum packed portions under refrigeration	1.091	0.949	1.020
Unwrapped portions under refrigeration	1.091	0.167	0.629
Mean	1.091	0.558	
CD(0.05) Treatments – 0.000 Days -0.000 T x D- 0.000			

Table 50(b). Texture(N) of vacuum packed ripe varikka portions during storage

Days after storage	Texture(N)*
3	0.94
6	0.94
9	0.85
12	0.85
*Average of seven replicated values	

Table 51(a). Bacterial count of ripe varikka portions till 2 days of storage

Bacterial count x 10^4 cfu/g		
Treatments	Days after storage	
	2	Mean
Vacuum packed portions under refrigeration	1.23	1.23
Unwrapped portions under refrigeration	6.24	6.24
Mean	3.73	
CD(0.05) Treatments – 0.324 Days -0.428T x D- 0.564		

Table 51(b). Bacterial count of vacuum packed ripe varikka portions during storage

Days after storage	Bacterial count x 10^4 cfu/g *
3	1.23
6	1.23
9	2.44
12	3.24
*Average of seven replicated values	

Table 52(a).Fungal count of ripe varikka portions till 2 days of storage

Fungal count x 10^3 cfu/g		
Treatments	Days after storage	
	2	Mean
Vacuum packed portions under refrigeration	2.50	2.50
Unwrapped portions under refrigeration	9.80	9.80
Mean	6.15	
CD(0.05) Treatments – 0.568 Days -0.568 T x D- 0.648		

Table 52(b).Fungal count of vacuum packed ripe varikka portions during storage

Days after storage	Fungal count x 10^3 cfu/g*
3	3.56
6	3.56
9	4.21
12	4.58
*Average of seven replicated values	

Bacterial load was less (3.21 x 10^4 cfu/g) in refrigerated ripe varikka portions under vacuum packaging in laminated pouches and the it was high (9.35 x 10^4 cfu/g) in unwrapped jackfruit portions on 2^{nd} day of storage (Table 51a). Bacterial count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased from 6.78 x 10^4 cfu/g on 3^{rd} day to 7.52 x 10^4 cfu/g on 12^{th} day of storage (Table 51b).

Fungal count was less (4.21 x 10^3cfu/g) in refrigerated ripe varikka portions under vacuum packaging in laminated pouches and the it was high (12.21 x 10^3cfu/g) in unwrapped jackfruit portions on 2^{nd} day of storage (Table 52a). Fungal count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased from 8.98 x 10^3cfu/g on 3^{rd} day to 9.56 x 10^3 cfu/g on 12^{th} day of storage (Table 52b).

4.2.3. Mature koozha

4.2.3.1. Physiological Parameters

Physiological parameter of mature koozha jackfruit portions were recorded at three days intervals and are shown below.

4.2.3.1.1. Shelf Life (day)

Shelf life of both mature koozha portions stored under refrigeration is shown in Table 53. Shelf life was high (15.71 days) for vacuum packed mature koozha portions stored under refrigeration in laminated pouches and low shelf life (2.85 days) was recorded by the unwrapped jackfruit portions.

Table 53. Shelf life(days) of maturekoozha portions

Treatment	Shelf life(days)
Vacuum packed portions under refrigeration	15.71
Unwrapped portions under refrigeration	2.85
C.D.	0.852

Table 54(a).Physiological Loss in Weight (%) of mature koozha portions till 3 days of storage

Physiological Loss in Weight (%)		
Treatments	Days after storage	
	3	Mean
Vacuum packed portions under refrigeration	0.159	0.159
Unwrapped portions under refrigeration	0.672	0.672
Mean	0.415	
CD(0.05) Treatments – 0.521 Days -0.521 T x D- 0.737		

Table 54(b).Physiological Loss in Weight (%)of vacuum packed mature koozha portions during storage

Days after storage	Physiological Loss in Weight (%)*
6	0.48
9	0.98
12	1.25
15	1.98
*Average of seven replicated values	

Table 55. O_2 and CO_2 (%) evaluation rate of mature koozha portions

O_2 and CO_2 (%)										
Treatment	At the time of storage		Days after storage							
			3		6		9		12	
Vacuum packed portions under refrigeration	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
	2	4	1.5	6	1	8	0.8	9	0.5	9

4.2.3.1.2. Physiological loss in weight (PLW)

Physiological loss in weight of the mature koozha portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days. Mean physiological loss in weight was less (0.16) for vacuum packed mature koozha portions and high (0. 67) weight loss was recorded by the unwrapped portions under refrigeration (Table 54a.)

Physiological loss in weight of portions under vacuum packaging and refrigeration was recorded till the end of shelf life. Physiological loss in weight of vacuum packed mature koozha portions under refrigeration gradually increased from 0.48% on 6^{th} day to 1.98% on 15^{th} day of storage (Table 54b.).

4.2.3.1.3. O_2 and CO_2 evolution rate

Oxygen and CO_2 rate of mature koozha jackfruit portions under vacuum packaging and refrigerated storage is shown in Table 55. At the time of storage oxygen concentration was 2% and CO_2 concentration was 4%. By the end of shelf life (15^{th} day) oxygen concentration was decreased to 0.5% and CO_2 rate increased to 9%.

4.2.3.2. Chemical parameters

Chemical parameters of the mature koozha portions packed and stored using selected treatment of vacuum packaging under refrigeration was recorded and compared with unwrapped portions up to three days. As the unwrapped portions were spoilt after 3 days (2.85 days shelf life) of storage, they were discarded and comparison between the treatments for chemical parameters could be made only up to 3 days. Chemical parameters of portions under vacuum packaging and refrigeration were recorded till the end of their shelf life viz., 15^{th} day.

Table 56(a). TSS (°B)of mature koozha portions till 3 days of storage

TSS (°B)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	20.45	20.81	20.63
Unwrapped portions under refrigeration	20.450	22.83	21.64
Mean	20.450	21.826	
CD(0.05) Treatments – 0.009 Days -0.009 T x D- 0.013			

Table 56(b).TSS (°B)of vacuum packed mature koozha portions during storage

Days after storage	TSS (°B)*
6	21.52
9	21.97
12	22.11
15	22.54
*Average of seven replicated values	

Table 57(a). Reducing sugar (%) of mature koozha portions till 3 days of storage

Reducing sugar (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	15.50	15.50	15.50
Unwrapped portions under refrigeration	15.50	16.45	15.97
Mean	15.50	15.97	
CD(0.05) Treatments – 0.009 Days -0.009 T x D- 0.013			

Table 57(b).Reducing sugar (%) of vacuum packed mature koozha portions during storage

Days after storage	Reducing sugar (%)*
6	15.62
9	15.82
12	16.15
15	16.34
*Average of seven replicated values	

Table 58(a). Non reducing sugar(%) of mature koozha portions till 3 days of storage

Non reducing sugar(%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	15.02	15.02	15.02
Unwrapped portions under refrigeration	15.02	14.21	14.62
Mean	15.02	14.61	
CD(0.05) Treatments – 0.004 Days -0.004 T x D- 0.006			

Table 58(b). Non reducing sugar(%) of vacuum packed mature koozha portions during storage

Days after storage	Non reducing sugar(%) *
6	15.01
9	14.89
12	14.88
15	14.58

*Average of seven replicated values

Table 59(a).Total sugar(%) of mature koozha portions till 3 days of storage

Total sugar(%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	30.50	30.50	30.50
Unwrapped portions under refrigeration	30.50	32.70	31.60
Mean	30.50	31.60	
CD(0.05) Treatments – 0.004 Days -0.004 T x D- 0.006			

Table 59(b).Total sugar(%) of vacuum packed mature koozha portions during storage

Days after storage	Total sugar(%)*
6	30.58
9	30.62
12	30.75
15	30.82

*Average of seven replicated values

4.2.2.2.1. TSS (°B)

TSS of mature koozha portions packed and stored using selected treatment (vacuum packaging under refrigeration) was compared with unwrapped portions up to three days and shown in Table 56a. TSS was less (20.63 °B) for vacuum packed mature koozha portions and high (21.64 °B) TSS was recorded by the unwrapped portions under refrigeration on 3rd day of storage.

TSS of portions under vacuum packaging and refrigeration was recorded till 15th day, the end of shelf life. TSS of vacuum packed portions under refrigeration gradually increased from 21.52 °B on 6th day to 22.54 °B on 15th day of storage (Table 56b.).

4.2.3.2.2. Sugars (reducing, non-reducing &total) (%)

4.2.3.2.2.1. Reducing sugar

Reducing sugar was less (15.50%) for vacuum packed mature koozha portions and high (15.97%) reducing sugar was recorded by the unwrapped portions under refrigeration (Table 57a.) on 3rd day of storage. Reducing sugar of vacuum packed portions under refrigeration gradually increased from 15.62% on 6th day to 16.34% on 15th day of storage (Table 57b.).

4.2.3.2.2.2. Non reducing sugar

Non reducing sugar of the vacuum packed mature koozha portions stored under refrigeration (selected treatment) was compared with unwrapped portions up to three days. Non reducing sugar was high (15.02%) for vacuum packed mature koozha

Table 60(a). Vitamin C (mg $100g^{-1}$) of mature koozha portions till 3 days of storage

Vitamin C (mg $100g^{-1}$)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	7.21	6.87	7.04
Unwrapped portions under refrigeration	7.21	6.30	6.75
Mean	7.21	6.58	
CD(0.05) Treatments – 0.006	Days -0.006	T x D- 0.008	

Table 60(b). Vitamin C (mg $100g^{-1}$) of vacuum packed mature koozha portions during storage

Days after storage	Vitamin C (mg $100g^{-1}$)*
6	6.22
9	5.88
12	5.12
15	4.59

*Average of seven replicated values

Table:61(a) : Total carotenoids (mg $100g^{-1}$) of mature koozha portions till 3 days of storage

Total carotenoids (mg $100g^{-1}$)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	0.50	0.51	0.51
Unwrapped portions under refrigeration	0.50	0.52	0.52
Mean	0.50	0.52	
CD(0.05) Treatments – 0.000	Days -0.000T x D- 0.000		

Table:61(b): Total carotenoids (mg $100g^{-1}$) of vacuum packed mature koozha portions during storage

Days after storage	Total carotenoids (mg $100g^{-1}$) *
6	0.53
9	0.58
12	0.59
15	0.60

*Average of seven replicated values

portions and low (14.62%) non reducing sugar was recorded by the unwrapped portions under refrigeration (Table 58a.) on 3rd day of storage.

Non reducing sugar of portions under vacuum packaging and refrigeration was recorded till 15th day, the end of shelf life. Non reducing sugar of vacuum packed portions under refrigeration gradually decreased from 15.01% on 6th day to 14.58 % on 15th day of storage (Table 58b.).

4.2.3.2.2.3. Total sugar

Total sugar was less (30.50%) for vacuum packed mature koozha portions and high (31.60%) total sugar was recorded by the unwrapped portions under refrigeration (Table 59a.) on 3rd day of storage. Total sugar of vacuum packed portions under refrigeration gradually increased from 30.58 % on 6th day to 30.82 % on 15th day of storage (Table 59 b.).

4.2.3.2.3. Vitamin C (mg $100g^{-1}$)

Vitamin C content was high (7.04 mg $100g^{-1}$) for vacuum packed mature koozha portions and low (6.75mg $100g^{-1}$) vitamin C was recorded by the unwrapped portions under refrigeration (Table 60a.) on 3rd day of storage.

Vitamin C content of vacuum packed portions under refrigeration gradually decreased from 6.22 mg $100g^{-1}$ on 6th day to 4.59 mg $100g^{-1}$ on 15th day of storage (Table 60b.).

4.2.2.2.4. Total carotenoids (mg $100g^{-1}$)

Table:62(a) :Titrable acidity(%) of mature koozha portions till 3 days of storage

Titrableacidity (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	0.015	0.013	0.014
Unwrapped portions under refrigeration	0.015	0.015	0.015
Mean	0.015	0.014	
CD(0.05) Treatments – 0.000	Days -0.000	T x D- 0.000	

Table:62(b): Titrable acidity(%) of vacuum packed mature koozha portions during storage

Days after storage	Titrableacidity (%)*
6	0.014
9	0.014
12	0.014
15	0.013
*Average of seven replicated values	

Table 63(a).Total phenol (mg $100gm^{-1}$)of mature koozha portions till 3 days of storage

Total phenol (mg $100gm^{-1}$)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	51.50	51.50	51.50
Unwrapped portions under refrigeration	51.50	50.54	51.02
Mean	51.50	51.02	
CD(0.05) Treatments – 0.004	Days -0.004	T x D- 0.006	

Table 63(b). Total phenol (mg $100gm^{-1}$)of vacuum packed mature koozha portions during storage

Days after storage	Total phenol (mg $100gm^{-1}$)*
6	50.78
9	50.24
12	49.23
15	48.98
*Average of seven replicated values	

Table 64(a). Marketability (%)of mature koozha portions till 3 days of storage

Marketablity (%)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	100.00	100.00	100.00
Unwrapped portions under refrigeration	100.00	1.42	50.71
Mean	100.00	50.71	
CD(0.05) Treatments – 0.004 Days -0.004 T x D- 0.006			

Table 64(b).Marketability(%) of vacuum packed mature koozha portions during storage

Days after storage	Marketablity (%)*
6	90
9	85
12	85
15	75
*Average of seven replicated values	

Table 65(a). Appearance of vacuum packed mature koozha portions

Appearance												
Treatments	Days after storage											
	At the day of storage		3		6		9		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.00	8.4	15.00 0	8.4
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-							
KW value	NA		53.393		0.000		0.0000		0.000		0.0000	
χ^2 **(0.05)**	1.79											

R – Rank
M S – Mean score

Mature koozha jackfruit portions under vacuum packaging in laminated pouches had less total carotenoids value of 0.50 mg $100g^{-1}$ and unwrapped sample had high total carotenoids value of 0.51 mg $100g^{-1}$ (Table 61a) on 3rd day of storage.

Total carotenoids content of vacuum packed portions under refrigeration gradually increased from 0.53 mg $100g^{-1}$on 6th day to 0.60 mg $100g^{-1}$on 15th day of storage (Table 61b.).

4.2.2.2.5. Titrable acidity (%)

Titrable acidity of both mature koozha portions stored under refrigeration up to 3rd day of storage is shown in Table 62a. Titrable acidity was the low (0.014%) for mature koozha portions under vacuum packaging in laminated pouches and high acidity (0.015%) was recorded by the unwrapped portions.

Titrable acidity content of vacuum packed portions gradually increased from 0.014% on 6th day to 0.013% on 15th day of storage (Table 62b).

4.2.2.2.5. Total phenol

Total phenol of the vacuum packed mature koozha portions stored under refrigeration (using selected treatment) was compared with unwrapped portions up to three days.

Total phenol was high (51.50 mg $100g^{-1}$) for vacuum packed mature koozha portions and low (51.02mg $100g^{-1}$) total phenol was recorded by the unwrapped portions under refrigeration (Table 63a.) on 3rd day of storage.

Total phenol of portions under vacuum packaging and refrigeration was recorded till 15th day, the end of shelf life. Total phenol content of vacuum packed portions under refrigeration gradually decreased from 50.78 mg $100g^{-1}$on 6th day to 48.98 mg $100g^{-1}$on 15th ay of storage (Table 63b.).

Table 65(b). Colour of vacuum packed mature koozha portions

Colour												
Treatments	Days after storage											
	At the day of storage		3		6		9		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.0	8.2	15.0	8.0
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-							
KW value	NA		53.393		0.000		0.0000		0.000		0.0000	
χ^2 **(0.05)**	1.79											

R – Rank
M S – Mean score

Table 65(c).Flavor of vacuum packed mature koozha portions

Flavor												
Treatments	Days after storage											
	At the day of storage		3		6		9		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.0	8.2	15.0	8.2
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-							
KW value	NA		53.393		0.000		0.0000		0.000		0.0000	
χ^2 **(0.05)**	1.79											

R – Rank
M S – Mean score

4.2.3.3. Marketability (%)

As the unwrapped portions were spoilt by the 3rd day of storage, comparison between the treatments for marketability could be made only up to 3rd day of storage.

Mature koozha jackfruit portions kept in refrigerated storage under vacuum packaging in laminated pouches had 100% marketability, whereas unwrapped portions had 50.71% marketability on 3rd day of storage (Table 64a).

Marketability of jackfruit portions under vacuum packaging in laminated pouches was gradually decreased from 90.00% on 6th day to 75 % on 15th day of storage (Table 64b.).

4.2.3.4. Organoleptic quality (hedonic rating)

Organoleptic evaluation of mature koozha jackfruit portions, subjected to selected treatments as well as untreated portions are shown in Tables 65 a-65f.

Mature koozha portions subjected to vacuum packaging and refrigeration had mean score of 8 for appearance, flavor and taste, 8.2 for texture, 8.4 for colour and 8.5 for overall acceptability on 15th day of storage. The unwrapped portion kept under refrigeration had a mean score of 3.2 for all parameters on 3rd day of storage.

4.2.3.5. Physical parameters

Physical parameters like colour and texture of the vacuum packed mature koozha jackfruit portions stored under refrigeration (selected treatment) were compared with unwrapped portions. As the unwrapped portions were spoilt after three days of

Table 65(d). Taste of vacuum packed mature koozha portions

Taste												
Treatments	Days after storage											
	At the day of storage		3		6		9		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.0	8.2	15.0	8
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-							
KW value	NA		53.393		0.000		0.0000		0.000		0.0000	
χ^2 (0.05)	1.79											

R – Rank
M S – Mean score

Table 65(e).Texture of vacuum packed mature koozha portions

Texture												
Treatments	Days after storage											
	At the day of storage		3		6		9		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.5	15.0	8.2	15.0	8
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-							
KW value	NA		53.393		0.000		0.0000		0.000		0.0000	
χ^2 (0.05)	1.79											

R – Rank
M S – Mean score

Table 65(f). Texture of vacuum packed mature koozha portions

Treatments	Overall acceptability											
	Days after storage											
	At the day of storage		3		6		9		12		15	
	R	M S	R	M S	R	M S	R	M S	R	M S	R	M S
Vacuum packed portions under refrigeration	30.5	9	45.5	9	45.5	9	15.00	8.8	15.0	8.6	15.0	8.5
Unwrapped portions under refrigeration	30.5	9	15.50	3.2	-							
KW value	NA		53.393		0.000		0.0000		0.000		0.0000	
χ^2 (0.05)	1.79											

R – Rank
M S – Mean score

Table 66. Colour of vacuum packed mature koozha portions

Treatments	Colour											
	At the time of storage		Days after storage									
			3		6		9		12		15	
	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C	C(mg $100g^{-1}$)	B C
Vacuum packed portions under refrigeration	0.49	Yellow	0.49	Yellow	0.49	Yellow	0.49	yellow	0.49	yello w	0.49	yellow
Unwrapped portions under refrigeration	0.486	Yellow	0.51	yellow	-		-		-		-	

Table 67(a) .Texture(N)of mature koozha portions till 3 days of storage

Texture(N)			
Treatments	At the time of storage	Days after storage	
		3	Mean
Vacuum packed portions under refrigeration	2.34	2.29	2.32
Unwrapped portions under refrigeration	2.34	0.79	1.56
Mean	2.34	1.54	
CD(0.05) Treatments – 0.001 Days -0.001 T x D- 0.001			

Table 67(b). Texture(N)of vacuum packed mature koozha portions during storage

Days after storage	Texture(N)*
6	2.12
9	1.98
12	1.52
15	1.11
*Average of seven replicated values	

Table 68(a).Bacterial count of mature koozha portions till 3 days of storage

Bacterial count x 10^4 cfu/g		
Treatments	Days after storage	
	3	Mean
Vacuum packed portions under refrigeration	1.24	1.24
Unwrapped portions under refrigeration	4.69	4.69
Mean	2.96	
CD(0.05) Treatments – 0.521 Days -0.521 T x D- 0.737		

Table 68(b). Bacterial count of vacuum packed mature koozha portions during storage

Days after storage	Bacterial count x 10^4 cfu/g*
6	1.28
9	1.98
12	2.54
15	2.86
*Average of seven replicated values	

Table 69(a). Fungal count of mature koozha portions till 3 days of storage

Fungal count x 10^3 cfu/g		
Treatments	Days after storage	
	3	Mean
Vacuum packed portions under refrigeration	2.23	2.23
Unwrapped portions under refrigeration	7.89	7.89
Mean	5.06	
CD(0.05) Treatments – 0.521 Days -0.521 T x D- 0.737		

Table 69(b). Fungal count of vacuum packed mature koozha portions during storage

Days after storage	Fungal count x 10^3 cfu/g *
6	2.56
9	289
12	3.67
15	3.89
*Average of seven replicated values	

storage, comparison between the treatments for physical parameters could be made only up to three days. Physical parameters of portions under vacuum packaging and refrigeration were recorded till 15th day, the end of shelf life.

4.2.2.5.1. Colour

Colour of mature vacuum packed mature koozha portions stored under refrigeration had a yellow colour with 0.49 mg 100g^{-1} carotenoid content and unwrapped portions had yellow color with 0.51 mg 100g^{-1} carotenoid content on 3rd day of storage. Colour of vacuum packed mature koozha portions stored under refrigeration was yellow in colour with 0.49 mg 100g^{-1} carotenoid content at 15th day of storage(Table 66).

4.2.2.5.2. Texture

Texture, expressed as flesh firmness, of mature vacuum packed koozha portions stored under refrigeration had high firmness with 2.32N and unwrapped portions had less texture value of 1.56N on 3rd day of storage (Table 67 a). Firmness of vacuum packed koozha portions stored under refrigeration gradually decreased from 2.12 N on 6th day to 1.11 N on 15th day of storage (Table 67 b).

4.2.2.6. Microbial load

Microbial load of the mature koozha jackfruit portions packed and stored using selected treatment (vacuum packaging under refrigeration) were compared with unwrapped portions. As the unwrapped portions were spoilt after three days of storage, comparison between the treatments for nicrobial load could be made only up to three days. Microbial load of portions under vacuum packaging and refrigeration was recorded till 15th day, the end of shelf life.

Table70. Cost of production of vacuum packed jackfruit portions under refrigeration

COST OF PRODUCTION (4 portions each with 250 g)			
Raw Materials	**Rate (Rs.)**	**Quantity required**	**Price (Rs.)**
Fruits			
Jackfruit	45-55/kg	1kg	40.00
CHEMICALS			
Citric acid	25/50g	5g	2.00
Potassium metabisulphite	27/50g	5g	2.00
PACKAGING MATERIAL			
Laminated pouch	150/150 no.s	4 no.s	4.00
OTHERS			
Labour cost			10.00
Miscellaneous			5.00
Vacuum packing machine (Unit of production method))	1,00,000		0.50
TOTAL COST FOR 4 PORTIONS EACH WITH 250 g (1kg) 63.50			
Portion packed jackfruit			87.00
BC ratio: 1.37			

Bacterial load was less (1.71 x 10^4 cfu/g) in refrigerated mature koozha portions under vacuum packaging in laminated pouches and the it was high (4.57 x 10^4 cfu/g) in unwrapped jackfruit portions on 3rd day of storage (Table 68a). Bacterial count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased from 1.28 x 10^4 cfu/g on 6th day to 2.86 x 10^4 cfu/g on 15th day of storage (Table 68b).

Fungal count was less (2.23 x 10^3cfu/g) in refrigerated mature koozha portions under vacuum packaging in laminated pouches and the it was high (7.89 x 10^3cfu/g) in unwrapped jackfruit portions on 3rd day of storage (Table 69a). Fungal count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased from 2.56 x 10^3cfu/g on 6th day to 3.89 x 10^3 cfu/g on 15th day of storage (Table 69b).

4.2.7. Cost of production

Cost of production of vacuum packed jackfruit portions using the standardized protocol was computed as per the current market rate (Table 70). Total cost of production of 1 kg of jackfruit portions (4 portions @ 250 g each) was around Rs.63.50/- and expected return based on current market price was Rs. 87.00/- for 1 kg of vacuum packed jackfruit portions . BC ratio was calculated as 1.37 which was considered as profitable.

Discussion

5. DISCUSSION

The results obtained from the investigation on "Portion packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.)" are discussed in this chapter under two headings.

1. Effect of portion packaging and storage on shelf life

2. Quality evaluation of selected treatment

Good quality jackfruit types were harvested, cleaned, outer spiny rind removed, cut in to portions of approximately 200-250 g weight, pre treated using 0.5% potassium meta bisulphite (KMS) and citric acid, surface drained and subjected to seven different packaging conditions, and stored under ambient and refrigerated storage conditions. The seven different packaging systems included use of polypropylene film with 5% ventilation, cling film wrapping, shrink wrapping, vacuum packaging in laminated pouches, modified atmospheric packaging (MAP) in laminated pouches with $KMnO_4$, MAP with silica gel and unwrapped portions.

The experiment was conducted independently for three different jackfruit types viz., mature varikka, ripe varikka and mature koozha. The pre treated portion packed and stored jackfruit types were evaluated for physiological, organoleptic and marketability parameters independently.

5.1. EFFECT OF PORTION PACAKAGING AND STORAGE ON SHELF LIFE

Packaging and storage treatments influenced all the physiological parameters of all jack fruit types significantly. Vacuum packed portions stored under refrigeration showed the highest shelf life, least physiological loss in weight (PLW), high marketability and maximum mean rank value for overall acceptability in all the three types of jackfruit portions evaluated.

Vacuum packed mature varikka portions stored under refrigeration had the highest shelf life of 20.33 days(Fig 1.), ripe varikka portions had 12.33 days shelf life(Fig 2.) and mature koozha portions packed and stored under similar conditions had 15.33 days shelf life(Fig 3.). The package film used for vacuum packaging was laminated film of PP/LDPE. Mature varikka

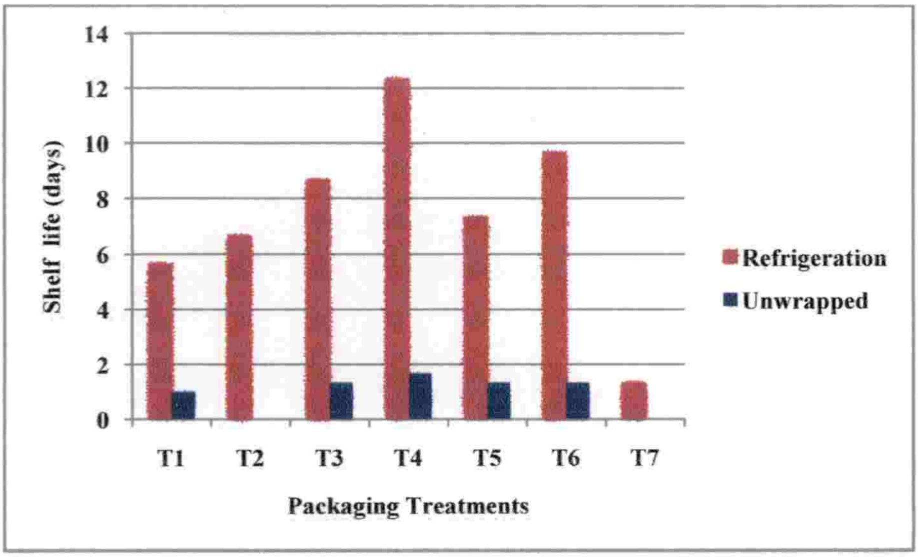

Fig 1. Effect of packaging on shelf life of mature varikka jackfruit portions

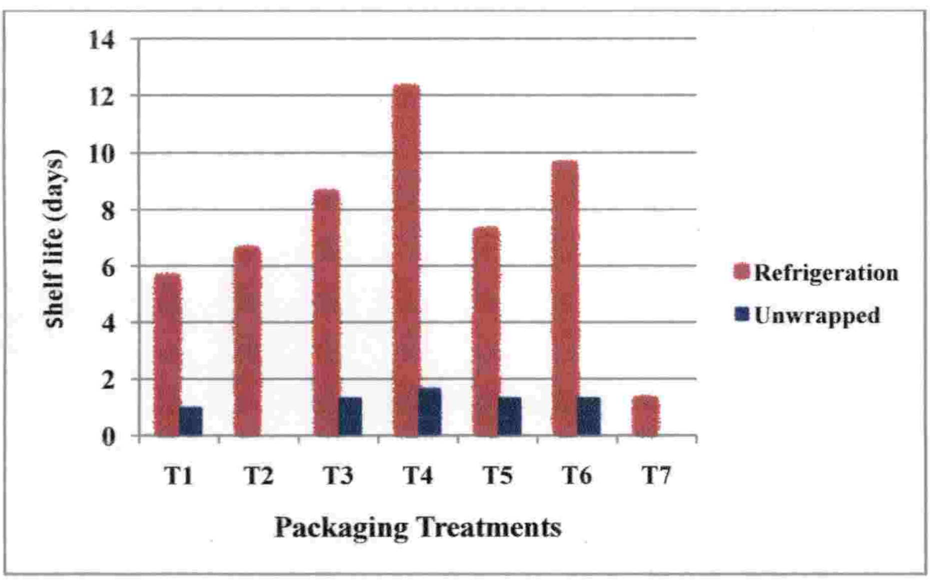

Fig 2. Effect of packaging on shelf life of ripe varikka jackfruit portions

portions had least PLW (1.08) and high marketability (94.54%)(Fig 4.) at the end of their shelf life when packed under vacuum packed and refrigerated. Ripe varikka portions exhibited least PLW (1.08%) and high marketability (80.47%) whereas mature koozha portions had 1.10% PLW and 88.75% marketability at the end of their respective shelf lives under vacuum packaging and refrigeration.

All the vacuum packed and refrigerated portions showed a high degree of acceptance in sensory analysis. Mature varikka had maximum (162.5) mean rank value with 8.0 mean score for overall acceptability, ripe varikka portions with163.95 and 8.7 and mature koozha portions showed a mean rank of 163.40 with and 8.0 overall acceptability score.

Vacuum packaging removes substantial amount of oxygen from the packaging system and reduction in ambient air from the package helps in reduction of deterioration progress (Wiley, 2009). Vacuum packaging of respiring foods is clearly a form of modified atmospheric packaging, because after initial modification of the atmosphere by removal of most of the air, biological action continues to alter or modify the atmosphere inside the package. As a general rule, if the oxygen concentration is decreased, the respiration rate and the storage life would be extended.

Mature varikka portions kept under MAP in laminated pouches with silica gel was the next best treatment with a shelf life of 18.33 days, 1.59 % PLW and mean rank value 92.45 for overall acceptability. This was observed for ripe varikka (9.66 days) and mature koozha (12.33days) too. Silica gel is an approved desiccant or moisture scrubber used in fruit and vegetable packaging, which was kept in the form of moisture absorbing sachet. According to Chauhan *et al.*, (2006) application of moisture scrubber enhanced the shelf life of banana up to 18 days. As a result of respiration and transpiration of the product, water vapour accumulates inside the package and permeates outward into the environment through the package walls. Depending on the product nature, this may bring about undesirable changes such as hardening as a result of desiccation, absorption of surface moisture, generation of liquid water and condensation on the packaging material. The resulting effect on the appearance of the product may lead to rejection by the consumer (Almenar *et al.*, 2006). As the product under the present

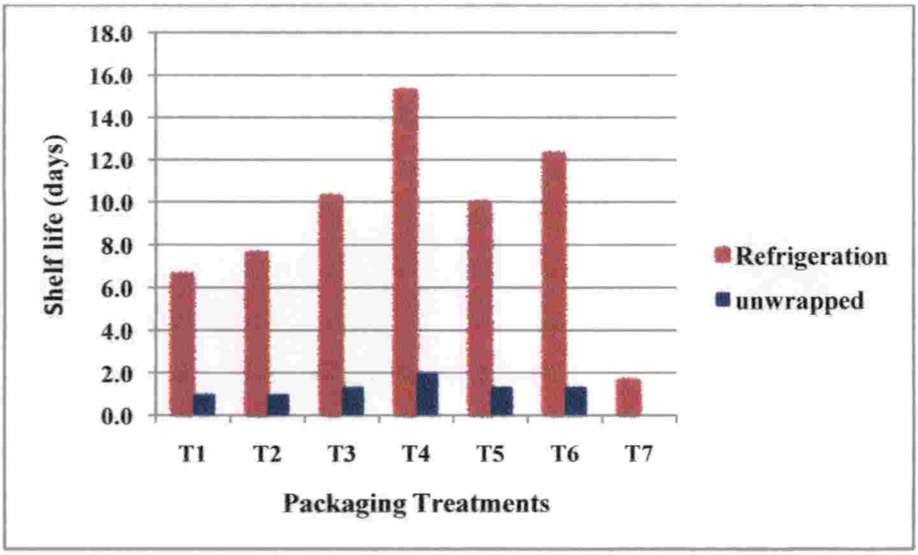

Fig 3. Effect of packaging on shelf life of mature koozha jackfruit portions

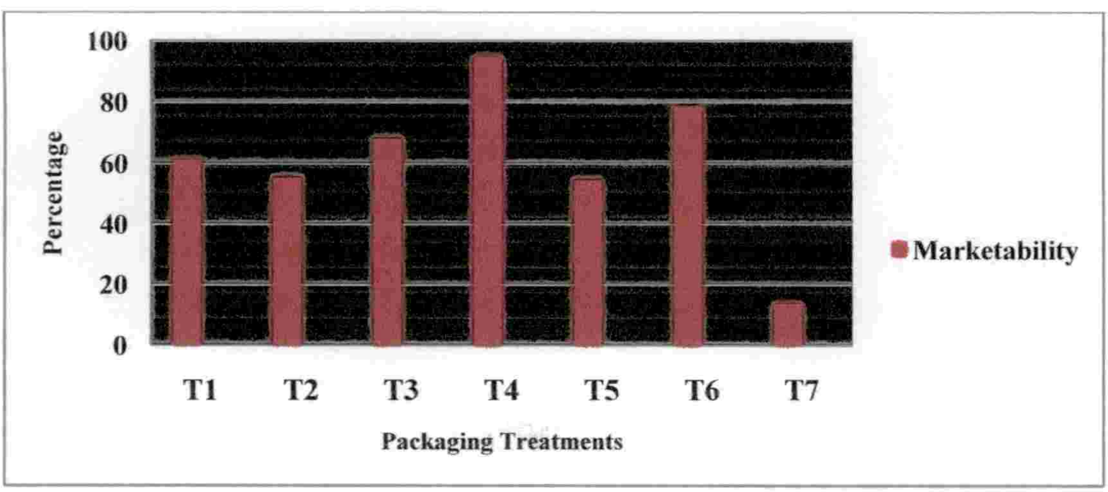

Fig 4. Effect of packaging on marketability of mature varikka portions under refrigeration

experiment is a highly respiring fresh cut commodity, accumulation of liquid water and condensation was high inside the package, which was absorbed by the silica gel, kept inside the package. The quantity of moisture accumulated inside the package is the result of the moisture generated by the product and the water transferred through the package wall, both of which depend on product's respiration rate and temperature fluctuations (Suppakul *et al.*, 2003). Moisture absorbing sachets reduce the product's surface water content by reducing vapour phase in the package headspace, thus controlling microbial growth (Vermeiren *et al*, 1999).There was no desiccation of the product as evidenced by reduced PLW.

The portions kept under shrink wrap packaging were also superior or equal to MAP in laminated pouches with silica gel. Individual shrink wrapped portions could be stored well up to 18 days in case of mature varikka, 8.66 days for ripe varikka and the mature koozha could be stored for 10.33 days with no spoilage, minimum weight loss, firmness loss and comparatively good sensory quality attributes. Shrink wrap film maintains high humidity levels reducing water loss from packaged produce and the potential for mould and bacterial growth and spoilage is reduced by the anti- fogging treatment, thus enhancing shelf life of the commodity (John, 2010). This was in accordance with reports of Nanda *et al.*,(2000) and Dhall *et al.*, 2012 who had observed enhanced shelf life of pomegranate and cucumbers respectively under shrink wrapping. Risse (1989) was of opinion that individual film wrapping of fresh fruits and vegetables will greatly reduce weight loss by reducing the transpiration rate, and maintain fruit firmness.

Cling film wrapping and packaging in polypropylene film with ventilation were not good for maintaining quality parameters. Cling film used in the present experiment was a LDPE film of 15 micron thickness and wrapping the produce with a low gauge PE film could not give any protection to the product. Though they have low water vapour transmission rate, their gas permeability is high, resulting in permeation of gases through the package film and ultimate damage of the commodity (John, 2010). As the films form intimate package with the produce, jackfruit portions was fresh looking initially.

Modified Atmospheric Packaging (MAP) in laminated pouches with $KMnO_4$ could not maintain the quality characters of jackfruit portions. Ethylene, a plant hormone produced during the ripening of fruits and vegetables is responsible for modifying their quality and longevity by increasing respiration rates, softening tissues and accelerating ageing (Zagory, 1995). The addition of ethylene absorbers to packaging has been shown to extend product shelf life. $KMnO_4$ is an ethylene scavenger and it was attached to the packaging material after enclosing in a sachet, although the current trend is to integrate them into the actual packaging material or printing ink. The reaction between $KMnO_4$ and ethylene is irreversible and $KMnO_4$ oxidizes ethylene to acetate and ethanol, changing colour from purple to brown. Considering the poisonous nature, the direct contact between $KMnO_4$ and jack fruit portion was avoided by carefully stapling the $KMnO_4$ sachets with the package and even then condensation of highly respiring jackfruit portions resulted in spreading of colour inside the package affecting the appearance of the commodity and reducing acceptability.

Unwrapped fruit portions lost marketability within 6 days of storage and none of the packaging systems was better in maintaining the physiological quality parameters of the jack fruit portions. Unpacked fruit portions resulted in loss of more moisture by being in direct contact with outer environment. This clearly indicates the influence of packaging in reducing the physical weight loss and moisture loss of fruits. Packaging is one of the main technologies for reducing or delaying the physical, chemical and microbiological changes that take place in fruits and vegetables after harvesting, thus diminishing the loss of quality and acceptability during distribution and marketing (Almenar *et al.*, 2006)

Even under packaging the product undergoes metabolic activities and resulting deteriorative changes. Similar trend was observed in refrigerated and ambient storage conditions in case of jackfruit portions as reported by Tefera *et al.*, (2007), who had found an accelerated increase in weight loss of litchi fruits during storage period, irrespective of packaging material used. Ambient storage was not at all efficient in maintaining physiological quality parameters as evidenced by low shelf life, low marketability and high PLW. Refrigeration could retain the quality of the produce for a produce. (Ferrer *et. al.*, 2002) Compared to other packaging systems, vacuum packaging was comparatively better even under ambient storage too.

Based on effectiveness of packaging and storage treatments in maintaining physiological, organoletic quality and marketability, portions under vacuum packaging in laminated pouches of PP/LDPE under refrigeration was selected as best treatment for further quality evaluation.

The product under the present study is a type of fresh cut produce or a minimally processed product which has high metabolic activity compared to intact jackfruit. The damaged tissue and absence of hard protective rind result in tissue disruption and release of enzymes (Lamikanra,2002) and then damaging the product. Gorny *et. al.*, (2000) reported the capability of MAP in lengthening shelf life of several fresh –cut horticultural products. Vacuum packaging is a type of modification of atmosphere condition with in the package and freshness state of the product is prolonged due to reduced concentration of air around the product (Church and Parsons, 1995). Vacuum packaging, refrigeration and use of laminated pouches helped in protecting the product from deterioration by extending shelf life, high marketability and overall acceptability.

5.2. QUALITY EVALUATION OF SELECTED TREATMENTS

Jackfruits were washed, spiny rind removed, cut into portions, surface treated, drained, subjected to the selected treatment viz., vacuum packaging and refrigerated storage and then subjected to a detailed evaluation for physical, physiological, chemical and sensory quality parameters and compared with the unpacked refrigerated portions. As in first part the evaluation was conducted independently for three different types viz., mature varikka, ripe varikka and mature koozha.

As the unwrapped portions were spoilt after three days of storage, they were discarded and comparison between the treatments for quality parameters could be made only up to three days.

Shelf life of all vacuum packed jackfruit portions under refrigeration was high compared to their corresponding portions under ambient storage. Shelf life was 21 days for mature varikka, 12.28 days for ripe varikka and 15.71 days for mature koozha, whereas shelf life for the corresponding unwrapped portions had shelf life of 4.28, 1.71 and 2 days respectively. Reduced PLW of 0.81%, 0.14% and 0.16% was observed in vacuum packed mature varikka , ripe varikka and mature koozha portions under refrigeration. Similar trend was observed in vacuum packed papaya by Wiley (2009).

As the product is a fresh cut portion having active respiration or high metabolic activity, even in the absence of oxygen under vacuum packaging system, the oxygen concentration reduced and CO_2 concentration increased thus proving that respiration continues even under absence of oxygen. Using a high barrier package film, O_2 will be fully depleted, the product will switch to anaerobic respiration, and quality will be lost. The laminated PP/LDPE used in the present experiment for vacuum packaging might not have complete prevention of oxygen entering in to the packaging system. Though there was increase or decrease in gas concentration, the selected treatment could enhance the shelf life of jack fruit portion considerably. Analysis of physiological parameters during storage clearly showed that parameters gradually changed indicating product deterioration.

Quality parameters are greatly influenced by the packaging system adopted. TSS, reducing sugars and total sugars of all the jackfruit types was less in vacuum packed portions compared to unwrapped portions. The less change in vacuum packed portions is due to delayed bio chemical changes occurring under vacuum. The packaging materials might have created favourable environment for slow conversion of insoluble sugars into soluble forms and least utilization of organic acids in respiration. TSS content varied with storage interval (Fig 5.) . The values for TSS, reducing sugars and total sugars, gradually enhanced during storage. Similar increase in TSS was noticed in fresh cut apples during storage (Rocha *et. al.*, 1995). Increased sugar content might be due to the maximum breakdown of polysaccharides and starch. Increased TSS and sugar content with reduced acidity observed in stored portions indicates increased bio chemical activity related to ripening during storage. Similar reduction in titratable acidity was noticed with the advancement of storage period as observed by Taj (2013) in minimally processed jackfruit bulbs.

Vitamin C content was high and phenol content was less in vacuum packed portions compared to unwrapped portions indicating superiority of vacuum packaging in maintenance of quality. Vacuum packaging technique, which expelled air (O_2) from the package headspace significantly influenced the retention of ascorbic acid in the minimally processed jackfruit bulbs

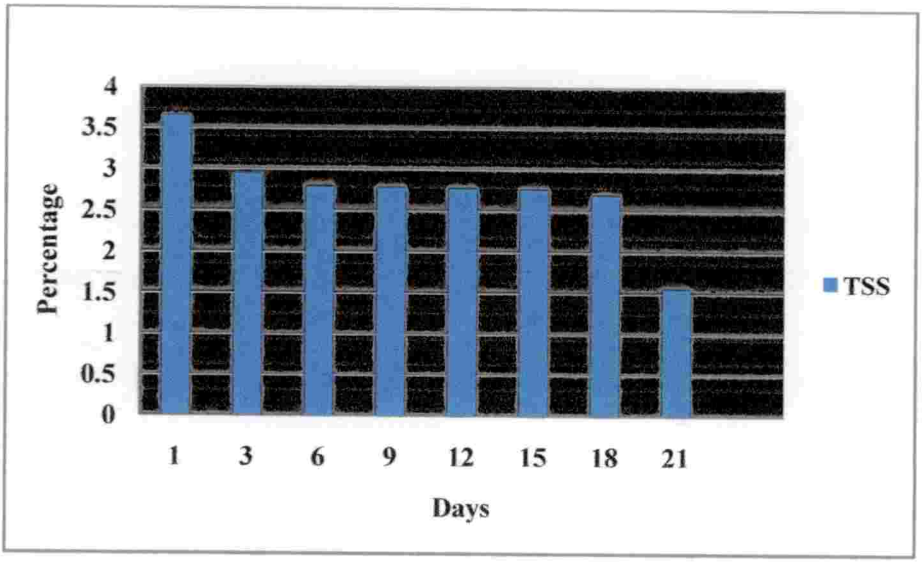

Fig 5. Effect of packaging on TSS of vacuum packed mature varikka portions under refrigeration

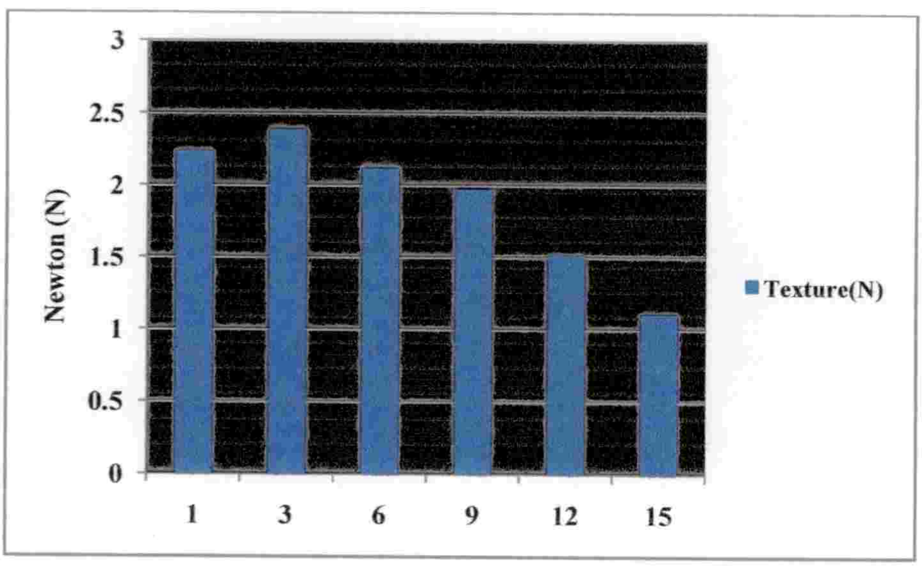

Fig 6. Effect of packaging on texture of vacuum packed mature varikka portions under refrigeration

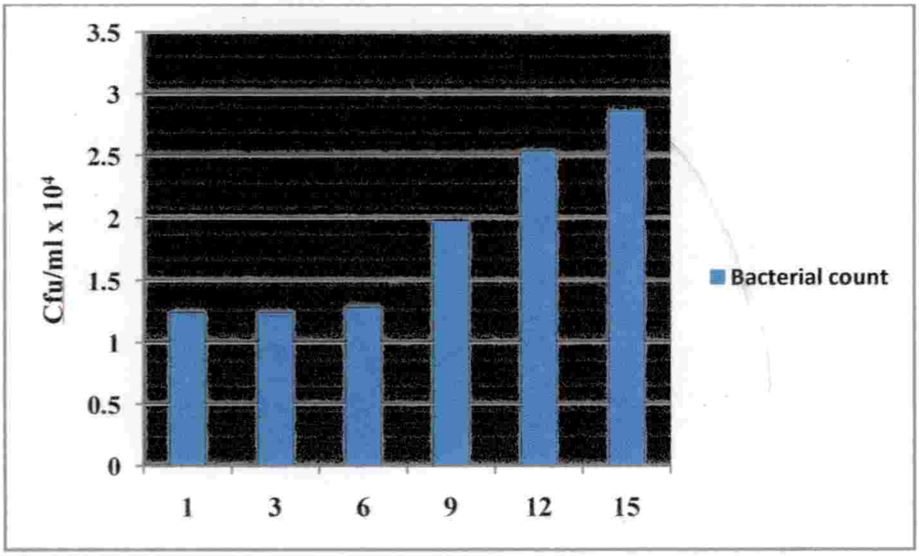

Fig 7. Effect of packaging on bacterial count of vacuum packed ripe varikka portions under refrigeration

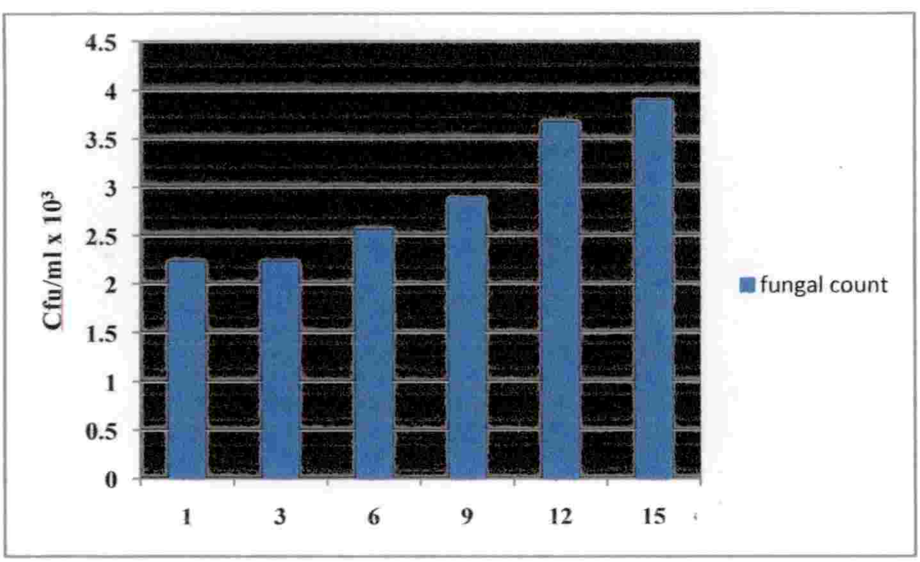

Fig 8.Effect packaging on fungal count of vacuum packed mature koozha portions under refrigeration

Plate 10. Colour of jackfruit bulbs

compared to the conventional packaging technique (Taj, 2013). Vitamin C and phenol content gradually decreased during storage. Gradual decrease in the vitamin C content was noticed during storage of pomegranate fruits, cv. Gok Bahce (Koksal, 1989) and Pro-long- treated 'Julie' mangoes at 25°C (Dhalla and Hanson, 1988). The loss in ascorbic acid on storage could be attributed to the rapid conversion of L-ascorbic acid into dehydro-ascorbic acid in the presence of ascorbinase enzyme (Mapson, 1970).

Jackfruits are rich in carotenoids, rendering the golden yellowish colour to the bulbs. During storage carotenoid content of all the jackfruit types increased, which indicates gradual development of pigments during ripening. These carotenoid content was correlated with colour as per Jagadessh *et al.*(2006). Colour is the first quality factor that the consumer appreciates and has a remarkable influence on its acceptance (Taj, 2013). Natural colourants are in general, unstable, highly susceptible to oxidative deterioration and colour of fruit products may change during processing and storage. Though the carotenoid showed an increase in trend during storage period, the initial colour of bulbs in jackfruit portions was retained even at the end of shelf life. Mature varikka bulbs had cream colour, ripe varikka with deep yellow colour bulbs and mature koozha had yellow colour bulbs, which were retained (Plate 10.)after safe storage period (shelf life).

The low O_2 environment created in vacuum packaging played a major role in terms of anti-browning function due to the anti-respiratory activity and lower availability of molecular O_2 required for the polyphenol oxidase (PPO) mediated enzymatic browning. Vacuum packaging resulted in sustenance of the original colour of the minimally processed jackfruit types for a longer time due to significant reduction in the rates of oxidative and deteriorative metabolic processes inside the packages.

Assessment of marketability (Mohammed, *et al.*,1999) revealed that vacuum packed portions had almost double marketability compared to unwrapped portions. On 3rd day, vacuum packed mature varikka and koozha had 100% marketability, where as mean value for marketability of the corresponding types under unwrapped condition were 50.00 and 50.71% respectively. The higher weight loss percent in the unwrapped fruits after 3rd day of storage at ambient conditions can be attributed to faster rate of respiration which makes the fruits unmarketable. Vacuum packed ripe varikka had 95.71% marketability; where as marketability of the unwrapped ripe varikka was only 51.52%. On storage, marketability of all vacuum packed portions reduced. Marketability was 80% for mature varikka on 21^{st} day, 70% for ripe varikka on 12^{th} day and marketability was 75% for mature koozha on 15^{th} day.

Texture is an important parameter to be judged in assessing the quality and acceptability of any product, especially horticultural perishables. Texture, as measured by flesh firmness was high for all types of vacuum packed jack portions and it was decreased during storage (Fig 6.). Tissue softening occurs as the maturity increases and softening has been attributed to the breakdown of cellular substances such as pectin, cellulose, hemicelluloses and other polysaccharides through hydration (Sharma and Singh, 2000)

Refrigerated vacuum packed jack portions had high acceptability as evidenced by high mean score and mean rank for all organoleptic quality parameters. High quality parameters viz., physiological, physical, chemical parameters recorded by the vacuum packed and refrigerated portions directly influenced the acceptability during hedonic rating.

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, even by pathogenic microorganisms (Romphophak *et al.*, 1995). Bacterial and fungal counts were less for all jackfruit portions refrigerated under vacuum packaging in laminated pouches. Microbial load was increased during storage.

Bacterial count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased and it was 2.34×10^4 cfu/g for mature varikka on 21^{st} day of storage, 7.52×10^4 cfu/g for ripe varikka on 12^{th} day of storage(Fig 7.) and 2.86×10^4 cfu/g for mature koozha on 15^{th} day of storage.

Fungal count of portions under vacuum packaging in laminated pouches and kept under refrigeration gradually increased to 3.42×10^3 cfu/g on 21^{st} day of storage for mv., 9.56×10^3 cfu/g on 12^{th} day of storage for ripe varikka and it was 3.89×10^3 cfu/g for mature koozha on 15^{th} day of storage(Fig 8.). Rocourt *et al.*, (2003) reported that microbial counts of 4.83 cfu/10g of sample observed in ready-to-eat salads and most of the vegetables were of satisfactory or of acceptable microbiological quality according to public health laboratory service food microbiological guidance. In another study, the enumeration of bacteria was conducted to assess the level of post harvest contamination and the mean value of total bacterial count in vegetables ranged between 109-250 cfu × 10^4 g-1 (Goyal and Jaj, 2006). Considering the reports, it can be assumed that all the vacuum packaged jack fruit portions under refrigeration had very low microbial load and hence were microbiologically safe at the end of shelf life.

Hence packing and storage conditions of such processed products must be very specific to maximize their shelf lives. Considering all the parameters, vacuum packaging in laminated pouches of PP/LDPE and storage under refrigeration was standardized as the best packaging and storage treatment for jack fruit portions.

Cost of production of jackfruit portions using the standardized protocol was computed as per the current market rate and BC ratio was calculated as 1.37 which was considered as profitable. This ratio is similar to the results of Taj (2013), who had calculated the cost economics taking into account all aspects of fixed and variable costs involved in his investigation. The cost: benefit ratio for vacuum packaging of the minimally processed jackfruit bulbs was found to be 1: 3.82. He has suggested that the minimal processing of jackfruit bulbs could be a potential business entity for a grower himself as an entrepreneur or any entrepreneur who is already in food business.

Modified atmospheric packaging and low temperature storage help in extending the shelf life and maintenance of quality of perishable produce by way of creation of appropriate gaseous atmosphere around the surroundings of produce packaged in suitable laminated plastic films. Vacuum packaging is a type of modified atmospheric packaging. Among all the postharvest technologies available for the retention of overall quality of fruit at low temperatures, modified atmosphere packaging (MAP) has the advantage of low cost and easy implementation at the commercial level (Flores *et al.*, 2004). The successful use of MAP is based on the specific permeability properties of polymer films to O_2 and CO_2 to generate atmospheres that are suitable for the postharvest life of many horticultural commodities (Pesis *et al.*, 2002). The plastic film used in the present experiment was a laminated film of polypropylene (PP) and Low Density

Polyethylene (LDPE). LDPE has a low (16-23 $g/m^2/24h$) water vapour transmission rate (WVTR) at 38^{0}Cand 90% RH and a high oxygen transmission rate (OTR) of 7000-8000 $CC/m^2/24h$ at 25^{0}C, allowing high permeation of oxygen molecules into the package. The high OTR of LDPE might have been compensated with the low oxygen permeability rate (15-20 l/m^2.day.atmosphere) of poly propylene film used. Selection of appropriate polymeric films of suitable semi-permeable nature or low barrier films has to be done to match the high respiration rate of the fresh cut products.

The storage temperature is one of the important factors affecting the physiology of minimally processed products regardless of the use of packages. They must be handled and stored at less than 5-8°C to achieve a reasonable shelf-life and ensure microbiological safety (Rolle and Chism, 1992). Fresh-cuts generally are much more perishable than intact products because they have been subjected to severe physical stress, such as peeling, cutting, slicing, shredding, trimming, and/or coring, and removal of the protective epidermal cells. They should be held at a lower temperature than that recommended for intact commodities. Although 0°C generally is the desirable temperature for most fresh-cuts, many are prepared, shipped and stored at 5°C and sometimes at temperatures as high as 10°C. Storage at this elevated temperatures can hasten product's deterioration substantially because the Q_{10} of biological reactions ranges from 3 to 4 and possibly as high as 7 within this temperature regime (Schlimme, 1995).

In short, absence of oxygen in the packaging system, selection of proper laminated films and low temperature storage helped to extend their shelf life of jack fruit portions with maintenance of quality parameters. Change in marketing system is of utmost necessity in the present scenario, where the status of jackfruit has received a boost with Kerala State recognizing it as the State Fruit. Developing appropriate packaging technology for shelf-life extension may facilitate quality sale and transportation from production site to remote location, thereby minimizing postharvest loss with great significance for food security, economic growth and welfare of the society. By adoption of the standardized technology, it is possible that the current trend of total unhygienic marketing system can be easily transformed into a totally different style, where hygienically packed quality jackfruit portions with sufficient prolonged shelf life can be marketed through our current retail outlets having refrigerated storage facility. Minimal processing in form of vacuum packed jackfruit portions could be easily initiated as a potential business by an entrepreneur who is already in food business. The system has to be properly modified in future to suit the ambient storage system so as to reduce the cost of production.

Summary

6. SUMMARY

The present investigation entitled "Portion packaging and storage of jackfruit (*Artocarpusheterophyllus* Lam.)" was conducted at Department of Post Harvest Technology, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, during the year 2016-2018 with the objective to standardize portion packaging and storage techniques for extending shelf life of jackfruit (*Artocarpus heterophyllus* Lam.) types.

The experiment was conducted as two separate parts. First part was studying the effect of packaging and storage on shelf life of jack fruit portions for selection of the best packaging and storage system and second part was quality evaluation of the selected treatment. The major findings are summarized as follows.

During the first part, good quality jackfruit types were harvested, cleaned, outer spiny rind removed, cut in to portions of approximately 200-250 g weight, pre treated using 0.5% potassium meta bisulphite and citric acid, surface drained and subjected to seven different packaging conditions and stored under ambient and refrigerated storage conditions. The seven different packaging systems included polypropylene film with 5 % ventilation, cling film wrapping, shrink wrapping, vacuum packaging in laminated pouches, modified atmospheric packaging (MAP) in laminated pouches with $KMnO_4$, MAP with silica gel and unwrapped portions.

The experiment was conducted independently for three different jackfruit types viz., mature varikka , ripe varikka and mature koozha. The pre treated portion packed and stored jackfruit types were evaluated for physiological, organoleptic and marketability parameters independently.

Packaging and storage treatments influenced all the physiological parameters of all jack fruit types significantly. Vacuum packed portions stored under refrigeration showed the highest shelf life, least physiological loss in weight (PLW), high marketability and maximum mean rank value for overall acceptability in all the three types of jackfruit portions evaluated.

Vacuum packed mature varikka portions stored under refrigeration had the highest shelf life of 20.33 days, ripe varikka portions had 12.33 days shelf life and mature koozha portions packed and stored under similar conditions had 15.33 days shelf life. Mature varikka portions had least PLW (1.08) and high marketability (94.54%) at the end of their shelf life. Ripe varikka portions exhibited least PLW (1.08%) and high marketability (80.47%) whereas mature koozha portions had 1.10% PLW and 88.75% marketability at the end of 15.33 days.

All the vacuum packed and refrigerated portions showed a high degree of acceptance in sensory analysis. Mature varikka had maximum (162.5) mean rank value with 8.0 mean score for overall acceptability, ripe varikka portions with163.95 rank and 8.7 score and mature koozha portions showed a mean rank of 163.40 with and 8.0 overall acceptability score.

Mature varikka portions kept under MAP in laminated pouches with silica gel desiccant was the next best treatment with a shelf life of 18.33 days, 1.59 % PLW and mean rank value 92.45 for overall acceptability. This was observed for ripe varikka (9.66 days) and mature koozha (12.33days) too. As the product under the present experiment is a highly respiring fresh cut commodity, accumulation of liquid water and condensation was high inside the package, which was absorbed by the silica gel, kept inside the package in the form of moisture absorbing sachet.

The portions kept under shrink wrap packaging were also superior or equal to MAP in laminated pouches with silica gel. Individual shrink wrapped portions could be stored well up to 18 days in case of mature varikka, 8.66 days for ripe varikka and the mature koozha could be stored for 10.33 days with no spoilage, minimum weight loss, firmness loss and comparatively good sensory quality attributes. Individual film wrapping of fresh fruits and vegetables will greatly reduce weight loss by reducing the transpiration rate, and maintain fruit firmness.

Cling film wrapping and packaging in polypropylene film with ventilation were not good for maintaining quality parameters. MAP in laminated pouches with $KMnO_4$ could not maintain the quality characters of jackfruit portions. Condensation of highly respiring jackfruit portions resulted in spreading of colour inside the package affecting the appearance of the commodity.

Unwrapped fruit portions lost marketability within 6 days of storage and none of the packaging systems was good in maintaining the physiological quality parameters of the jack fruit portions, as they lost more moisture by being in direct contact with outer environment. Compared to other packaging systems, vacuum packaging was comparatively better even under ambient storage too. Ambient storage was not at all efficient in maintaining physiological quality parameters as evidenced by low shelf life, low marketability and high PLW.

Based on effectiveness of packaging and storage treatments in maintaining physiological, organoletic quality and marketability, vacuum packaging in laminated pouches of PP/LDPE and storage under refrigeration was selected as the best treatment for further quality evaluation.

During the second part of the study, jackfruit was washed, spiny rind removed, cut into portions, treated with 0.5% KMS and citric acid, surface drained, subjected to the selected treatment from first part of the experiment viz., vacuum packaging and refrigerated storage. The stored portions were subjected to a detailed evaluation for physical, physiological, chemical and sensory quality parameters and compared with the unpacked portions. As in first part the evaluation was conducted independently for three different types viz., mature varikka, ripe varikka and mature koozha.

As the unwrapped portions were spoilt after two to three days of storage, they were discarded and comparison between the treatments for quality parameters could be made only up to two to three days.

Shelf life of all vacuum packed jackfruit portions under refrigeration was high compared to their corresponding portions under ambient storage. Shelf life was 21 days for mature varikka, 12.28 days for ripe varikka and 15.71 days for mature koozha, whereas shelf life for the corresponding unwrapped portions had shelf life of 4.28, 1.71 and 2 days respectively. Reduced PLW of 0.81%, 0.14% and 0.16% was observed in vacuum packed mature varikka, ripe varikka and mature koozha portions under refrigeration at the end of their respective shelf lives.

As the product is a fresh cut portion having high metabolic activity, the oxygen concentration reduced and CO_2 concentration increased under vacuum packaging system thus proving that respiration continues even in the absence of oxygen, which is mediated through permeability of the laminated firm used.

TSS, reducing sugars, total sugars and phenol content of all the jackfruit portions were less and vitamin C content was high in vacuum packed portions compared to unwrapped portions indicating reduced biochemical activity and superiority in quality of vacuum packaging and refrigeration.

Assessment of marketability revealed that vacuum packed portions had almost double marketability compared to unwrapped portions. On storage, marketability of all vacuum packed portions reduced and it was 80% for mature varikka on 21st day, 70% for ripe varikka on 12th day and marketability was 75% for mature koozha on 15th day.

Refrigerated vacuum packed jack portions had high acceptability as evidenced by high mean score and rank for all organoleptic quality parameters. Flesh firmness was high and bacterial and fungal counts were low in all types of vacuum packed refrigerated jack portions.

Analysis of physiological parameters during storage clearly showed that parameters gradually changed indicating product deterioration in storage. TSS, reducing sugars, total sugars and phenol content gradually enhanced and vitamin C content and acidity gradually decreased during storage due to increased bio chemical activity related to ripening.

During storage carotenoid content of all the jackfruit types increased indicating gradual development of pigments during ripening. Though the carotenoid showed an increase in trend during storage period, the initial bulb colour was retained even at the end of shelf life. Mature varikka bulbs had cream colour, ripe varikka with deep yellow colour bulbs and mature koozha had yellow colour bulbs, which were retained after safe storage period.

Texture was decreased during storage indicating tissue flaccidity. Bacterial and fungal counts were increased during storage. Still all the vacuum packaged portions under refrigeration had very low microbial load and hence considered microbiologically safe at the end of shelf life.

Considering all the parameters, vacuum packaging in laminated pouches of PP/LDPE and storage under refrigeration was standardized as the best packaging and storage treatment for jack fruit portions. Cost of production of jackfruit portions using the standardized protocol was computed as per the current market rate and BC ratio was calculated as 1.37 which was considered as profitable.

Absence of oxygen in the packaging system, selection of proper laminated films and low temperature storage had helped to extend the shelf life of jack fruit portions while maintaining quality parameters. Adopting the above packaging technology for shelf-life extension may facilitate quality sale and transportation from production site to remote locations, thereby minimizing postharvest loss with great significance for food security and economic growth. Minimal processing in the form of vacuum packed jackfruit portions could be easily initiated as a potential agri-business and it is possible to transform the current trend of unhygienic marketing systems into an entirely different system, where hygienically packed quality jackfruit portions with sufficient prolonged shelf life can be marketed through our retail outlets with refrigerated storage facilities. The technology has to be properly modified in future to suit the ambient storage system so as to reduce the cost of production.

References

REFERENCES

Ahvenainen, R. 1996. New approaches in improving the shelf-life of minimally processed fruits and vegetables. *Trends in Food Sci. Technol.* 7: 179-187.

Almenar, E., Munoz, P.H., Laagaron, J.M., Catala, R. and Gavara, R. 2006. Advances in packaging technologies fro fresh fruits and vegetables. *Research Signpost*. 37/661 (2).1-25

Amerine, M. A., Pangborn, R. M. and Roessler, E. B. 1965. Principles of sensory evaluation of food Academic Press. *New York/London*.

APAARI. 2012. Jackfruit improvement in the Asia-Pacific region—a status report. Asia-Pacific Association of Agricultural Research Institutions, Bangkok. p.182.

Benedetti, B.C., Golinelli, C.C. and Sarantopoulos, C. I. 2002. Minimamente processado em rodelas e tiras, armazenadonas temperatures de 5 - 10°C. In: *Congresso Braceileiro de Ciencia E Tecnologia Alimentos*, Porto Alegre, SBCTA, n. 18: 1241-1245.

Burdon, J.N. 2001. Postharvest handling of tropical and subtropical fruit for export. In: Mitra, S. (Ed.) Postharvest physiology and storage of tropical and subtropical fruits. Wallingford, Oxon, UK ; New York, CAB International. pp. 1–19.

Chauhan, O.P., Raju, P.S., Dasgupta, D.K. and Bawa, A.S., 2006. Modified atmosphere packaging of banana (cv. Pachbale) with ethylene, carbon di-oxide and moisture scrubbers and effect on its ripening behaviour. *Am .J. Food Technol.* 1(2):179-189.

Church, I. J. and Parsons, A. L. 1995. Modified atmosphere packaging technology. *J. Sci Food Agric.* 67: 143-152.

Day, B. 2007. Fresh prepared produce: GMP for high oxygen MAP and non – sulphite dipping guideline.pp.31: 76.

Dhall, R.K., Sharma, S.R. and Mahajan, B.V.C. 2012. Effect of shrink wrap packaging for maintaining quality of cucumber during storage. *J. Food Sci. Technol.* 49(4):495-499.

Dhalla, R. and Hanson, S.W.1988. Effect of permeable coatings on the storage life of fruits. *Int. J. Food Sci. Technol. 23*(1):107-112.

Dunn, O.J. 1964. Multiple comparisons using rank sums. *Technometrics*. 6(3): 241-252.

Elevitch, C. R. and Manner, H. I. 2006. *Artocarpus heterophyllus* L. (Jackfruit), ver.1.1v. In: Elevitch, C.R. (Ed.). *Species Profiles for Pac. Isl. Agrofor. Permanent Agric. Resour. (PAR), Holualoa, Hawai'i.* pp. 1-17.

Ferrer, M. M., Harper, C., Muntoz, F.P. and Chaparro, M. 2002. Modified Atmosphere Packaging of Minimally Processed Mango and Pineapple Fruits. 67: 3365–3371.

Flores, F.B., Martínez-Madrid, M.C., Amor, M.B., Pech, J.C., Latché, A. and Romojaro, F., 2004. Modified atmosphere packaging confers additional chilling tolerance on ethylene-inhibited cantaloupe Charentais melon fruit. *European food research and technology*, 219(6):614-619.

Francis, G. A., and O'Beirne, D. 1997. Effect of gas atmosphere, antimicrobial dip and temperature on the fate of *Listeria innocuous* and *Listeria monocytogens* on minimally processed lettuce. *Int. J. Food Sci. Technol.* 32: 141-151.

Gorny, J.R., Cifuents, R. A., Pierce, B. H. and Kader, A.A.2000. Quality changes in fresh cut pear slices as affected by cultivar ripeness stage, fruit size and storage regime. *J. Food Sci.* 65: 541-544.

Goyal,D. and Jaj, N. 2006. Coliforms and heavy metal contamination in vegetables. *Indian J. Microbiol.* 46(3):217-221.

Gunes, G. and Lee, C.Y. 1991. Color of minimally processed potatoes as affected by modified atmosphere packaging and antibrowning agents. *J Food Sci.*62(3):572-575.

Heimdal, H., Kuhn, B.F., Poll, L. and Larsen, L.M. 1995. Biochemical changes and sensory quality of shredded and modified atmosphere packaged iceburg lettuce. *J. Food Sci.* 60:1265- 1268.

Hicks, J. R. and Hall, C. B. 1973. Control of shredded cut lettuce discoloration. *Fla. State. Hort. Sci.* 85: 219.

Hong, J. H. and Gross, K.C. 2001. Maintaining quality of fresh cut tomato slices through modified atmospheric packaging and low temperature Storage. *J. Food Sci.* 66: 960-965.

Jagadeesh, S.L., Reddy, B.S., Swamy,G.S.K., Kirankumar Gorbal, Laxminarayan Hegde , and Raghavan, G.S.V. 2006. Chemical composition of jackfruit (*Artocarpus heterophyllus* Lam.) selections of Western Ghats of India. *Food Chem.* 102:361-365.

John, P.J. 2010. A Handbook on Food Packaging. Daaya Publishing House. Delhi. 202 P.

Kader, A. A. 2008. Fresh-cut mangoes as a value-added product (literature *Rev.* and interviews). *Kader Consulting Serv. Davis, CA, USA*. pp.1-33.

Kakiomenou, K., Tassou, C. and Nychas, G. 1996. Microbiological, physiochemical and organoleptic changes of shredded carrots under modified storage. *Int J. Food Sci. Technol.* 31: 359-366.

Kale, S. and Kadavu, R. 2003. Quality and shelf life of fresh cut asparagus (*Asparagus officinalis* L.) in different packaging films. *Act. Hort.* 600: 787-790.

Kaur, C. and Kapoor, T. B. 2000. Minimal processing of fruits and vegetables. *Indian Food Packer*. pp.156-164.

Köksal, A.I., 1989. Research on the storage of pomegranate (cv. Goek Bahce) under different conditions. *Acta Horticulturae (Netherlands)*.258p.

Lamikanra, O. 2002. Fresh cut fruits and vegetables, science technology and market. Boca Raton, *Fla. CRC Press.LLA*.

Lee, C. Y. and Smith, N. L. 1995. Minimal processing of New York apples. *New York's Food and Life Sci. Bull.* 145: 1-11.

Limbanyen, A. J. K., Brecht, S. A., Sargent., and Bartz, J. A. 1998. Fresh-cut mango fruit slices. *Hort. Sci.* 33:456- 457.

Limbo, S. and Piergiovanni, L. 2006. Shelf life of minimally processed potatoes: effects of high oxygen partial pressures in combination with ascorbic and citric acids on enzymatic browning. *Post harvest Biol. Technol.* 39: 254–264.

Luna-Guzmán, I. and Barrett, D.M.2000. Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. *Postharvest Biol. Technol. 19*(1):.61-72.

Majumdar, T. K., Wadikar, D. D., Vasudish, C. R., Premavalli, K. S. and Bawa, A. S., 2010. Effect of storage on physico-chemical, microbiological and sensory quality of bottle gourd-basil leaves juice. *J. Food Technol.* 6: 226-234.

Mandhare, S. K. 2008. Studies on minimal processing of carrot (Daucus carota L.) Unpublished M.Tech. (Agril. Eng.) thesis, UAS, Bangalore.155p.

Manolopoulou, E., and Varzakas, T. 2011. Effect of storage conditions on the sensory quality, colour and texture of fresh-cut minimally processed cabbage with the addition of ascorbic acid, citric acid and calcium chloride. *Food Nutr. Sci.* 2: 956-963.

Mapson, L.W., 1970. Biosynthesis of ethylene and the ripening of fruit. *Endeavour*, 29:29-33.

Marrero, A. and Kader, A.A. 2006. Optimal temperature and modified atmosphere for keeping quality of fresh-cut pineapples. *Postharvest Bio. Technol. 39*(2):163-168

Mattheis, J., and Fellman, J. K. 2000. Impacts of modified atmosphere packaging and controlled atmosphere on aroma, flavour and quality of horticultural commodities. *Hort. Technol.* 18: 507-510.

Mohammed, M., Wilson, L. A.and Gomes, P.L. 1999. Postharvest sensory and physiochemical attributes of processing and non-processing tomato cultivar. *J. Food Qual.* 9(22):167–182..

Morettie, C. L., Baldwin, E. A., Sargent, S. A., and Hurber, D. J. 2002. Internal bruising alters aroma volatile profiles in tomato fruit tissues. *Hort. Sci.* 37: 378-382.

Nanda, S., Rao, D.S. and Krishnamurthy, S., 2000. Effects of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits cv. Ganesh. *Postharvest Biol Technol*. 22(1):61-69.

Neeraj, J. M. and Bhatia, S. K. 2003. Use of plastics in fruit packaging: *A Rev.*. *Haryana J. Hort. Sci*. 32: 1-8.

Ngarmsak, M. 2010. Antifungal activity of vanillin on fresh - cut tropical fruits. *Acta Hort.*746: 409-415.

NHB [National Horticulutre Board]. 2015. Indian Horticulture Database-2014. National Horticulture Board, Gurgaon. 350p.

Parish, M. E., Beuchat, L. R., Suslow, T.V., Harris, L.J., Garrett, E.H., Farber, J. N. 2001. Analysis and evaluation of preventive control measures for the control and reduction/ elimination of microbial hazards on fresh and fresh cut produce. *Comprehensive Rev. Food Sci. Food Saf.* 2: 161-173.

Pesis, E., Ackerman, M., Ben-Arie, R., Feygenberg, O., Feng, X., Apelbaum, A., Goren, R. and Prusky, D. 2002. Ethylene involvement in chilling injury symptoms of avocado during cold storage. *Postharvest Biol. Technol.* 24(2):171-181.

Piga, A., Daquino, S., Agabbio, M., Emonti, G., and Farris, G. A. 2000. Influence of storage temperature on shelf-life of minimally processed cactus pear fruits. *Lebensmittel-Wissenschaft und- Technology.* 33: 15–20.

Pilon, L., Oetterer, M., Claudio, R., Gallo. and Marta, H. F. 2006. Shelf-life of minimally processed carrot and green pepper. *Ciencia e Tecnologia de Alimentos, Washington*. 26(1): 150-158.

Okan ,E. Zehraayhan and Mehmet ali ustunel.2011.Modified atmospheric packaging of "Napoleon" cherry: Effect of Packaging Material and Storage Time On Physical, Chemical, and Sensory Quality , *Food Bioprocess Technol.* pp:1-10.

Rai, D. R., Tyagi, S. K., Jha, S. N. and Mohan, S. 2008. Qualitative changes in the broccoli under modified atmosphere packaging in perforated polymeric film. *J. Food Sci. Techno.* 45(3): 247–250.

Ranganna, S. 1986. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education. 35-36.

Rinaldi, M. M., Sarantopoulos, C. I. G. L., Benedetti B. C. and Moretti, C. L. 2010. Storage of minimally processed cabbage in different packaging systems. *ActaHortic.* 877: 597-602.

Risse, G., Jooss, K., Neuberg, M., Brüller, H.J. and Müller, R.1989. Asymmetrical recognition of the palindromic AP1 binding site (TRE) by Fos protein complexes. *EMBO J.* *8*(12):3825-3832.

Rocha, A. M. C. N., Brochando, C. M., Kirby, R. and Morais, A. M. M. B. 1995. Shelf-life of chilled cut orange determined by sensory quality. Food Control. 6: 317–322.

Rocourt, J., BenEmbarek, P., Toyofuku, H. and Schlundt, J. 2003. Quantitative risk assessment of Listeria monocytogenes in ready-to-eat foods: the FAO/WHO approach. *FEMS Immunol. Med. Microbiol.* 35(3):.263-267.

Rolle R, S. and Chism, G. W. 1992. Physiological consequence of minimally processed fruits and vegetables. *J. Food Qual.* 10:157-177.

Romphophak, T., Kareeros, P. and Tantirungkij, M. 1995. Microbial Contamination in Minimally Processed Fruits and Vegetables. An article from the Central Laboratory & Greenhouse Complex and Faculty of Science, Kasetsart University, Bangkok, Thailand.pp.4-5.

Roshita, I., Azizah, O., Nazamid, S. and Rahman, A. 2005. Effect of packaging film on the physical characteristic and sensory aspects of shredded cabbage at different storage conditions. *J. Food Agric. Environ*. 3: 58-65.

Sadasivam, S., and Manikam, A. 1992. Biochemical methods for agricultural science. Wiley Eastern Ltd. New Delhi. 246p.

Saini, R. S., Sharma, K. D., Dhankar, O. P. and Kaushik, R. A. 2001. Laboratory manual of analytical techniques in horticulture. AgroBios. India. 135p.

Sakane, Y., Arita, N. and Shimokana, S. 1990. Storage of shredded cabbage in plastic films using ethylene acetaldehyde or sucrose fatty acid esters. 37: 281-286.

Saxena, A. , Bawa, A. S., and Raju, P. S. 2008. Use of modified atmosphere packaging to extend shelf-life of minimally processed jackfruit (*Artocarpus heterophyllus* L.) bulbs. *J. Food Eng*. 87: 455–466.

Saxena, A., Bawa, A. S. and Raju, P. S. 2009. Phytochemical changes in fresh-cut jackfruit (*Artocarpus heterophyllus* L.) bulbs during modified atmosphere storage. *Food Chem*. 115: 1443–1449.

Sieve and Pal. 2006. Effect of polymeric film its thickness and performance level on keeping quality of chopped carrot and refrigeration storage condition. *Food Technol*. 48: 154-159.

Schlimme, D.V. 1995. Marketing lightly processed fruits and vegetables. *Hort. Sci.* 30: 15-17.

Sharma, R.M. and Singh, R.R. 2000. *Harvesting, postharvest handling and physiology of fruits and vegetables*. Indus Publishing Co. Tagore Garden, New Delhi. pp 94–147.

Somasegaran, P. and Hoben, J.H.1985. Methods in Legume-Rhizobium Technology. In: Handbook for Rhizobia. Springer-Verlag publishers, Netherlands. pp 450

Srivastava, M.P. and Tandon, R.N. 1968. Influence of temperature on Botryodiplodia rot of citrus and sapota. *Indian Phytopathol.* 21: 195-207.

Suppakul, P., Miltz, J., Sonneveld, K. and Bigger, S.W. 2003. Active packaging technologies with an emphasis on antimicrobial packaging and its applications. *J. food sci. 68*(2):408-420.

Taj, F. 2013. Vacuum Packaging of Minimally Processed Jackfruit *(Artocarpus Heterophyllus L.)* Bulbs for Long Distance Transportation (Doctoral dissertation, University of Agricultural Sciences, GKVK).115p.

Tefera, A., Seyoum, T. and Woldetsadik, K. 2007. Effect of disinfection, packaging, and storage environment on the shelf life of mango. *Biosystems Eng.* 96(2):201-212.

Vandekinderen, I., Van, J., Camp, Devlieghere, F., Veramme, K., Denon, Q., Ragaert, P. and De Meulenaer, B. 2008. Effect of decontamination agents on the microbial population, sensorial quality, and nutrient content of grated carrots (*Daucuscarota* L.). *J. Agric. Food Chem.* 56(14): 5723–5731.

Vermeiren, L., Devlieghere, F., Van Beest, M., De Kruijf, N. and Debevere, J., 1999. Developments in the active packaging of foods. *Trends food sci. Technol.* 10(3):77-86.

Watada, A. E., Kon, P. and Minott, D. A. 1996. Factors affecting quality of fresh-cut horticultural products. *Postharvest Biol. Technol.* 9: 115-125.

Watada, A. E., and Qi, L. 1999. Quality of fresh-cut produce. *Postharvest Biol. Technol.* 15: 201–205.

Wiley, R. C. 1994. Introduction to Minimally Processed refrigerated fruits and vegetables. In: Wiley R. C. (ed.), *Minimally Processed Refrigerated Fruits and Veg.* Chapman and Hall publishers, New York, US. pp.1-14.

Wiley, J. 2009. Vacuum packaging technology. *J. Food Sci. Technol.* 42: 10-13.

Zagory, D. 1995. Active food packaging. In Rooney, M.L. (Ed)., Backie Academic and Professional, Glasgow, I.

Abstract

PORTION PACKAGING AND STORAGE OF JACKFRUIT

(*Artocarpus heterophyllus* Lam.)

by

GANA K.R.

(2016-12-024)

Abstract of the thesis
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

2018

ABSTRACT

The investigation entitled "Portion packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.)" was conducted at the Department of Post Harvest Technology, College of Agriculture, Vellayani, during the year 2016-2018, with the objective to standardize portion packaging and storage techniques for extending shelf life of jackfruit types. Experiment was carried out independently for mature varikka, ripe varikka and mature koozha jack fruit types.

Good quality jackfruit types were harvested, cleaned, outer spiny rind removed, cut in to portions of 200-250 g weight, pre-treated using 0.5% potassium meta bisulphite (KMS) and citric acid, surface drained and subjected to seven different packaging conditions, and stored under ambient and refrigerated storage conditions. The seven different packaging systems included use of polypropylene film with 5% ventilation, cling film wrapping, shrink wrapping, vacuum packaging in laminated pouches, modified atmospheric packaging (MAP) in laminated pouches with $KMnO_4$, MAP with silica gel and unwrapped portions.

Based on efficiency in maintaining physiological parameters, organoletic quality and marketability, portions under vacuum packaging in laminated pouches of PP/LDPE under refrigeration was selected as best treatment for further quality evaluation. MAP in laminated pouches with silica gel sachet was considered as the second best packaging treatment. Jackfruit portions stored under ambient condition were spoilt within a day in all types.

Quality evaluation of jackfruit portions stored under refrigeration after vacuum packaging in laminated pouches of PP/LDPE revealed that mature varikka portions had 21 days shelf life with 2.34% physiological loss in weight and 80% marketability. Vacuum packed mature koozha portions under refrigeration exhibited 15.71 days shelf life with 2.89% PLW and 75% marketability. Ripe varikka portions

had 12.28 days shelf life with 3.42% PLW and 70% marketability under similar packaging and storage. Unwrapped jack fruit portions under refrigeration were spoilt within 3 days after storage.

Oxygen concentration gradually decreased and CO_2 concentration gradually increased in all the vacuum packaged jackfruit portions, indicating high respiration rate of the fresh cut commodity. TSS, reducing sugars and total sugars increased during storage, where as vitamin C and acidity showed a decrease during storage. Vacuum packed refrigerated jackfruit portions had good sensory acceptability even at the end of shelf life, though there was reduction in firmness. Despite an increase in the carotenoid content, vacuum packed refrigerated jack fruit bulbs retained their natural colour, which stayed even during the storage period. The mature varikka bulbs held a cream colour while the ripe varikka ones were a deep yellow, and the mature koozha bulbs remained yellow even at the end of storage. Cost of production of vacuum packed jack fruit portion was calculated and the BC ratio was found to be 1.37.

Vacuum packaging in laminated pouches of PP/LDPE and storage under refrigeration was standardized as the best packaging and storage treatment for all jack fruit portions. Adoption of the standardized technology may help to transform the current trend of total unhygienic marketing system into a totally different style, where hygienically packed quality jackfruit portions with sufficient prolonged shelf life can be marketed through the current retail outlets having refrigerated storage facility. The system has to be properly modified in future to suit the ambient storage system so as to reduce the cost of production.

Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Title: packaging and storage of jackfruit (*Artocarpus heterophyllus* Lam.)

Score card for assessing the organoleptic qualities of portion packed jackfruit

Sample: Bulbs from Portion packed jackfruit

Instructions: Your are given 9 samples of jackfruit bulbs. Evaluate them and give scores for each criteria

Criteria	Samples								
	1	2	3	4	5	6	7	8	9
Taste									
Colour									
Flavour									
Texture(hard/firm/soft)									
Overall acceptability									
Any other remarks									

<u>Score</u>

Like extremely -9
Like very much -8
Like moderately -7
Like slightly -6
Neither like nor dislike -5
Dislike slightly -4
Dislike moderately -3
Dislike very much -2
Dislike extremely -1

Date :

Name :

Signature :