

**POST HARVEST MANAGEMENT OF
READY - TO - COOK (RTC) TENDER JACKFRUIT**

BRUNDA, R.

PALB 2301

DEPARTMENT OF AGRICULTURAL ENGINEERING

UNIVERSITY OF AGRICULTURAL SCIENCES

GKVK, BENGALURU

2014

**POST HARVEST MANAGEMENT OF
READY - TO - COOK (RTC) TENDER JACKFRUIT**

BRUNDA, R.

PALB 2301

Thesis submitted to the
University of Agricultural Sciences, Bengaluru

In partial fulfillment of the requirements
for the award of the degree of

MASTER OF TECHNOLOGY

(Agricultural Engineering)

In

PROCESSING AND FOOD ENGINEERING

BENGALURU

JULY, 2014



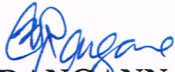
*Dedicated to
my beloved
Family Members
&
Chairman
Dr. B. Ranganna*

**DEPARTMENT OF AGRICULTURAL ENGINEERING
UNIVERSITY OF AGRICULTURAL SCIENCES
G.K.V.K., BENGALURU- 560 065**


CERTIFICATE

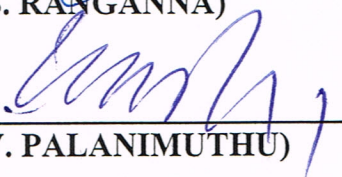
This is to certify that the thesis entitled "POST HARVEST MANAGEMENT OF READY - TO - COOK (RTC) TENDER JACKFRUIT" submitted in partial fulfillment of the requirements for the award of the degree of MASTER OF TECHNOLOGY (Agricultural Engineering) in PROCESSING AND FOOD ENGINEERING of the University of Agricultural Sciences, Bangalore, is a bonafide record of research work done by Ms. BRUNDA, R., ID No. PALB 2301 during the period of her study in the University under my guidance and supervision and that no part of this thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.


Bengaluru
July, 2014



(B. RANGANNA)
Professor Emeritus
Department of Agricultural Engineering
UAS, GKVK, Bengaluru-560 065


Approved By:

Chairperson : 
(B. RANGANNA)

Members : 1 
(V. PALANIMUTHU)

2 
(G. SENTHIL KUMARAN)

3 
(K.B. MUNISHAMMANA)

4 
(R. CHANDRU)

ACKNOWLEDGEMENT

It always is a nostalgic feeling whenever one back to the days of hard work, tensions and the need of the hour to excel. One would not achieve whatever he is now, without all the help, encouragement and the wishes of near and dear part ones. Teachers, parents, friends and well-wishers are an integral task of this. The beatitude and euphoria that accompanies successful completion of any task would be incomplete without expression of appreciation of simple certitude to the people who made it possible to achieve the goal by their encouraging guidance and proper steering.

*I cannot but consider myself lucky to have worked under the guidance of excellence pursuing and ever helpful personality **Dr. B. RANGANNA**, Emeritus Scientist, Department of Agricultural engineering, UAS, GKVK, Bangalore and chairman of my advisory committee. I am immensely grateful to him for his genuine guidance, constant fomenting, punctilious and impeccable advice, recurring encouragement, scholarly advice, sustained interest and above all his affectionate way of dealing with the things throughout the course of my investigation, which helped me to consummate the research work,*

*I equally avail this opportunity to express my deep sense of gratitude to member of my advisory committee **Mr. Munishamanna**, Associate Prof. of Agricultural Microbiology, UAS, GKVK, Bangalore for his kind perusal, counseling, encouragement, valuable suggestions and constructive critical guidance during my course of research.*

*I am immensely grateful to members of my advisory committee **Dr. V. Palanimuthu**, Research engineer and Head, UAS, GKVK, Bengaluru-65, **Dr. G. Senthil Kumaran**, Senior scientist, Division of Agricultural engineering, IIHR, Hesarahatta, Bangalore and **Mr. Chandru, R.**, Associate Professor of Biochemistry, PHT scheme, UAS, GKVK, Bengaluru-65, for his valuable guidance, suggestions and overwhelming support to pursue my research programme is deeply acknowledge with due respect.*

*It is my privilege to express my gratitude, heartfelt thanks to **Ramchandrappa sir, Ganesh sir, Suresh sir, Manjula madum, Ramya madum, Veena madum, Kalpana madum** for their help and support during the course of my study.*

I will be failing in my duty if I do not acknowledge the Staff members and labour faculty of Post harvest technology scheme, UAS, GKVK who were the heart and soul of this research programme.

*I would like to take this opportunity to tell heartfelt special thanks to my brother **Santhosh N**, I am heart fully thanking him for his kindful help, guide and supportness during my study period and senior friends like **Varun anna, Naveen anna, Ashwini, Fareen taj, Sudha, Sadvatha, Arun sir, Naveen sir, Reddy sir.***

*On a personal note, I record my respectful indebtness and gratitude to my beloved parents, Mother **Smt. Gangamma** and Father **Late Sri Renukamurthy**, and my aunt **Vijayalakshmi**, Uncle **Anandhamurthy** whose love and affection have no equivalent and as an everlasting source of inspiration to me. Wish to record my extreme heartfelt thanks to my brother **Rajesh, N**, sister-in-law **Lavanya** and my sisters **Bindhu and Bhoomika** and my relative family members for their co-operation, guidance, support during the course of my study.*

*Friends are our biggest assets who make life colourful and cheerful. I fail in my duty if I do not express my warm thanks to my unmemorable friends. Their lively companionship and spontaneous help enabled me to complete this mammoth task. To name my U.G friends **Gurulakshmi, Nethra, Dhanu, Chaitra, Malithi, Sankalpa, Mala A.N, Bharani, Anu, Joyleen, Chaitra N, Ashwini M, Abhi, Divya** and my PG friends **Akhila, Suchi, Bhavya, Pampangouda.***

*I would like to express my deepest special thanks to my dearest classmates like **Madhusudhan, Mohan, Channa basamma, Shwetha, Chandan, Satish** for their help and moral supporting during the course of my study. Names are many if I recall, I am very thankful to all my U.G., P.G friends, Senior and Junior friends and to all my well wishers.*

*Above all I am extremely thankful and grateful to my **almighty God** who has blessed me to be what I am today.*

Bengaluru

July, 2014

(BRUNDA, R.)

**POST HARVEST MANAGEMENT OF READY - TO - COOK (RTC) TENDER
JACKFRUIT**

ABSTRACT

A research study was carried out to investigate the effect of pretreatments and different types of packages on shelf-life and quality of ready-to-cook (RTC) tender jackfruit. Four jackfruit genotypes, namely, Swarnahalasu, HV1, HV2 and PHT were selected to optimize pretreatments [blanching (75⁰C), blanching followed by citric acid (0.5%), blanching followed by potassium metabisulphate (0.5%), blanching followed by potassium metabisulphate (1.0%), brine solution (4%), potassium metabisulphate (0.5%), blanching followed by brine solution (4-5%)] through minimal processing for prevention of browning. Among genotypes, HV2 was found to be best; and among pretreatments, blanching followed by KMS (0.5%) was found effective in preventing browning of ready-to-cook tender jackfruit. Based on the results of preliminary trails RTC tender jackfruit HV2 variety was preferred for storage. The pretreated samples of RTC tender jackfruit were filled in two different types of packages (polyethylene and polypropylene of 300 gauge with 0, 0.1% ventilation and vacuum) and sealed air tight. These packages were then stored in refrigerated (3-5⁰C) and low temperature (8-10⁰C) storages for 4 weeks. The findings of results indicated that vacuum packaging was the best in extending shelf-life of RTC tender jackfruit. In refrigerated storage, pretreatment with KMS 0.5%+polyethylene (300G) and vacuum packaging was found best for storage up to 3-4 weeks. At low temperature storage, KMS 0.5% + polypropylene (300G) and vacuum packaging did extend shelf-life up to 21 days. Cost: benefit ratio for vacuum packaged RTC tender jackfruit was 1.00 : 2.22.

Signature of Student
(BRUNDA R)

Signature of Chairman
(B. RANGANNA)

ಅಡುಗೆಗೆ ಸಿದ್ಧಪಡಿಸಿದ (RTC) ಕೋಮಲ ಹಲಸಿನ ಹಣ್ಣಿನ ಕೋಯ್ಲಿನೋತ್ತರ

ನಿರ್ವಹಣೆ

ಅಮೂರ್ತ

ಸಂಶೋಧನಾ ಅಧ್ಯಯನವು ಅಡುಗೆಗೆ ಸಿದ್ಧಪಡಿಸಿದ (RTC) ಹಲಸಿನ ಶೇಖರಣಾವಧಿ ಮತ್ತು ಗುಣಮಟ್ಟ ಕಾಯ್ದಿರಿಸಲು ಪೂರ್ವಚಿಕಿತ್ಸೆ ಮತ್ತು ವಿವಿಧ ಪ್ಯಾಕೇಜ್‌ಗಳ ಬಳಕೆಯ ತನಿಖೆ ನಡೆಸಲಾಯಿತು. ನಾಲ್ಕು ಹಲಸಿನ ತಳಿಗಳಾದ ಸ್ವರ್ಣ ಹಲಸು, ಹೆಚ್ ವಿ೧, ಹೆಚ್ ವಿ೨, ಮತ್ತು ಪಿ.ಹೆಚ್.ಟಿ ತಳಿಗಳನ್ನು ಉತ್ತಮ ಪೂರ್ವ ಚಿಕಿತ್ಸೆ ನಿಯೋಜನೆಗೆ ಬಳಸಲಾಯಿತು. ವಿವಿಧ ಪೂರ್ವ ಚಿಕಿತ್ಸೆಗಳೆಂದರೆ: ಬಿಳಿಚಿಸುವಿಕೆ (blanching) (೭೫^೦ ಸೆಲ್ಸಿಯಸ್), ಬಿಳಿಚಿಸುವಿಕೆ ಜೊತೆಗೆ ಸಿಟ್ರಿಕ್ ಆಮ್ಲ (೦.೫%) ಬಿಳಿಚಿಸುವಿಕೆ ಜೊತೆಗೆ ಪೊಟಾಸಿಯಮ್ ಮೆಟಾ ಬೈ ಸಲ್ಫೇಟ್ (೧.೦%) ಉಪ್ಪಿನ ದ್ರಾವಣ (೪%) ಪೊಟಾಸಿಯಮ್ ಮೆಟಾ ಬೈ ಸಲ್ಫೇಟ್ ದ್ರಾವಣ (೦.೫%) ಬಿಳಿಚಿಸುವಿಕೆ ಜೊತೆ ಉಪ್ಪಿನ ದ್ರಾವಣ (೪.೫%) ಮುಖೇನ ಕನಿಷ್ಠ ಸಂಸ್ಕರಿಸಿದ ಕೋಮಲ ಹಲಸಿನ ಮಾದರಿಯ ಬಣ್ಣ ಕಳೆಗುಂದುವಿಕೆಯನ್ನು ತಡೆಯುವ ಅಧ್ಯಯನಕ್ಕೆ ಬಳಸಲಾಯಿತು. ಮೇಲ್ಕಂಡ ತಳಿಗಳಲ್ಲಿ ಹೆಚ್ ವಿ೨ ತಳಿ ಉತ್ತಮವೆಂದು ಕಂಡುಬಂದಿರುತ್ತದೆ. ವಿವಿಧ ಪೂರ್ವ ಚಿಕಿತ್ಸೆಗಳಲ್ಲಿ ಬಿಳಿಚಿಸುವಿಕೆ ಜೊತೆಗೆ ಪೊಟಾಸಿಯಮ್ ಮೆಟಾ ಬೈ ಸಲ್ಫೇಟ್ (೦.೫%) ಬಳಕೆಯಿಂದ ಬಣ್ಣ ಕಳೆಗುಂದುವಿಕೆ ತಡೆಗಟ್ಟುವಲ್ಲಿ ಅತ್ಯುತ್ತಮ ಪೂರ್ವ ಚಿಕಿತ್ಸೆ ಎಂದು ಕಂಡುಬಂದಿತು. ಪ್ರಾಥಮಿಕ ಫಲಿತಾಂಶಗಳನ್ನು ಆಧರಿಸಿ ಅಡುಗೆಗೆ ಸಿದ್ಧಪಡಿಸಿದ ಹಲಸಿನ ಸಂಸ್ಕರಣಾ ಅಧ್ಯಯನಕ್ಕೆ ಹೆಚ್ ವಿ೨ ತಳಿಯು ಉತ್ತಮ ಎಂದು ಪರಿಗಣಿಸಿ ಆಯ್ಕೆ ಮಾಡಲಾಯಿತು. ಚಿಕಿತ್ಸೆಗೆ ಒಳಪಡಿಸಿದ ಹಲಸಿನ ಹಣ್ಣನ್ನು ೨ ವಿವಿಧ ಪ್ಯಾಕೇಜ್‌ಗಳಲ್ಲಿ ಮೊಹರು ಮಾಡಲಾಯಿತು (೩೦೦ ಗೇಜ್ ೦, ೦.೧% ವಾತಾಯನ ವ್ಯವಸ್ಥೆ ಮತ್ತು ನಿರ್ವಾತ ಪಾಲಿಥೀನ್ ಮತ್ತು ಪಾಲಿಪ್ರೊಪಿಲೀನ್ ಪ್ಯಾಕೇಜ್‌ಗಳು). ಈ ಪ್ಯಾಕೇಜ್‌ಗಳನ್ನು (೩-೫^೦ ಸೆಲ್ಸಿಯಸ್) ಶೈತೀಕರಣ ಮತ್ತು ಕಡಿಮೆ ಉಷ್ಣಾಂಷ ವಾತಾವರಣ (೮-೧೦^೦ ಸೆಲ್ಸಿಯಸ್) ತಾಪಮಾನಗಳಲ್ಲಿ ೪ ವಾರಗಳ ಕಾಲ ಶೇಖರಿಸಿಡಲಾಯಿತು. ಸಂಸ್ಕರಣೆ ಸಮಯದಲ್ಲಿ ಕೋಮಲ ಹಲಸಿನ ಮಾದರಿಗಳ ಜೀವಸತ್ವಗಳಾದ ತೇವಾಂಶ, ಸಸಾರಜನಕ, ಕೊಬ್ಬು, ನಾರು, ಶರ್ಕರ ಪಿಷ್ಟ, ಮತ್ತು ಬೂದಿ ಅಂಶಗಳನ್ನು ಪರೀಕ್ಷಿಸಲಾಯಿತು. ಸಂಶೋಧನೆಯ ಅಧ್ಯಯನದಿಂದ ನಿರ್ವಾತ ಪ್ಯಾಕೇಜ್ ಶೇಖರಣಾಧಿಯನ್ನು ಹೆಚ್ಚಿಸುವಲ್ಲಿ ಅತ್ಯುತ್ತಮ ಎಂದು ಕಂಡುಬಂದಿತು, ಶೈತೀಕರಣದಲ್ಲಿ (೩-೫^೦ ಸೆಲ್ಸಿಯಸ್) ಅಡುಗೆಗೆ ಸಿದ್ಧಪಡಿಸಿದ ಕೋಮಲ ಹಲಸಿನ ಹಣ್ಣನ್ನು ೩-೪ ವಾರಗಳ ಕಾಲ ಶೇಖರಿಸಿಡಬಹುದೆಂದು ಮತ್ತು ಕಡಿಮೆ ಉಷ್ಣಾಂಷ ವಾತಾವರಣದಲ್ಲಿ ಪೊಟಾಸಿಯಮ್ ಮೆಟಾ ಬೈ ಸಲ್ಫೇಟ್ (೦.೫%) + ಪಾಲಿಪ್ರೊಪಿಲೀನ್ ನಿರ್ವಾತ ಪ್ಯಾಕೇಜ್ ಮಾಡಿದ ಕೋಮಲ ಹಲಸಿನ (ಬಿಳಿಚಿಸುವಿಕೆ ಜೊತೆಗೆ) ಹಣ್ಣನ್ನು ೨೧ ದಿನಗಳವರೆಗೆ ಶೇಖರಿಸಿಡಬಹುದೆಂದು ಕಂಡುಬಂದಿದೆ. ಅಡುಗೆಗೆ ಸಿದ್ಧಪಡಿಸಿದ ಕೋಮಲ ಹಲಸನ್ನು ನಿರ್ವಾತ ಪ್ಯಾಕೇಜ್ ಮಾಡಿದ ತಂತ್ರಜ್ಞಾನದ ಲಾಭ ಮತ್ತು ವೆಚ್ಚಗಳ ಅನುಪಾತದ ವಿಶ್ಲೇಷಣೆ ಮಾಡಲಾಗಿ ನಿರ್ವಾತ ಪ್ಯಾಕೇಜ್ ಮಾಡಿ ಅಡುಗೆಗೆ ಸಿದ್ಧಪಡಿಸಿದ ಕೋಮಲ ಹಲಸಿನ ಆರ್ಥಿಕ ಅನುಪಾತವು ೧.೦೦ : ೨.೨೨ ಆಗಿರುತ್ತದೆ.

ವಿದ್ಯಾರ್ಥಿಯ ಸಹಿ
(ಬೃಂದ, ಆರ್)

ಪ್ರಧಾನ ಮಾರ್ಗದರ್ಶಕರ ಸಹಿ
(ಬಿ. ರಂಗಣ್ಣ)

INFLUENCE OF PRETREATMENTS ON BROWNING OF DIFFERENT GENOTYPES OF TENDER JACKFRUIT



Brunda, R

Department of Agriculture Engineering, UAS, GKVK, Bangalore 560 065



Introduction

- ❖ Jackfruit (*Artocarpus heterophyllus* .L) is an important underutilized fruit of India. It is grown in southern and northeastern states of the country.
- ❖ It is very delicious and nutritious fruit, next only to mango. One rough estimate projects the post harvest losses of jackfruit to be about 50 per cent valued at Rs. 2000 crores, annually.
- ❖ During the peak season, fruits encounter glut in the market, resulting in price crashes causing enormous economic loss to the growers and traders.
- ❖ There is a great demand for the tender jackfruit as a vegetable, particularly, in the northern and northeastern states. Enzymatic browning is one of the most limiting factors on the shelf- life of fresh-cut products. The application of anti-browning agents is one of the most effective methods for controlling the enzymatic browning reaction in fresh-cut fruits and vegetables.
- ❖ A study has been initiated to optimize the pretreatment for preventing browning/discoloration of different genotypes of tender jackfruit. Development of this technology is likely to benefit jackfruit growers and traders across the country.

Objectives

- To study the physical, engineering and biochemical properties of tender jackfruit
- To optimize the pretreatment for preventing browning / discoloration of different genotypes of tender jackfruit

Materials and methods

- Selected different genotypes of tender jackfruit: swarna halusu, HV1, HV2, PHT
- physical and biochemical properties: size, shape, color, weight, texture, protein, fat, fibre and ash
- Pretreatments:
 - Blanching (75°C)
 - Blanching followed by citric acid(0.5%)
 - Blanching followed by KMS (0.5%)
 - Blanching followed by KMS (1.0%)
 - Brine solution (4%)
 - KMS (0.5%)
 - Blanching followed by brine solution (4-5%)

Observation on intensity of browning

Process Flow Chart for Ready-to-Cook Tender Jackfruit



Results

Physical and biochemical properties of tender jackfruit of different genotypes at initial stage of study is presented in Table1.

Different physical and biochemical properties of tender jackfruit is recorded for different genotypes which are under study.

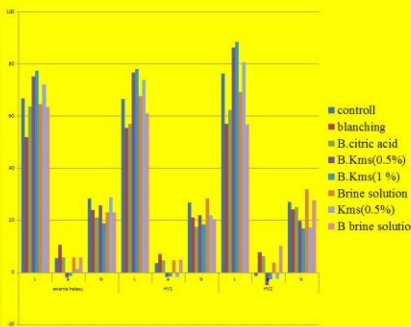
Influence of pretreatments on browning of different genotypes of tender jackfruit is presented in fig 1.

HV2 genotype has given highest L values (lightness) as compared to other genotypes. And KMS(1%) as shown more lightness followed by KMS(0.5%).

Table 1: Physical and biochemical properties of tender jackfruit of different genotypes

Parameters	varities		
	Swarna halusu	HV1	HV2
shape	oblong	oblong	oblong
weight	1.344	1.5	1.65
moisture content	87.622	88.011	85.25
protein	1.805	2.327	2.417
fat	1.908	2.052	2.52
fibre	1.5	2.53	2.6
ash	1.106	1.129	1.165

Fig1 : INFLUENCE OF PRETREATMENTS ON BROWNING OF DIFFERENT GENOTYPES OF TENDER JACKFRUIT



Discussion

HV2 genotype has shown highest L values which indicates more lightness which results in less browning (Adiyaman *et al* .2013 and Mandhare, 2008)

KMS(1%) has given better results followed by KMS (0.5%). No much differences observed among KMS (1%) and KMS (0.5%) even though KMS (1%) had given good results because of higher concentration; however, KMS (0.5%) was preferred. The findings are confirmity with Barwal *et.al*. 2005.



Summary

In the present study, four genotypes were taken to optimize the pretreatment for preventing browning / discoloration by imposing seven different treatments. Results revealed that blanching followed by KMS (0.5%) was found o be effective. Among the four different genotypes, HV2 was fund better. In conclusion, the combination of HV2 and blanching followed by KMS (0.5%) was effective in preventing browning/discoloration of ready-to-cook tender jackfruit.

Advisory Committee

Chairperson : Dr.B. Ranganna

Members:

- Dr.V. Palanimuthu
- Mr. K. B. Munishamanna
- Dr.G. Senthil Kumaran
- Mr. R. Chandru

CONTENTS

Chapter No.	Particulars	Page No.
I	INTRODUCTION	1-2
II	REVIEW OF LITERATURE	3-30
III	MATERIAL AND METHODS	14-21
IV	EXPERIMENTAL RESULTS	22-40
V	DISCUSSION	41-44
VI	SUMMARY	45-46
VII	REFERENCES	47-51
	APPENDICES	52-57

LIST OF TABLES

Table No.	Titles	Page No.
1	Physical and Biochemical properties of tender (green) jack fruit of different genotypes	24
2	Influence of pre-treatment on browning/discoloration of different tender jack fruit genotypes	26
3	Influence of pre-treatment on firmness of different tender jack fruit genotypes	27
4	Influence of packaging material and ventilation on intensity of browning of RTC tender jack fruit in low temperature storage	28
5	Influence of packaging material and ventilation on intensity of browning of RTC tender jack fruit during refrigeration storage	30
6	Influence of packaging material and ventilation on moisture content of RTC tender jack fruit during storage	31
7	Influence of packaging material and ventilation on protein content of RTC tender jack fruit during storage	32
8	Influence of packaging material and ventilation on fat content of RTC tender jack fruit during storage	33
9	Influence of packaging material and ventilation on fibre content of RTC tender jack fruit during storage	34
10	Influence of packaging material and ventilation on ash content of RTC tender jack fruit during storage	35
11	Influence of packaging material and ventilation on carbohydrate content of RTC tender jack fruit during storage	37
12	Visual observation of microbial growth on RTC tender jack fruit during storage	38
13	Sensory evaluation of stored minimally processed RTC tender jack fruit at low temperature	39
14	Sensory evaluation of stored minimally processed RTC tender jack fruit at refrigeration temperature	40

LIST OF PLATES

Plate No.	Titles	Between Pages
1	Colourimeter	15-16
2	Texture analyser	15-16
3	Vacuum packaging	21-22
4	Influence of pre-treatments on browning of RTC tender jackfruit	27-28
5	Influence of packaging material and ventilation on colour of RTC tender jackfruit at 0 days of storage	27-28
6	Influence of packaging material and ventilation on colour of RTC tender jackfruit at 7 days of low temperature storage	29-30
7	Influence of packaging material and ventilation on colour of RTC tender jackfruit at 20 days of storage	29-30
8	Influence of packaging material and ventilation on colour of RTC tender jackfruit at 15 days of refrigeration storage	31-32
9	Influence of packaging material and ventilation on colour of RTC tender jackfruit at 30 days of refrigeration storage	31-32

I. INTRODUCTION

The jackfruit (*Artocarpus heterophyllus* L), is a species of tree in the *Artocarpus* genus of the mulberry family (*Moraceae*). It is native to parts of South and Southeast Asia, and is believed to have originated in the southwestern rain forests of India. The jackfruit tree is well suited to tropical lowlands, and is the largest tree borne fruit in the world, with its diameter being at least 25 cm. There can be jackfruits measuring as much as 36 kg in weight, 90 cm in length and 50 cm in diameter.

The jackfruit tree is widely cultivated in tropical regions of India, Bangladesh, Nepal, Sri Lanka, Vietnam, Thailand, Malaysia, Indonesia and the Philippines. Jackfruit is also found across Africa, i.e., in Cameroon, Uganda and Tanzania, as well as throughout Brazil and Caribbean nations such as Jamaica. In Karnataka, it is cultivated in an area of about 11,333 ha mostly in the southern plains and western Ghats producing about 2,60,500 tones of fruits per annum (Anon, 2000).

Fresh jackfruit is an excellent source of vitamin-A, which has powerful antioxidant properties and is essential for vision. Vitamin A is also required for maintaining integrity of mucus membranes and skin and to boost immunity. Consumption of natural fruits rich in vitamin-A known to protect from lung and oral cavity cancers. It is also rich in antioxidant flavonoids like β -carotene and lutein. These antioxidants are found to be protective against colon, prostate, breast, endometrial, lung, and pancreatic cancers. Jackfruit is also a good source of Vitamin C. The human body does not make vitamin C naturally, so people must eat foods that contain it.

The International Fresh-cut-Produce Association (IFPA) defines fresh-cut products as fruit or vegetables that have been trimmed and/or peeled and/or cut into 100% usable product that is bagged or pre-packaged to offer consumers high nutrition, convenience, and flavour while still maintaining its freshness. In particular, fresh-cut vegetables attract consumers because they are fresh, nutritious, low priced, and ready-to-cook. As a consequence, a wide range of minimally processed vegetables has been developed to meet consumer's needs for "quick" and convenient products. Minimal processing gives additional value to fresh-cut vegetables in terms of convenience and time saving.

Enormous and prickly on the outside, jackfruit looks somewhat like durian (though jackfruit is usually even larger). Once a jackfruit is cracked open, one would find inside pods or "bulbs". Often referred to as the seeds, this bulb is actually a kind of fleshy covering for the true seeds or pits, which are round and dark like chestnuts. The fleshy part (the "bulb") can be eaten as is, or cut up and cooked. When unripe (green), it is remarkably similar in texture to chicken meat making jackfruit an excellent vegetarian substitute for meat. In fact, canned jackfruit in brine is sometimes referred to as "vegetable meat".

Ready-to-cook tender jackfruit is popular in urban areas of India, Sri Lanka and other jackfruit growing countries. The Saras Company in Kerala developed a new

product from tender jackfruit which is being marketed as a ready-to-cook product. Instead of selling tender jackfruit, farmers themselves harvest and convert the fruit into RTC and supply locally to the markets (Anon, 2013).

Packaging is a fundamental tool for the post-harvest management of perishable fruits. Proper packaging helps in maintaining quality and enhancing the shelf-life of fruits. The present system of packaging of fresh fruits depends on the traditional forms of packages like bamboo baskets, wooden boxes and gunny sacks. However, these packages are not suitable for enhancing the shelf-life and quality of fruits (Krishnamurthy and Rao, 2001). Therefore, the use of alternative packages like corrugated fibre board (CFB) boxes, woven sacks, reusable plastic containers, polypropylene and polyethylene bags, modified atmosphere and controlled atmosphere packages have been attempted (Krishnamurthy and Rao, 1998).

Blanching consists of a mild heat treatment (60-100⁰C) given to plant material for inactivating enzymes and killing plant tissues to prevent enzymatic and microbial deterioration. It prevents discolouration, softening and off-flavour development during subsequent storage. Blanching also has an additional cleaning effect and reduces microbiological load of vegetative cells on the vegetable. The factors influencing blanching are size of product particle, shape of particle, heating medium and duration of the process.

Tender jackfruit is harvested for use as vegetable during early spring and summer. The fruit matures towards the beginning of summer in March. The period of fruit development is January to June. The optimum stage of maturity (harvest) of jackfruit has been reported to be 90-110 days after the appearance of the spike.

The post harvest losses of the jackfruit are very high due to high perishability of the fruit. During the peak season, fruits appear in truck loads to the market and form glut, as a result the price crashes causing economic loss to growers and traders. Further, the tender jackfruit is being consumed since decades by people, as a vegetable, across the country. Also the tender jackfruit is considered as a nutri-rich vegetable and has great demand. Development of a suitable technology package will lead to its commercial spread across the country helping a large section of jackfruit growers, traders and consumers. Therefore, a research study on “Postharvest management of Ready-to-Cook (RTC) tender Jackfruit” was undertaken with the following objectives:

- i. To study the physical, engineering and biochemical properties of tender (green) jackfruit of different genotypes
- ii. To optimize the pretreatment for preventing browning / discoloration of different genotypes of tender jackfruit
- iii. To study packaging and storage of ready to cook (RTC) tender jackfruit for domestic distribution
- iv. To workout cost economics

II. REVIEW OF LITERATURE

The jackfruit (*Artocarpus heterophyllus* L) is one of the most common and popular fruits of India. However, not much systematic research work has been done on the aspects of post harvest management of Ready-to- Cook Tender Jackfruit. Hence, a brief review of the earlier work done on jackfruit and other related fruit crops are presented in this Chapter.

2.1 Physico-chemical properties of Jackfruit

Immature jackfruit is boiled, fried or roasted. Chunks are cooked in lightly salted water until tender and served. Before cutting the fruit, it is important to guard against the sticky latex. Immature fruit have more latex, coating of the knife, hands and center of the cutting board with vegetable oil is needed.

Mathur *et al.* (1952) studied the changes in chemical composition of jackfruit bulbs during storage at different temperatures and found that storage at 11.1-12.8°C and 85-90% RH for 42 days resulted in decrease of sucrose content from 9.5-5.0%, while reducing sugars increased from 2.00-5.98%.

The ripe jackfruit bulbs are rich in sugars with about 90 calories per 100g fresh weight. Bhatia *et al.* (1955) reported that ripe bulbs contain 20.6% of total sugars with practically no starch. The edible bulbs are reported to contain 1.74% fructose, 5.96% glucose and 6.9% sucrose and calcium, potassium, iron and a fair amount of carotene (Chan *et al.*, 1974) it was also reported that the principal sugar – sucrose in jackfruit was 6.90% and total sugar was 14.59%.

Jackfruit is a nutritious fruit and is a rich source of vitamins A and C. The edible pulp is a rich source of carbohydrates (23.4%) which also contain protein (0.6%), fat (0.6%), minerals (0.9%), fibre (1.8%) and ash (0.5%). The seeds contain fat (0.4%), fibre (1.5%) and ash (1.5%) (Purseglove, 1968).

Gopalan *et al.* (1985) reported that the edible portion of the jackfruit had 76.2% - moisture, 1.9% - protein, 0.1% - fat, 0.9%- ash, 1.1% - fibre and carbohydrates - 19.8%. Ripe fruits are rich in nutritive value containing 18.9g carbohydrates, 0.8g minerals, 30 IU vitamin A and 0.25mg thiamine for every 100g.

The physico-chemical composition of any fruit is influenced by a number of factors such as variety, location and stage of harvesting (Saxena *et al.* 1987) and jackfruit is also found to be influenced by such factors. Jacob and Narasimhan (1998) reported that jackfruit consists of 32% of edible portion (pulp), 18% seed and about 50% rind (waste) on weight basis. The dry matter content of jackfruit perianth increased from 10.0 to 32.4% with increase in maturity. At full maturity, the maximum dry matter content recorded in soft form was 26.5%, while it was 32.4% in the firm forms of jackfruit.

Berry and Kalra (1989) reported that ripe jackfruit bulbs contain 77.2% moisture, 18.9% carbohydrates, 1.9% protein, 0.1% fat, 1.1% fibre, 0.8% total mineral matter with

a calorific value of 84 kcal per 100g pulp. Sonde (1989) reported that there was a significant difference in pulp composition among hard and soft varieties of jackfruit. The hard variety jackfruit was better than soft variety as it had higher proteins, reducing sugars and total sugars.

According to Nanjundaswamy (1990) the edible bulbs had a pH of 5.1, 25% carbohydrates and 1% total ash. The ash content of all the jackfruit samples decreased with the increase in maturity. The values of ash content varied from 5.7 to 2.0% and 4.9 to 1.6% in soft and firm forms, respectively. The gradual decrease in ash content may be due to increase in relative percentage of dry matter content (Rahman *et al.*, 1999).

A 100g of edible portion (ripe flesh) of jackfruit contains moisture (72.0-77.2%), energy (58 kcal), protein (1.3-1.9g), fat (0.1-0.3g), carbohydrates (18.9-25.4g), fibre (1.0-1.18g), ash (0.8-1.0g), calcium-22mg, phosphorus-38mg, iron-0.5mg, sodium-2mg, potassium-407mg, vitamin A-540 µg, thiamine-0.03mg, niacin-4mg and ascorbic acid (8-10mg) (Anon., 2003).

Crane *et al.* (2005) reported that fresh jackfruit per 100g contains 73% moisture, 1.5g protein, 0.3g fat, 24g carbohydrates, 1.6g fibre, 0.6mg iron, 37.0mg magnesium, 36.0mg phosphorus, 303.0mg potassium, 3.0mg sodium, 6.7mg of vitamin C, 397 µg of vitamin A and 94 kcal energy. An average TSS content of 13 clusters of jackfruit studied by Maiti *et al.*, (2002), observed °Brix ranging from 15.1 to 25.9. In another study, the highest TSS of 40.5°Brix was recorded in Acc. No. G-18 and minimum acidity in Acc. No. G-2 (0.68%) (Reddy *et al.*, 2004).

A study was undertaken by Goswami *et al.* (2011) to determine the physical properties and chemical composition of three types of jackfruit (Khaja, Dorasha and Ghila) pulps collected from different growing areas for a period of 6 months. The pulps of Khaja (both Modhupur and Valuka) were found to be firm textured and those of Ghila were very soft. Correspondingly, intermediate textures of pulps were observed in case of Dorasha. Furthermore, the pulps colour of Khaja fruits were whitish yellow whereas that of Ghila pulps were deep yellow. The colour of Dorasha pulps were light yellow. The Khaja, Dorasha and Ghila pulps were found less, medium and very juicy, respectively. Highest carotene content was observed in Modhupur Ghila (520.46 µg/100g) while lowest in Valuka Khaja (334.06 µg/100g). TSS, starch, total sugar, non-reducing sugar and carotene content were higher in the jackfruit pulps from modhupur than that of Valuka.

2.2 Prevention of browning of tender Jackfruit

Enzymatic browning is one of the most limiting factors on the shelf- life of fresh-cut products. During the preparation stages, produce is submitted to operation where cells are broken causing to be liberated from tissues and put in contact with their substrates. Enzymatic browning is the discoloration which results from the action of enzymes called polyphenol oxidases (PPO) which have been reported to occur in all plants, and exist in particularly high amounts in mushroom, banana, apple, pear, potato, avocado and peach. (Elisabeth Garcia and Barrett, 1989).

Buta and Abbott (2000) optimised the treatments to inhibit browning and maintain quality of fresh-cut 'Anjou', 'Bartlett', and 'Bosc' pears (*Pyrus communis* L.). Slices of 'Anjou', 'Bartlett', and 'Bosc' pears (firmness 22, 36, and 22N, respectively) were dipped in solutions of 4-hexylresorcinol, isoascorbic acid, N-acetylcysteine, and potassium sorbate prior to storage in air for up to 14 days at 5°C. Inhibition of browning without loss of firmness and with no microbial growth was achieved for the three cultivars for 14 days. Inhibition of browning during 14 days storage at 5°C was not affected by initial firmness (21–52 N) of 'Anjou' pear slices.

Gonzalez-Aguilar *et al.* (2000) investigated the treatments to inhibit browning and decay and prolong shelf-life of fresh-cut mangoes. Combinations of anti-browning agents and modified atmosphere packaging (MAP) resulted in the reduction of browning and deterioration of fresh-cut mangoes stored at 10°C. Combinations of several browning inhibitors were more effective than those applied individually. Among these treatments, solutions containing 4-hexylresorcinol (0.001 M) (HR) plus potassium sorbate (0.05 M) (KS) and HR plus KS plus D-isoascorbic acid (0.5 M) (ER) reduced changes in colour (L^* , a^* , and b^*) and microbial growth and did not affect sensory characteristics of fresh-cut mangoes. In general, these treatments did not affect significantly the changes in organic acids and sugar content of slices during the 14 days of storage at 10°C. High humidity created in the in-package atmosphere alleviated tissue dryness and was an important factor in the ability of the anti-browning solutions to prevent browning and decay.

Gonzalez-Aguilar *et al.* (2001) evaluated those treatments with inhibitors of enzymatic activity or microbial growth to retard browning and decay of fresh-cut radish slices. Slices were dipped in solutions of natural products and their derivatives, 4-hexylresorcinol, isoascorbic acid, N-acetylcysteine and potassium sorbate alone or in combination prior to storage in air for up to 14 days at 10°C. Inhibition of browning and deterioration without affecting texture of slices was achieved during 14 days in cold storage. From the different solutions evaluated, the combination of 4-hexylresorcinol (0.001 g/L), potassium sorbate (0.05 g/L) and N-acetylcysteine (0.025 g/L) was most effective in preventing browning and deterioration of radish slices for up to 18 days at 10°C.

Among the various pre-treatments, given to potato cubes, the soaking in 0.2 per cent metabisulphite, blanching in two per cent brine for two minutes, blanching in two per cent brine for two minutes followed by soaking in 0.2 per cent KMS treatment produced dehydrated potato cubes with high rehydration ratio (3.49:1.00) and low non enzymatic browning of 0.36 OD (Sandhu and Parhawak, 2002).

Cauliflower can be preserved by using different concentrations and combinations of potassium metabisulphite (KMS) and citric acid. Cauliflower steeped in 10 and 15 per cent salt solutions containing 0.25 KMS were rated best among different treatments in maintaining better physico-chemical, sensory qualities and checking microbial growth (Barwal *et al.*, 2005).

Pietro *et al.* (2007) reported the physiological effects of the application of anti-browning substances on metabolically active potato tissues. The use of citric acid, ascorbic acid and L - cysteine helped in prevention of browning in fresh cut potatoes evidenced that chemicals used in the prevention of enzymatic browning might had physiological effect on the tissues rich in reducing sugars.

Lu *et al.* (2007) used sodium chloride in fresh cut apple slices as a dipping treatment. Sodium chlorite acidified with organic acids, and other salts. Apple slices treated in acidified sodium chlorite or sodium chlorite alone had a significantly smaller decrease in lightness value (L^*) indicating less browning than those treated in citric acid or water control at 4 hours. After 2 weeks of storage, only sodium chlorite (0.5–1.0 g/L), sodium bisulfite (0.5 g/L) and calcium l-ascorbate (10 g/L) continued to inhibit browning. Treatment with 0.5 g/L sodium chlorite and pH adjusted in the range from 3.9 to 6.2 using citric acid reduced browning more effectively than 0.5 g/L sodium chlorite without pH adjustment. Two organic acids, salicylic acid and cinnamic acid, when added to sodium chlorite solution, were found to achieve even better inhibition of browning than citric acid at the same pH level.

Teixeira *et al.* (2007) studied fresh cut carambola, which is a fruit affected a lot by surface browning due to the activity of polyphenol oxidase. The slices were rinsed with NaCl (20mg/l) drained and packed in PET (polyethylene terephthalate) trays, polystyrene trays covered with PVC 0.017mm or vacuum-sealed polyolefin bags and stored. The results showed a lower PPO activity in the slices packaged in the vacuum-sealed bags, which stored better for up to 12 days.

Bieganska *et al.* (2007) studied the effect of sample processing with solutions containing inhibitors of enzymatic browning and tissue softening and sucrose on the quality of minimally processed apples. Ascorbic acid, citric acid, 4-hexylresorcinol, sodium chloride, calcium chloride, sodium lactate, calcium lactate and sucrose were used as inhibitors. The application in apple slice processing of a solution containing 1% ascorbic acid, 0.005% 4-hexylresorcinol, 0.5% calcium chloride, 20% sucrose effectively inhibited the browning and softening of apple slices during storage. A good quality product is obtained using a solution of citric acid and sucrose.

Qiang He *et al.* (2007) investigated the effect of sodium chloride on polyphenol oxidase (PPO) and its substrate, chlorogenic acid, as it relates to the mechanisms of browning inhibition by sodium chloride. Results indicate that the browning reaction of chlorogenic acid (1.0 mM) catalyzed by polyphenol oxidase (33 U/mL) was significantly inhibited by 1.0 mM sodium chloride at pH 4.6. Two polyphenol oxidase isoforms were identified by native polyacrylamide gel electrophoresis, and both were inactivated by sodium chloride (3.0 mM). This suggested that sodium chloride served as a polyphenol oxidase inhibitor to prevent enzymatic browning. Furthermore, the effect of sodium chloride on the stability of chlorogenic acid in both acidic (pH 4.5) and basic conditions (pH 8.3) was studied by UV–Vis scan and LC–MS analysis. The results showed that at the presence of sodium chloride (3.0 mM), chlorogenic acid (0.1 mM) degraded to quinic acid and caffeic acid as well as other intermediates. The anti-browning property of

sodium chloride was attributed to the two modes of action: the inactivation of polyphenol oxidase directly and the oxidative degradation of phenolic substrates.

Addition of sodium alginate (edible coating) during pre-treatment improved the colour of minimally processed carrot cubes. The combination of citric acid, ascorbic acid, potassium meta-bi-sulfite and sodium alginate significantly affected colour, flavour, taste and the overall quality of minimally processed carrot cubes. The L^* value of control carrot samples was lower (58.77, 58.33) than T2 (59.90 and 59.17) followed by T3 (61.30, 60.13) and T1 (62.50, 61.93) for low density polyethylene and polypropylene, respectively (Mandhare, 2008).

Suttirak and Manurakchinakorn (2010) reported that, the market for fresh-cut fruits and vegetables has grown rapidly in recent years as a result of their freshness, convenience, and human health benefits. However, fresh fruits and vegetables deteriorate very rapidly after processing, especially cut-surface browning resulting from wound-induced physiological and biochemical changes. The application of anti-browning agents is one of the most effective methods for controlling the enzymatic browning reaction in fresh-cut fruits and vegetables. This article reviews the use of nature identical anti-browning agents, which are generally recognized as safe (GRAS) including ascorbic acid, citric acid and oxalic acid for prevention of browning in fresh-cut fruits and vegetables. Factors affecting inhibitory efficiency of the anti-browning agents and synergistic effects of the mixtures in various fresh-cut fruits and vegetables are presented.

Pavlos Tsouvaltzis *et al.* (2011) reported that Enzymatic browning is a serious quality limitation for fresh-cut potato (*Solanum tuberosum* L.) that has been successfully controlled by heat treatment in other commodities. The use of brief heat treatments with 55⁰C hot water applied to 'Russet Burbank' tubers for 10, 20, 30, or 40 min before cutting was evaluated for potential implementation to control tissue browning. After heat treatment, tubers were held at 20⁰C for 0 or 1 day before peeling and slicing. Control tubers were not previously immersed in hot water. All slices were placed in perforated plastic bags and stored at 5⁰C for 6 days. Exposure to hot water for 30 or 40 min caused severe heat injury. Browning developed in all treatments as indicated by colour measurements and discoloration scores (index of extent of discoloured area on the slice surface) during storage. Hot water treatment for 10 min best reduced browning, but only when treated tubers were stored intact for 1 day at 20⁰C before cutting, as indicated by discoloration scores and changes in L^* , a^* , and b^* values, which were significantly different from either the control or the other hot water treatments. Generally, the severe browning that developed in control slices during storage was associated with significant increases of 25% and 71% in phenolic content and antioxidant capacity, respectively. On the other hand, phenolic synthesis increased by only 6.25% to 13.2% in hot water treated slices during storage and polyphenoloxidase (PPO) activity was 24% to 31% lower compared with the activity before storage.

Mozumber *et al.* (2012) conducted research to analyze the yield, physico-chemical and nutritional quality of a cabinet dried tomato powder as affected by three (3) chemical treatments (KMS, CaCl₂ and both). Dehydration process was carried out using a

cabinet dryer at a constant air flow velocity of 0.7m/s and air temperature in the range of 60-65⁰C. Based on preliminary tests by dipping in 0.2% (w/w) potassium metabisulphite (T1) and 1% (w/w) calcium chloride (T2) independently and 1% (w/w) calcium chloride (CaCl₂) along with 0.2% (w/w) potassium metabisulphite (KMS) in water solution (T3) for 10 minutes. The effect of 3 pre-drying treatments on quality of cabinet dried tomato powder was analyzed by determining moisture content, rehydration ratio, total sugar, total acidity, fat, protein, ash, crude fiber, pH, total carotenoids, vitamin-C, minerals (calcium, iron, phosphorus) and sensory analysis. The results showed that the treatment T3 achieved the highest yield of tomato powder (4.6g/100g). The control sample showed highest moisture content (6.9g/100g) and dipping in 1% CaCl₂ along with 0.2% KMS presented the lowest moisture content (5.9g/100g). Sample T3 showed highest total sugar content (49.1g/100g). The study also depicted that the total carotenoids content in tomato powder was 0.21mg/100g which was lower than that of fresh tomato (2.1mg/100g). Micronutrients such as vitamin-C, Calcium, phosphorus and iron were found to be 35.30mg/100g, 336.72mg/100g, 105mg/100g and 12.23mg/100g, respectively, in case for T3 sample.

Adiyaman *et al.* (2013) studied the effect of pre-packaging [1 per cent vented High Density Polyethylene (200 gauge) bag] and pre-treatments [1.5 per cent potassium metabisulphite (KMS) solution (T1) and 2 per cent sodium chloride (NaCl) and calcium chloride (CaCl₂) solution (T2)] on physiological loss in weight (PLW), total soluble solids (TSS), pH, titratable acidity, firmness and colour (L* a* b*) of star fruit, egg fruit and fig was studied during storage in ambient (R1) and refrigeration (R2) conditions (4±1⁰C). The experimental results indicated that a decrease in titratable acidity, fruit firmness, increase in pH and total soluble solids (TSS) content under both pre-treatments and storage conditions. The pre-treatment (T2) however extended star fruit and egg fruit marketable life with lowest PLW (8.04% and 4.52%) and physico-chemical constituents up-to till the 22th and 16th days at ambient temperature and more than 25th (7.47%) and 20th (3.40%) days under refrigeration condition. This might be due to the pre-treatment with 2 per cent NaCl and CaCl₂ solution which delayed fruits ripening periods during storage. Whereas the fig pre-treated with T1 had better shelf life (4 days) with respect to physical properties during storage at refrigeration temperature than control. The results of the study indicated that pre-treatments T2 and T1 found to be better for improving the shelf-life of star fruit (25 days), egg fruit (20 days) and fig (4 days) storage at ambient and refrigerated conditions.

Ghidelli *et al.* (2013) studied the effect of wide range of antioxidants on enzymatic browning of 'Rojo Brillante' persimmon combining in-vitro (extracts and precipitates) and in-vivo (cut tissue) studies. Preliminary screening of the antioxidants, determined by absorbance and colour measurements of persimmon extracts and pellets, showed that 4-hexylresorcinol (Hexyl), citric acid and calcium chloride (CaCl₂) were effective at controlling browning at 10 mm; whereas, ascorbic acid required a higher concentration (25 mm). Peracetic acid, cyclodextrin, cysteine, and hexametaphosphate were not effective at controlling browning, even at a concentration of 50 mm. In in-vivo studies, ascorbic acid (1.12%) and citric acid (0.21%) were the most effective treatments to control enzymatic browning of fresh-cut material, reaching the limit of marketability in

5–7 days, whereas, Hexyl and CaCl₂ did not reach 1 day of storage. The results showed that optimum concentrations in cut tissue did not always correlate with the in-vitro studies, indicating that anti-oxidants have an effect not only in browning reactions, but also in metabolic activity and cell wall changes during wound-induced reactions. The results provide relevant information for further development of minimally processed 'Rojo Brillante' persimmon during storage at 5⁰C.

Manolopoulou and Varzakas (2014) investigated the effect of storage at 0°C and 5°C on the colour and organoleptic quality, of fresh-cut cabbage during the addition of ascorbic acid, citric acid and calcium chloride and during Modified Atmosphere Packaging (MAP) with low O₂ concentrations (1.5%) and high concentrations of CO₂ (17%). Of the two studied temperatures (0 and 5°C) the temperature of 0°C maintained better quality parameters (colour, organoleptic quality) and increased the shelf-life of minimally processed cabbage. Among the treatments (MAP, citric acid, ascorbic acid, calcium chloride) MAP and citric acid showed the best results. The combination of low temperature storage (0°C) with MAP or citric acid treatment prolonged the shelf-life of minimally processed cabbage for 22 days, time sufficient for acceptable marketing of the product.

2.3 Packaging

Exama *et al.*(1993) suggested that micro holes of a definite size and number in the packaging material is suitable to avoid anaerobes in the produce having high respiration rate and reported that micro-perforated PP packaging of sliced carrot provided a better retention of shelf-life when stored at 4⁰ C.

Rathod *et al.* (2011) evaluated the storage condition and pre-treatment on Carambola fruits. The freshly harvested Carambola (*Averrhoa Carambola* L.) fruits were packed in different packaging materials like high density polyethylene (HDPE) with 1% and 2% ventilation with a pre-treatment of 2% CaCl₂ and stored at ambient as well as in refrigerated conditions. The temperature was in the range of 18 to 21⁰C and relative humidity of about 86 per cent. The result showed that, the Carambola fruits stored in 200 gauge HDPE polyethylene bag with 1% ventilation stored at refrigerated temperature and pre-treatment with 2% CaCl₂ showed encouraging result with respect to biological properties and organoleptic evaluation compared to other treatments.

2.3.1 Vacuum packaging

In recent years, consumers have become more health conscious in their food choices but they also have less time to prepare healthy meals. As a result, minimally processed (MP) products have become an important sector of the food industry because of their 'fresh-like' qualities, convenience and speed of meal preparation.

In a study on potatoes, the physical qualities of minimally processed potatoes (Desiree variety) stored for 7 days in vacuum packaging were evaluated. The shelf-life of minimally processed potatoes was effectively extended to nearly 1 week under

refrigerated storage by using vacuum packaging systems. The main quality parameters were constant during storage (Ada and Rocha *et al.*, 1955).

Geetha and Thirumaran (2010) investigated the effect of vacuum packaging on the shelf-life of papaya. The fruits were pre-treated with wax, oil, parafil packets and tissue paper wrapping along with the control and were packed in 150 gauge thickness polyethylene film bags under vacuum and another set of these samples without vacuum. The fruits were then stored at room and refrigeration temperatures and analyzed for chemical changes. The shelf-life of the fruits was increased under vacuum packing at room and refrigeration temperatures for one and 4 weeks, respectively. The pre-treatment with waxing maintained the quality with minimum changes followed by parafil and oil application. During storage, moisture, acidity, vitamin C, and total sugars decreased, whereas reducing sugar and total soluble solids (TSS) increased.

A study was conducted by Padmanaban *et al.* (2014) to increase the shelf-life of fruits through vacuum packing. Papaya fruits were pretreated with waxing, oil application, parafil packets, tissue paper wrapping given along with control and were packed in 150 gauge thickness polyethylene film bags under vacuum and another set of these samples under without vacuum. The fruits were then stored at room and refrigerated temperatures and analyzed for chemical changes. Results showed that the shelf-life of the fruits increased under vacuum packing with room and refrigeration temperatures for one and four weeks respectively. The fruits packed without any pretreatment in 150 gauge polyethylene bags maintained the quality with minimum changes followed by waxing, parafil and oil application. During storage moisture, acidity, Vitamin C and total sugar decreased whereas reducing sugar and total soluble solids (TSS) increased during storage.

2.3.2 Modified atmosphere packaging

Martinez *et al.* (2002) developed a modified atmosphere packaging (MAP) system for pineapple and mango for increasing shelf-life of the fruits. Sample preparation consisted of hand-peeling, dicing, blanching, dipping in ascorbic acid and packaging. The treatments were: gas mixture (4% O₂, 10% CO₂ and 86% N₂); vacuum packaging; 100% oxygen, and control. Microbial growth, texture, and colour were significantly (P, 0.005) different between the gas and other treatments. The gas mixture treatment achieved the longest shelf-life. The sensory analysis showed slight difference between fresh and MAP mango and no difference between fresh and MAP pineapple. MAP could be used as a technology to extend shelf-life of mango and pineapple.

Ralph Gunther Klaiber *et al.* (2005) different applications of cold and warm tap water (4⁰C and 50⁰C) with and without chlorination, respectively, in the washing of uncut peeled carrots (*Daucus carota* L.) were conducted, and their effects on sensory and microbiological properties during storage for 9 days at 4⁰C were assessed. To minimise cross-contamination of almost sterile inner root parts with the highly contaminated outer cortex during processing the peeled carrots were washed prior to cutting. The washing treatments were carried out using a commercial processing line, thus facilitating the scale-up to industrial production. Populations of aerobic mesophilic bacteria, lactic acid bacteria and entero bacteria on these minimally processed carrots were determined, and

the sensorial quality of shredded carrots was evaluated, besides analysing for colour, texture, sugars, and trichloromethanes. Washing uncut carrots with cold chlorinated water (200 mg/l, 4⁰C) and warm tap water (50⁰C) ensured sugar retention and reduced aerobic mesophilic bacteria by 1.7 and 2.0 log₁₀ colony forming units per gram (cfu/g), respectively, while washing with warm chlorinated water (200 mg/l) resulted in a 2.3 log₁₀ cfu/g reduction. By-product formation due to chlorination was negligible. Sensorial properties of the latter samples were slightly affected. It was found that both washing uncut knife-peeled carrots with cold chlorinated water (4⁰C) and warm tap water (50⁰C), respectively, provided good microbiological safety paired with improved sensorial properties.

Saxena *et al.* (2007) carried out a study to investigate the effect of different modified atmosphere packaging (MAP) techniques for extending the shelf-life of fresh-cut jackfruit (*Artocarpus heterophyllus* L.) bulbs kept under low temperature conditions. MAP consisted of 3 kPa O₂ + 5 kPa CO₂ (with balance of N₂) gas mixture flushed polyethylene (PE) bags, polyethylene terephthalate (PET) jars with silicon membrane window on lid and PE bag with air. Fresh-cut jackfruit bulbs were given a post-cutting phytosanitation wash followed by a dip pre-treatment with calcium chloride, ascorbic acid and sodium benzoate under mild acidified conditions prior to MAP. Non dipped samples packaged in same type of MAP conditions were used as control. Dip pre-treatment along with different MAP was found effective in establishing optimum O₂ and CO₂ concentrations, reducing the respiration rate, ethylene production and electrolyte leakage, restricting changes in total soluble solids (TSS)/titrable acid (TA) ratio and maintaining sensory attributes of the samples compared to control (non-dip) samples kept under same MAP conditions at 6⁰C. Dip pre-treated sample packed in 3 kPa O₂ + 5 kPa CO₂ gas mixture flushed PE bags was found to preserve the initial firmness value of the jackfruit bulbs (about 44 N) with a minor loss of around 7% after 35 days compared to significantly higher loss in the control samples packaged in the same MAP. Dipped samples also maintained a significantly higher lightness (L value) and colour intensity (chroma) of jackfruit bulb surface compared to the control fruit. PET jar with silicon membrane window was also found to be capable of achieving equilibrate atmosphere more efficiently than PE bags which maintained more stable gas composition and minimized physiological and quality changes. On the basis of sensory quality attributes, the shelf-life of pre-treated jackfruit bulbs packaged in gas mixture flushed PE bags, in PET jars with silicon membrane window and in PE bag were 35, 31 and 27 days, respectively.

Munishamanna *et al.* (2008) studied a Modified Atmosphere Packaging (MAP) of whole jackfruit to enhance the shelf-life of the fruit. Jackfruits were stored in Corrugated Fiber Boxes (CFB) at ambient (25–27⁰C), low (16⁰C) and refrigerated (10–12⁰C) temperatures under MAP conditions using silicone membrane (window area–3cm²) and diffusion channel (glass tube –50 mm length, 5 mm dia.) to attain the desired level of O₂ (15 -16%) and CO₂ (10 -12%) surrounding the fruit. The shelf-life of fruit was 2–3 days under normal conditions at room temperature. They reported that the fruits could be stored for 8 and 10 days under MAP conditions at ambient and low temperature conditions, respectively.

Montero-Calderona *et al.* (2008) reported that influence of packaging conditions on fresh-cut 'Gold' pineapple shelf-life were studied during 20 days of storage at 5⁰C. Fresh-cut fruit pieces were packed in polypropylene trays (PP) and wrapped with polypropylene film under active (high 40% or low oxygen, 11.4%) or passive modified atmospheres (air or cut fruit coated with 1%, w/v alginate). Changes in headspace composition, titratable acidity, pH, soluble solids, juice leakage, colour, texture, and microbial growth were evaluated over time. In all packaging conditions, oxygen concentration continuously decreased below its initial concentration over 20 days storage, but never reached levels below 2% O₂. CO₂ concentration inside all packages continuously increased over time up to 10.6–11.7% from the initial conditions. Ethylene concentrations were always less than 0.4/1L while ethanol was detected only after 13 days of storage. Colour parameters L^* and b^* significantly decreased over time in all packaging conditions and were directly attributed to the translucency phenomenon in the fruit flesh. When alginate coating was used, juice leakage was significantly reduced in contrast with the substantial juice accumulation observed in the rest of the packaging conditions. Texture profile analysis (TPA) parameters, did not significantly change over time, suggesting that structural characteristics of fresh-cut pineapple pieces were preserved throughout storage. From the microbial point of view, the shelf-life of 'Gold' fresh-cut pineapple was limited to 14 days by mesophilic bacterial growth. Further studies are needed to evaluate the sensory aspects, as well as to characterize the flesh translucency phenomenon and reduce juice leakage of fresh-cut pineapple.

Fresh produce is more susceptible to disease causing organisms because of increase in the respiration rate after harvesting. The respiration of fresh fruits and vegetables can be reduced by many preservation techniques. Modified atmosphere packaging (MAP) technology is largely used for minimally processed fruits and vegetables including fresh, "ready-to-use" vegetables. Extensive research has been done in this area since many decades. Oxygen, CO₂, and N₂, are most often used in MAP. The recommended percentage of O₂ in a modified atmosphere for fruits and vegetables for both safety and quality falls between 1 and 5%. Although other gases such as nitrous and nitric oxides, sulphur dioxide, ethylene, chlorine, as well as ozone and propylene oxide have also been investigated, they have not been applied commercially due to safety, regulatory standards and cost considerations. Successful control of both product respiration and ethylene production and perception by MAP can result in a fruit or vegetable product of high organoleptic quality; however, control of these processes is dependent on temperature control. (Sandhya, 2009).

Lucera *et al.* (2009) studied the different packaging strategies to prolong the shelf-life of minimally processed zucchini. Two different cultivars (Sofia and Diamante) were tested. The sliced zucchini were packaged in oriented polypropylene-based (OPP) bag and into a bio-polymeric film (COEX) under passive and active MAP. The investigated produce was stored at 5°C for approximately 9 days. Headspace gas concentrations, pH, mass loss, sensory quality and viable cell load of main spoilage microorganisms were monitored for the entire observation period. To determine the respiration activity, O₂ and CO₂ concentrations were monitored not only in OPP and COEX packages but also in the headspace of an aluminium-based package. Results

suggested that for Diamante cultivar OPP film under active and passive MAP showed slightly better performances in prolonging the shelf-life, compared to COEX film; instead, for Sofia cultivar better results were obtained with OPP film only under active MAP conditions.

2.4 Refrigeration storage

Sally (2011) studied packaging and storage of minimally processed jackfruits bulbs and evaluated different packaging including vacuum packing. They reported that the packages such as PE/PP (300 Gauge) and PS packages, vacuum packaging enhanced the shelf-life of the minimally processed jackfruit bulbs to 3-4 weeks in refrigeration storage (3-5°C) and over 6 weeks in deep freeze storage (-12°C) compared to the conventional technique which resulted in 1-2 weeks of storage under refrigeration (3-5°C), 2-3 weeks for the untreated samples under deep freeze storage for the pretreated samples, and 1 week in refrigeration (3-5°C) and 1-2 weeks in deep freeze storage (-12°C).

Shafiq Alam *et al.* (2013) conducted experiments in completely randomized design in order to assess the shelf-life and quality of minimally processed papaya stored under refrigerated condition ($5^{\circ}\text{C}\pm 1^{\circ}\text{C}$ and 95% RH). Before minimal processing, the semi ripe whole papaya was divided into two lots: control (untreated) and mild heat pre-treated. The mild heat pre-treatment (MHPT) of 45°C constant temperature for different exposure time (15, 30 and 45 min) was given to whole papaya followed by 24 h conditioning in cold room (1°C and 95% RH). Both the untreated and mild heat pre-treated samples were packed in four different packaging materials i.e. polyethylene film (LDPE), polypropylene (PP), cling film and open tray. The stored samples were examined for its quality attributes i.e. physical loss in weight (PLW), colour, texture (firmness), acidity, TSS and overall acceptability (%) at regular intervals. The results revealed that the packaging material and MHPT exposure time significantly affected the quality attributes. The 30 minutes as well as 45 minutes MHPT exposed samples when packed in LDPE witnessed minor change in colour, texture, acidity and better retention of quality in terms of overall acceptability. Overall, the minimally processed papaya when MHPT for 45 min and packed in LDPE can be stored safely for 8 days under refrigerated condition.

2.5 Cost economics

Considering all variable and fixed costs involved in the investigation for the minimal processing of carrots, Mandhare (2008) reported the cost: benefit ratio of 1.00:1.38 for low density polyethylene (LDPE) package which was more than 1.00:1.28 for polypropylene (PP).

III. MATERIAL AND METHODS

The investigation on Post harvest management of ready-to-cook (RTC) tender Jackfruit (*Artocarpus heterophyllus* L.) was conducted at the Post Harvest Technology Scheme, Gandhi Krishi Vigyan Kendra, University of Agricultural Sciences, Bangalore, during 2013-2014. In this Chapter, the material used and methods adopted for carrying out the studies on post harvest management of ready-to-cook (RTC) tender Jackfruit have been described here under.

3.1 Procurement of raw materials

Different genotypes of tender jackfruit were procured from Horticulture College, UAS, Bangalore. The selections of different genotypes were based on the identification by the Department of Biotechnology, UAS, Bangalore.

3.2 Equipment and instruments

The various instruments used in the present study were weighing balance for weighing the chemicals and sample, hot air oven for determination of moisture content, Kjeltex unit to determine the protein content, Fibra-Plus apparatus to determine the fibre content, Soxhlet apparatus to determine the fat content, muffle furnace to determine the ash content, colourimeter for measurement of colour values and texture analyser for measurement of firmness of the RTC tender jackfruit sample.

3.3 Physical and engineering properties

3.3.1 Shape

For the identification of the shape of different genotypes of tender jackfruit, tracing of the longitudinal and lateral cross sections of the tender jackfruit was compared with the shapes listed on standard chart. The shape of the tender jackfruit was defined by a number on the chart or by descriptive terms.

3.3.2 Weight

The selected tender jackfruits were weighed with the help of an electronic balance and the mean weight was computed and recorded as weight of the tender jackfruit, and expressed as gram.

3.3.3 Colour

The tri- stimulus colour values of RTC tender jackfruit samples of each trial were determined using a colourimeter (Make: Minolta Co; Japan Model: CR-200b).

Measuring system

Minolta Chroma meter CR-200b uses diffuse illumination, 0° viewing angle geometry for colour measurements of a wide variety of surfaces. A pulsed xenon arc (PXA) lamp inside a mixing chamber provided diffuse, even lighting over the sample. Only the light reflected perpendicular to the surface is collected by the optical cable for

colour analysis. The received light is divided into three ways and passed through special filters whose light-absorbing characteristics combine with the special spectral response of the photocells to duplicate CIE 1931 colour matching. A double feedback system is used to ensure that lighting remains consistent for each measurement. In addition to the sensors which measure the light from the sample, three other photocells read the colour of the incident light each time the lamp is fired. The microcomputer then uses this data to check and compensate for any changes in the illumination. Upon striking the silicon photocells, light energy is converted into electrical signals and sent to the microprocessor, where it is adjusted for the illumination condition desired and then converted into coordinates for the chosen colour space. These readings are displayed in the LCD panel and can be transferred to a separate computer through the data-output terminal

Colour measurement

The RTC tender jackfruit sample was filled in a special colour measuring cell (supplied with instrument). The tri-stimulus colour of the sample was then measured in L^* , a^* , b^* coordinates system.

3.4 Texture analysis

Texture is one of the most important quality attributes affecting the acceptability of minimally processed ready-to-cook (RTC) tender jackfruit by the consumers.

About the texture analyzer

The texture analyzer (TA-XT2 Stable micro-systems) is a microprocessor controlled texture analysis system, which can be interfaced to a wide range of peripherals, including PC type computers. It is versatile and easy to use. The texture analyzer consists of two separate modules: the Test-bed and the Control console (keyboard). By connecting the texture analyzer to an IBM PC, we can see the data in the graphical format to find multiple peaks, measure gradients, areas, averages and the data was saved on a disc. Many other features such as a fully automated T.P.A. analysis, keyboard macros and an interface to a variety of printers, including some colour ones. The following test was performed using the texture analyzer in the present study:

3.4.1 Firmness

The firmness of RTC tender jackfruit sample was evaluated by performing a puncture test on the cubes using a Texture Analyzer (TA-XT2 Stable with micro systems with a 50kg load cell, equipped with a rounded 2mm dia. steel probe) and taken the force value obtained during test to penetrate the distance of 5mm at 1mm/s before and after the storage of RTC tender jackfruit samples. Puncture is a characteristic of certain type of materials usually with a thin surface layer that is determined by measuring force to penetrate the surface layer. The test settings of the texture analyzer are given below:

Texture analyzer (TA-XT2) settings

1. Mode: Measure force in compression
2. Option: Return to Start



Plate 1: COLOURIMETER CR-200b (Minolta Chroma Instrument, Japan) used for the assessment of colour



Plate 2: TEXTURE ANALYSER

3. Data Acquisition Rate: 400PPS
4. Pre test speed: 1.5mm/s
5. Test speed:1.0mm/s
6. Post test speed:10.0mm/s

The firmness was determined by measuring the force (N) required for the probe to penetrate the cube to a depth of 5mm. Five samples from each replicate pack were used to determine the firmness. Three measurements were made on each face of the RTC tender jackfruit on flesh tissue. RTC tender jackfruit samples were centred over the jig hole and tested in the core or xylem tissue so that the probe entered the specimen parallel to the long axis of the root. Force-deformation curves were recorded and stored electronically and the computer analysis resulted F_{max} (N) and deformation values (mm) for firmness. Texture Expert Exceed software supplied with texture analyser was used to analyze the force time/distance data to identify the peaks. Instrumental textural data were stored and graphed, results were tabulated and statistical analysis performed.

3.5 Proximate analysis of ready-to-cook (RTC) tender jackfruit

The biochemical parameters of the minimally processed RTC tender jackfruit samples were monitored till the end of the storage period. The proximate composition of ready-to-cook tender jackfruit *viz.*, moisture content, crude protein, crude fat, total ash/mineral, crude fibre content were estimated by following standard procedures.

3.5.1 Moisture content

The moisture content of the minimally processed ready-to-cook tender jackfruit samples were determined by following AOAC method (AOAC, 2005: method No.:925.10). A brief description of the method is as follows. A 10g of ready-to-cook tender jackfruit samples were kept in a pre-dried moisture box. The mass of the sample was recorded as W_1 . The box was placed in the hot air oven maintained at $75^{\circ}C$ for 24 hours. After drying, the box was kept in the desiccator and then weighed. The mass of the dried sample was recorded as W_2 . All measurements were replicated thrice and the average moisture content was calculated. The moisture content of the sample was calculated by using the following equation.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad \dots\dots\dots 3.1$$

Where,

W_1 = Initial weight of the sample, g

W_2 = Final weight of the sample, g

3.5.2 Crude protein

The crude protein of minimally processed ready-to-cook tender jackfruit was determined using micro Kjeldahl method (AOAC, 2005: method No.:960.524). A finely chopped 1g of ready-to-cook tender jackfruit sample was transferred to a digestion tube;

to this digestion mixture 7-8ml of concentrated sulphuric acid were added. The sample was digested in a digestion unit until it became colourless. Then the tubes were cooled and transferred to the distillation unit. Forty ml of 40% sodium hydroxide was allowed into the tube. Liberated ammonium was absorbed in 4% boric acid solution containing mixed indicator, the pink colour of the boric acid solution was turned to green and this was titrated against 0.1N of HCl until the pink colour was obtained. The titre values obtained were incorporated in the equation below to obtain the per cent nitrogen present in the sample which, in turn, was multiplied by the factor 6.25 to obtain the per cent protein.

The protein, in per cent, was obtained by using the following formula:

$$\text{Protein (\%)} = \frac{(\text{ml of HCl} - \text{ml of blank}) \times \text{molarity} \times 14.007 \times 100}{\text{mg test portion}} \times 6.25 \quad \text{.....3.2}$$

3.5.3 Crude fat

The crude fat content of the minimally processed ready-to-cook tender jackfruit sample were estimated by Soxhlet extraction method (AOAC, 2005: method No.:920.39) using SOCS-PLUS apparatus (make: Pelican Equipments; model: SCS-08).

Minimally processed ready-to-cook tender jackfruit sample of 2.5g was weighed accurately and transferred to a thimble. An empty beaker weight was taken and all the beakers were loaded into the system. The petroleum ether was poured into the beaker from the top and boiled for about 45 min at 75°C. After the completion of process time, the temperature was raised to 150°C for 15-20 min to collect the petroleum ether. All the beakers were removed and placed in a desiccator for about 5 min. The final weight of the beaker was noted down and fat content was estimated by using the following equation;

$$\text{Fat content (\%)} = \frac{W_2 - W_1}{W} \times 100 \quad \text{.....3.3}$$

Where,

W_1 = Initial weight of the beaker, g

W_2 = Final weight of the beaker, g

W = Weight of the sample taken, g

3.5.4 Total ash

The total ash content of the fresh and dried samples was determined as per AOAC, 2005 (AOAC, 2005: method No.:923.03) using muffle furnace (make: MAC; model: MSW-251). Accurately 3g of the sample was weighed into a crucible (which was previously heated to about 550°C and then cooled). The crucible was placed on a clay pipe triangle and heated first over a low flame till all the material was completely charred, followed by heating in a muffle furnace for about 3-5 h at 600°C. It was then cooled in desiccators and weighed. The percentage of ash was calculated by using the following expression:

$$\text{Total ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100 \quad \dots\dots\dots 3.4$$

3.5.5 Crude fiber

The crude fiber content of minimally processed ready-to-cook tender jackfruit sample was determined by sequential acid and alkali hydrolysis method using Fibra-Plus (make: Pelican Equipments; model: FES-08S) apparatus (AOAC, 2005: method No.:978.10). Accurately weighed 2g moisture and fat free sample was taken in a crucible. The sample was boiled in 1.25 per cent sulphuric acid and subsequently boiled in 1.25 per cent sodium hydroxide solution. The sample was dried in hot air oven at 100°C till all the moisture was evaporated. The weight of the crucible before ashing was noted down. The dried sample was made into ash in a muffle furnace at 200°C for 4 h. After ashing, the crucibles were cooled in a desiccator and reweighed. The residue obtained after subtraction of the ash was regarded as fibre. The crude fiber was obtained by using the following equation:

$$\text{Crude fibre (\%)} = \frac{W_1 - W_2}{W} \times 100 \quad \dots\dots\dots 3.5$$

Where,

W_1 = Weight of the sample before ashing, g

W_2 = Weight of the sample after ashing, g

W = Weight of the sample, g

3.6 Experimental details

3.6.1 Preparation of Minimal processing of ready to cook tender jackfruit

The minimal processing of ready-to-cook tender jackfruit involved the following steps outlined below:-

- i. Collection of healthy, suitable green of RTC green jackfruit
- ii. Removal / chopping of outer surface portion of spines of green jackfruit
- iii. Washing with 1% KMS solution
- iv. Cutting to required sizes of RTC green jackfruit
- v. Pre-treatment: blanching in hot water, air drying and treating with citric acid followed by KMS
- vi. Packaging and storage

3.6.2 Treatment details

Pre-treatment details

- I. Blanching (75⁰C)
- II. Blanching followed by citric acid (0.5%)
- III. Blanching followed by Potassium meta bisulphate(0.5%)

- IV. Blanching followed by Potassium meta bisulphate (1.0%)
- V. Brine solution(4%)
- VI. Potassium meta bisulphate (0.5%)
- VII. Blanching followed by Brine solution (4-5%)

Observation: Observation on intensity of browning, proximate composition for best treatment

Packaging materials

- T1: Poly propylene (300G) with 0% ventilation
- T2: Poly propylene (300G) with 0.1% ventilation
- T3: Poly propylene (300G) Vacuum packaging (90%)
- T4: Poly ethylene (300G) with 0% ventilation
- T5: Poly ethylene (300G) with 0.1% ventilation
- T6: Poly ethylene (300G) Vacuum packaging (90%)

Storage: Two temperatures

- 1. Low temperature(8-10⁰C)
- 2. Refrigeration temperature (3-5⁰C)

Storage period: 3-4 weeks

Type of package with ventilation percentage

Both polyethylene (PE) and polypropylene (PP) packages of 300 gauge measuring 7.8” × 6.1” (62000mm²) were used. The two levels of ventilations *i.e.* no ventilation, 0.1% ventilation, of 2mm diameter each were made on both the sides of the packages for both PE and PP.

Calculations for perforation percentage

$$\begin{aligned}
 \text{Area of the bag} &= l \times b \times 2 \text{ sides} \\
 &= 7.8'' \times 6.1'' \times 2 \\
 &= 62000\text{mm}^2
 \end{aligned}$$

Diameter of the hole = 2mm

$$\begin{aligned}
 \text{Area of each hole} &= \text{Area of the circle} \\
 &= \pi r^2 \\
 &= 3.14 \times (1)^2 \\
 &= 3.14\text{mm}^2
 \end{aligned}$$

0.1% ventilation

It is required to make 0.1mm² ventilation area in 100mm² of polyethylene and polypropylene packages.

$$\begin{aligned} 0.1 \text{ percent area (mm}^2\text{)} &= \frac{0.1 \text{ mm}^2 \times 62000}{100} \\ &= 62(\text{mm}^2) \end{aligned}$$

$$\begin{aligned} \text{Total No. of holes} &= \frac{62}{3.14} \\ &= 19.74 \text{ holes} \end{aligned}$$

Minimally processed RTC tender jackfruit samples were then packaged in 150g lots in perforated PE and PP packages and sealed with a Multvac A300 sealing machine. The bagged minimal processed product was stored at ambient, refrigerated and low temperature environments. Each treatment was replicated thrice and two sets were maintained to record non-destructive and destructive observations.

3.7 Vacuum packaging of minimally processed jackfruit bulbs

The experiment was carried out to investigate the influence of vacuum packaging of minimally processed ready-to-cook tender jackfruit samples at different packaging materials and different storage temperatures with pre-treatment. The minimally processed RTC tender jackfruit samples were packed in PE and PP packages with blanching followed by KMS (0.5%) pre-treatment, Vacuum packaged samples were stored in refrigeration and low storage room for a period of 3 weeks and 4 weeks, respectively. The details of the experimental treatments are follows:

Vacuum packaging

Vacuum packaging of tender jackfruit done in polyethylene (PE) and polypropylene (PP) packages of 300 gauge using a laboratory model vacuum packaging machine (Reepack- RV 50, Italy). The bulbs were packed at different vacuum levels and thermally sealed. The Reepack vacuum packaging machine consisting 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. However, in this study, no internal gas flushing was done.

The pre-treated and RTC tender jackfruit samples were placed in polyethylene and polypropylene pouches. A pouch with the product was kept inside the product chamber of the Reepack machine such that the opening of the pouch covered the gas flushing nozzle and the sealing bars could seal the pouches properly. As soon as the lid of the product chamber was closed, the 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 initiated. 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. The sealing time of pouch was programmed earlier depending upon the packaging material; in the present the study sealing time was 2.5 second. Once the sealing was finished, the lid of the product chamber opened automatically and the packaged sample was taken out and kept in refrigerated and low temperature environments.

3.8 Sensory evaluation

Analytical sensory evaluation was used to differentiate between the colour, texture, flavour, shelf life and overall acceptability of ready-to-cook tender jackfruit by different treatments. The products were scored for colour, texture, flavour, shelf-life on a numerical scoring method (Amerine *et al.*, 1965). The 9 point 'hedonic scale' was employed. Samples were ranked for quality parameters from higher to lower in descending order of acceptability.



Plate 3: Vacuum packaging machine (Reepack - RV 50, Italy)

IV. EXPERIMENTAL RESULTS

The present investigation on “Post harvest management of Ready-to-Cook (RTC) Tender Jack fruit” was undertaken during the year 2013- 2014 at the AICRP on Post Harvest Technology, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bangalore.

The results of the investigation are discussed in the following sub headings:

- I. Physical and Biochemical properties of tender (green) jackfruit of different genotypes.
- II. Optimization of different pre-treatments for preventing browning /discolouration of different genotypes of tender jackfruit.
- III. Storage studies for the best performed genotype for tender jackfruit.
- IV. Economic cost analysis.

4.1 Physical and biochemical properties of different genotypes of tender (green) jackfruits

Four different genotypes for the study were selected from the list of identified jackfruit genotypes by the Department of Biotechnology, University of Agricultural Sciences, Bangalore.

These genotypes were –Swarna halasu, Horticulture vegetable purpose1 (HV1), Horticulture vegetable purpose 2(HV2), and PHT (post harvest technology).

4.1.1 Area

The length and diameter of the Swarna halasu was found to be 31.50, 19.50(cm), HV1-43.00, 16.50(cm), HV2- 34.00, 21.50(cm) and PHT-36.00, 19.00(cm) respectively (Table 1).

4.1.2 Shape

The shapes of all the jackfruit genotypes used as tender vegetables, namely, Swarna halasu was found to be round, HV1, HV2 and PHT were found have a typical oblong shape (Table 1).

4.1.3 Unit weight

The unit weights of different genotypes of tender jackfruit were Swarna halasu with 1.33 kg, HV1 with 1.5kg, HV2 with 1.65kg and PHT with 1.5kg (Table 1).

4.1.4 Texture

The mean values of texture (force N) of different genotypes of tender jackfruits were recorded to be 4.58 N for Swarna halasu, 7.57 for HV1, 6.77 for HV2 and 6.52 for PHT. Highest texture value was recorded in respect of HV1 variety (Table 1).

4.1.5 Moisture content

The mean values of moisture contents (w.b) of different genotypes of tender jackfruit were found to be Swarna halasu with 87.62%, HV1 with 88.01%, HV2 with 82.42%, and PHT with a moisture content of 85.65%. HV1 was found to possess highest moisture content among the genotypes (Table 1).

4.1.6 Protein

The mean value of protein content of different genotypes of tender jackfruit was found to be swarna halasu with 1.805%, HV1 with 2.327%, HV2 with 2.417% and PHT variety with 2.885% (Table 1).

4.1.7 Fat

The mean values of fat contents of different genotypes of tender jackfruit were found to be Swarna halasu with 1.90%, HV1 with 2.05%, HV2 with 2.52% and PHT with 1.98% (Table 1).

4.1.8 Fibre

The mean values of fibre contents of different genotypes of tender jackfruit were found to be Swarna halasu with 1.5%, HV1 with 2.53%, HV2 with 2.6% and PHT variety with 2.1%. Among the jackfruit varieties highest fibre content was found in HV2 genotype (Table 1).

4.1.9 Ash

The mean values of ash contents of different genotypes of tender jackfruit were Swarna halasu with 1.106%, HV1 with 1.129%, HV2 with 1.160% and PHT variety with 1.250% (Table 1).

4.1.10 Carbohydrate

The mean values of carbohydrate contents of different genotypes of tender jackfruit were found to be Swarna halasu with 6.061%, HV1 with 3.951%, HV2 with 6.048% and PHT with 6.640% (Table 1).

4.2 Optimization of pre-treatments on browning/discolouration of different genotypes of tender jackfruit

The major reason for colour change is the presence of polyphenol oxidase enzyme. Immediately after cutting tender jackfruit, browning/discolouration of the outer surface will occur. For overcoming this problem different pre-treatments were imposed on to RTC tender jackfruit.

The effect of pre-treatments such as blanching, blanching followed by citric acid (0.5%), blanching followed by KMS(1.0%), brine solution(4%), KMS(0.5%), blanching followed by brine solution(4-5%) were compared with respect to colour of the minimally processed RTC tender jackfruit. The L^* , a^* , b^* values of control were lower

Table 1. Physical and biochemical properties of tender (green) jackfruit of different genotypes

Property	Swarnahalasu	HV1	HV2	PHT
Size(cm)	L: 31.50 D: 19.50	L:43.00 D:16.50	L:34.00 D:21.50	L:36.00 D:19.00
Shape	Round	Oblong	Oblong	Oblong
Weight (kg)	1.340	1.500	1.650	1.500
Texture (force N)	4.580	7.570	6.770	6.520
Moisture content (%)	87.620	88.011	85.250	85.650
Protein (%)	1.800	2.320	2.410	2.380
Fat (%)	1.900	2.050	2.520	1.980
Fibre (%)	1.500	2.530	2.600	2.100
Ash (%)	1.106	1.129	1.160	1.250
Carbohydrate (%)	6.061	3.951	6.048	6.640

(66.86, 5.5, 28.33) indicating more browning. The L^* , a^* , b^* values of different pre-treatments of tender jackfruit of different varieties are presented in Table 2.

4.3 Texture/firmness

The mean peak forces required to penetrate the tender jackfruits with a 2 mm needle were found to be Swarna halasu with 4.58 N, HV1 with 7.57 N, HV2 with 6.77 N and PHT with 6.52N, respectively (Table 3). Highest textural force was recorded in HV1 variety of tender jackfruit.

4.4 Storage of tender jackfruit

Storage studies were conducted after pre-treatments to explore the possibility of extending shelf-life of tender jackfruits with a view to market all across the country. The major threat in achieving this was the browning of outer surface due to enzymatic reaction.

Among the four genotypes studied, HV2 genotype was performing better in respect of controlling browning or discolouration of tender jackfruit surface. Among the different pre-treatments, blanching followed by KMS 0.5% and blanching followed by KMS 1% found to be performing in controlling browning due to higher concentration of KMS 1%. With this finding, HV2 genotype was selected for further studies and for pre-treatment blanching followed by KMS 0.5% was selected.

Polyethylene and poly propylene packaging materials were employed with 0% and 0.1% ventilation and vacuum packaging to study the storability of tender jackfruit in two different storage environments viz., low temperature (8-10⁰C) and refrigeration temperature (3-5⁰C). For the study visual observations were recorded on freshness and shelf-life of RTC tender jackfruit.

4.4.1 Storage in low temperature (8-10⁰C)

Among the different packages, samples in vacuum packaging exhibited delayed browning. The samples in PE and PP vacuum packaging recorded higher L^* , a^* , b^* values for T3 (81.73, -2.73, 12.51) followed by T6 (80.74, -2.1, 12.2) respectively, in the beginning and on 21st day of refrigeration storage). The rate of decline in L^* , a^* , b^* values was greater in T5 (69.06, 1.33, 13.62). The influence of packaging material and ventilation on colour (L^* , a^* , b^* values) of RTC tender jackfruit are presented in Table 4. The results showed significant differences between treatments. Both PE and PP vacuum packaged samples recorded higher L^* , a^* , b^* values.

4.4.2 Storage at refrigeration temperature (2-3⁰C)

Among the different packages studied, samples in vacuum packaging exhibited delayed browning. The samples in PE and PP vacuum packaging recorded higher L^* , a^* , b^* values for T6 (84.46, -3.8, 15.53) treatment followed by T3 (83.56, -3.038, 15.84) respectively, at the beginning of storage and on 30th day of refrigeration storage). The decline in L^* value was greater in T4 (69.18). Influence of packaging material and

Table 2. Influence of pre-treatments on browning/discolouration of different tender jackfruit genotypes

Treatment	Swarnahalasu			HV1			HV2			PHT		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Control	66.86	5.50	23.33	66.73	3.60	26.96	76.40	1.66	28.06	69.40	5.20	27.40
T1	52.06	10.60	24.06	55.46	7.10	21.13	57.20	7.85	24.30	43.00	10.60	20.36
T2	63.76	5.76	21.13	57.16	4.60	18.00	62.40	6.30	25.43	53.83	6.78	21.86
T3	77.43	-1.33	25.80	77.86	-1.10	27.13	81.35	-4.95	31.75	74.20	-0.86	28.86
T4	79.23	-1.23	28.93	78.16	-1.16	28.40	86.23	-2.65	32.93	76.83	-0.66	29.26
T5	64.33	4.80	22.93	67.76	4.50	22.86	69.25	3.60	19.98	62.10	8.24	21.93
T6	72.16	1.68	24.93	76.33	-1.70	26.45	80.75	-2.18	16.25	74.00	-2.26	26.30
T7	64.65	5.90	17.76	61.30	4.80	19.90	56.85	10.15	27.75	55.70	7.98	26.47
F test	*			*			*			*		
SEm ±	3.43			1.57			0.64			0.81		
CD at 5%	5.64			2.57			1.06			1.33		

* significant

 T1: Blanching(75⁰C)

T2: Blanching followed by citric acid (0.5%)

T3: Blanching followed by KMS (0.5%)

T4: Blanching followed by KMS (1%)

T5: KMS (1%)

T6: Brine solution (4%)

T7: Blanching followed by brine solution (4-5%)

Table 3. Influence of pre-treatments on firmness of different tender jackfruit genotypes

Treatment	Force (N)			
	Swarna halasu	HV1	HV2	PHT
Control	4.58	7.57	6.77	6.52
T1	2.36	3.36	3.72	3.21
T2	1.81	3.11	3.12	3.01
T3	3.36	3.51	3.77	3.27
T4	2.11	4.03	3.84	3.06
T5	4.95	8.40	7.32	7.10
T6	3.56	8.40	7.32	7.07
T7	3.36	4.00	3.96	4.58
F test	*	*	*	*
SEm ±	0.23	0.21	0.13	0.27
CD at 5%	0.70	0.63	0.40	0.81

*significant

T1: Blanching(75⁰C)

T2: Blanching followed by citric acid (0.5%)

T3: Blanching followed by KMS (0.5%)

T4: Blanching followed by KMS (1%)

T5: KMS (1%)

T6: Brine solution (4%)

T7: Blanching followed by brine solution (4-5%)



CONTROLL



BLANCHING



BLANCHING FOLLOWED
BY CITRIC ACID



BLANCHING FOLLOWED
BY KMS (0.5%)



BLANCHING FOLLOWED
BY KMS (1%)



KMS SOLUTION (0.5%)



BRINE SOLUTION (4%)



BLANCHING FOLLOWED
BY BRINE (4-5%)

Plate 4: Influence of pre-treatments on browning of RTC (HV2 genotype) tender jackfruit



PP 0% ventilation



PP 0.1% ventilation



PP vacuum packaging



PE 0% ventilation



PE 0.1% ventilation



PE vacuum packaging

Plate 5: Influence of packaging material and ventilation on colour of RTC (HV2 genotype) tender jackfruit at 0 days of storage

Table 4. Influence of packaging material and ventilation on intensity of browning of RTC tender jackfruit in low temperature storage

Treatment	Colour (at 8-10°C)					
	7 th day			21 st day		
	L*	a*	b*	L*	a*	b*
T1	81.47	-3.00	15.44	71.52	1.40	14.22
T2	82.10	-2.90	14.38	72.06	1.26	13.46
T3	84.39	-3.13	13.33	81.73	-2.73	12.51
T4	80.21	-2.71	15.44	71.18	1.08	13.63
T5	80.97	-3.79	14.24	69.06	1.33	13.12
T6	84.35	-3.44	13.48	80.74	-2.10	12.20
F test	*	*	*	*	*	*
SEm ±	0.61	0.20	0.55	0.61	0.20	0.55
CD at 5%	1.04	0.34	0.33	1.04	0.34	0.33

*significant

PE –Polyethylene

PP - Polypropylene

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

ventilation on colour (L^* , a^* , b^* values) of RTC tender jackfruit are presented in Table 5. The results showed a significant difference among different packaging treatments.

4.4.3 Moisture

The RTC tender jackfruit exhibited slight decrease in moisture content during storage. Maximum retention of moisture content found was observed in T2 (85.43) followed by T4 (85.18) and lowest moisture content was recorded in T5 (84.86) at 21st day in low temperature storage. While the moisture content recorded high in T5 (85.51) under refrigerated temperature followed by T1 (85.50) and lowest moisture content was recorded in T2 (85.16) at 30th day of refrigerated storage (Table 6).

4.4.4 Protein

The possible effect of packaging materials were compared on protein content of minimally processed RTC tender jackfruit during storage (Table 7). The highest protein content was recorded in T3 (1.90) followed by T4 (1.81) and lowest value was in T2 (1.50) at 21st day in low temperature storage. The protein content was highest in T6 (1.64) followed by T4 (1.61) and lowest was recorded in T2 (1.31) at 30th day of storage in refrigerated storage. The results found that there were significant differences established between and within the treatments.

4.4.5 Fat

The results of fat content during storage of the minimally processed RTC tender jackfruit are presented in Table 8. The results showed a reduction in fat contents of the minimally processed RTC tender jackfruits. The highest fat content was noticed in T3 (0.36) followed by T1 (0.33) and lowest in T4 (0.29) at 21st days in low temperature storage. Whereas, fat content was higher in T2 (0.25) followed by T4 (0.22) and lowest values in T3 and T6 (0.20) at 30th day of refrigerated storage.

4.4.6 Fibre

The results of fibre contents of the minimally processed RTC tender jackfruit are presented in Table 9. A slight decrease in fibre content of minimally processed RTC tender jackfruit was observed during storage. The results showed that highest fibre content observed in T6 (2.27) and lowest in T2 (1.99) at 21st day in low temperature storage. Also, the fibre content was high in T6 (2.38) and low in T1 (2.09) at 30th day of refrigerated storage.

4.4.7 Ash

The effect of packaging materials were compared on Ash content of minimally processed RTC tender jackfruit during storage (Table 10). The highest Ash content was found in T3 (1.21) and lowest value recorded in T1 and T4 (1.04) at 21st day of low temperature storage. While in refrigerated storage Ash content found highest in T6 (1.28) and lowest was recorded in T5 (1.02) at 30th day of storage.



PP 0% ventilation



PP 0.1% ventilation



PP vacuum packaging



PE 0% ventilation



PE 0.1% ventilation



PE vacuum packaging

Plate 6: Influence of packaging material and ventilation on colour of RTC (HV2 genotype) tender jackfruit at 7 days of low temperature storage



PP 0% ventilation



PP 0.1% ventilation



PPvacuum packaging



PE 0% ventilation



PE 0.1% ventilation



PEvacuum packaging

Plate 7: Influence of packaging material and ventilation on colour of RTC (HV2 genotype) tender jackfruit at 21 days of low storage

Table 5. Influence of packaging material and ventilation on intensity of browning of RTC tender jackfruit during refrigeration storage

Treatment	Colour (3-5°C)					
	15 th day			30 th day		
	L*	a*	b*	L*	a*	b*
T1	82.26	-3.36	15.38	76.94	2.20	13.36
T2	84.46	-3.30	15.49	74.51	2.46	13.30
T3	86.11	-4.09	16.41	83.56	-3.03	15.84
T4	80.85	-3.06	14.49	69.18	2.70	14.55
T5	83.30	-3.11	15.18	72.34	2.09	14.19
T6	86.22	-4.03	16.59	84.46	-3.80	15.53
F test	*	*	*	*	*	*
SEm ±	0.47	0.21	0.39	0.47	0.21	0.39
CD at 5%	0.80	0.35	0.66	0.80	0.35	0.66

*significant

PE - Polyethylene

PP – Polypropylene

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

Table 6. Influence of packaging material and ventilation on moisture content of RTC tender jackfruit during storage (days)

Treatment	Moisture Content (%)						
	Low temperature (8-10 ⁰ C)				Refrigerated temperature (3-5 ⁰ C)		
	0	7	14	21	0	15	30
T1	86.79	85.06	85.00	84.87	86.79	85.56	85.50
T2	86.79	85.71	85.52	85.43	86.79	85.80	85.16
T3	86.79	85.50	85.50	85.00	86.79	85.66	85.48
T4	86.79	85.21	85.10	85.18	86.79	85.48	85.40
T5	86.79	85.22	85.10	84.86	86.79	85.82	85.51
T6	86.79	85.56	85.45	84.93	86.79	85.47	85.36

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)



PP 0% ventilation



PP 0.1% ventilation



PPvacuum packaging



PE 0% ventilation



PE 0.1% ventilation



PEvacuum packaging

Plate 8: Influence of packaging material and ventilation on colour of RTC (HV2 genotype) tender jackfruit at 15 days of refrigeration storage



PP 0% ventilation



PP 0.1% ventilation



PP vacuum packaging



PE 0% ventilation



PE 0.1% ventilation



PE vacuum packaging

Plate 9: Influence of packaging material and ventilation on colour of RTC (HV2 genotype) tender jackfruit at 30 days of refrigeration storage

Table 7. Influence of packaging material and ventilation on protein Content of RTC tender jackfruit during storage (days)

Treatment	Protein (%)						
	Low temperature (8-10 ⁰ C)				Refrigerated temperature (3-5 ⁰ C)		
	0	7	14	21	0	15	30
T1	2.23	1.660	1.63	1.613	2.23	1.46	1.50
T2	2.23	1.513	1.51	1.506	2.23	1.35	1.31
T3	2.23	1.900	1.90	1.900	2.23	1.52	1.46
T4	2.23	1.820	1.82	1.810	2.23	1.63	1.61
T5	2.23	1.840	1.80	1.800	2.23	1.65	1.53
T6	2.23	1.600	1.59	1.576	2.23	1.69	1.64

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

Table 8. Influence of packaging material and ventilation on fat content of RTC tender jackfruit during storage (days)

Treatment	Fat (%)						
	Low temperature (8-10°C)				Refrigerated temperature (3-5°C)		
	0	7	14	21	0	15	30
T1	0.63	0.34	0.34	0.33	0.63	0.23	0.21
T2	0.63	0.33	0.33	0.32	0.63	0.26	0.25
T3	0.63	0.38	0.37	0.36	0.63	0.22	0.20
T4	0.63	0.32	0.32	0.29	0.63	0.23	0.22
T5	0.63	0.32	0.32	0.30	0.63	0.22	0.21
T6	0.63	0.32	0.32	0.30	0.63	0.21	0.20

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

Table 9. Influence of packaging material and ventilation on fibre content of RTC tender jackfruit during storage (days)

Treatment	Fibre (%)						
	Low temperature (8-10 ⁰ C)				Refrigerated temperature(3-5 ⁰ C)		
	0	7	14	21	0	15	30
T1	2.56	2.11	2.10	2.03	2.56	2.13	2.09
T2	2.56	2.20	2.20	1.99	2.56	2.24	2.22
T3	2.56	2.32	2.21	2.17	2.56	2.49	2.32
T4	2.56	2.27	2.20	2.15	2.56	2.26	2.19
T5	2.56	2.34	2.25	2.08	2.56	2.36	2.23
T6	2.56	2.32	2.25	2.27	2.56	2.40	2.38

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

Table 10. Influence of packaging material and ventilation on as content of RTC tender jackfruit during storage (days)

Treatment	Ash (%)						
	Low temperature (8-10 ⁰ C)				Refrigerated temperature (3-5 ⁰ C)		
	0	7	14	21	0	15	30
T1	1.32	1.14	1.10	1.04	1.32	1.18	1.11
T2	1.32	1.25	1.20	1.15	1.32	1.20	1.13
T3	1.32	1.23	1.23	1.21	1.32	1.13	1.10
T4	1.32	1.08	1.08	1.04	1.32	1.24	1.19
T5	1.32	1.15	1.13	1.11	1.32	1.13	1.02
T6	1.32	1.15	1.15	1.13	1.32	1.35	1.28

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

4.4.8 Carbohydrate

The results of Carbohydrate content during storage of the minimally processed RTC tender jackfruit are presented in Table 11. There was a reduction in carbohydrate content of the minimally processed RTC tender jackfruit. The results indicated that highest carbohydrate content noticed in T3 (0.36) followed by T1 (0.33) and lowest in T4 (0.29) at 21st day in low temperature storage. Whereas at 30th day of refrigerated storage. Also, carbohydrate content was high in T2 (0.25) followed by T4 (0.22) and lowest in T3 and T6 (0.20).

4.4.9 Microbial analysis

The microbial profile by visual observation of the minimally processed RTC tender jackfruit during storage is presented in Table 13. In low temperature on 21st day and in refrigeration temperature on 30th day microbial growths were observed. However, no microbial growth was observed in PE and PP vacuum packages.

4.4.10 Sensory Evaluation

The judges opined that the vacuum packages of minimally processed RTC tender jackfruit found to be good during storage. The interaction of pre-treatment and vacuum packaging contributed towards higher shelf-life of the Ready-to-Cook tender jackfruit.

Table 11. Influence of packaging material and ventilation on Carbohydrate content of RTC tender jackfruit during storage

Treatment	Carbohydrate (%)						
	Low temperature (8-10 ⁰ C)				Refrigerated temperature (3-5 ⁰ C)		
	0	7	14	21	0	15	30
T1	7.87	9.24	9.83	9.99	7.87	9.44	9.59
T2	7.87	8.99	9.24	9.60	7.87	9.15	9.81
T3	7.87	9.10	8.79	9.05	7.87	8.98	9.44
T4	7.87	9.29	9.48	9.91	7.87	9.16	9.39
T5	7.87	8.77	9.40	9.83	7.87	8.82	9.50
T6	7.87	9.38	9.24	9.79	7.87	8.88	9.14

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

Table 12. Visual observation of microbial growth on RTC tender jackfruit during storage (days)

Treatment	Microbial analysis						
	Low temperature				Refrigeration temperature		
	0	7	14	21	0	15	30
T1	-	-	-	+	-	-	+
T2	-	-	-	+	-	-	+
T3	-	-	-	-	-	-	-
T4	-	-	-	+	-	-	+
T5	-	-	-	+	-	-	+
T6	-	-	-	-	-	-	-

+ microbial growth

- No microbial growth

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

Table 13. Sensory evaluation of stored Minimally Processed RTC tender Jackfruit

Treatment	Low temperature											
	Texture			Colour			Flavor			Overall acceptability		
	7	14	21	7	14	21	7	14	21	7	14	21
T1	8.1	7.9	7.1	7.2	7.2	7.1	7.8	7.6	7.0	7.4	7.2	7.0
T2	8.0	7.7	7.1	7.0	7.0	7.1	7.3	7.3	7.0	7.1	7.1	7.0
T3	8.5	8.0	7.5	8.0	7.9	7.5	8.5	8.0	7.6	8.1	7.9	7.7
T4	8.1	7.7	7.1	7.0	7.0	7.1	7.1	7.1	7.1	7.2	7.2	7.0
T5	8.1	7.7	6.8	7.0	7.0	6.8	7.1	7.1	6.9	7.1	7.0	6.1
T6	8.4	8.0	7.7	8.4	8.3	7.4	8.4	8.2	7.9	8.3	8.3	8.0
F value	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm ±	-	-	-	-	-	-	-	-	-	-	-	-
CD at 5%	-	-	-	-	-	-	-	-	-	-	-	-

(9 point hedonic scale) NS - Non Significant

- T1:** Poly propylene (300G) with 0% ventilation
- T2:** Poly propylene (300G) with 0.1% ventilation
- T3:** Poly propylene (300G) vacuum packaging (90%)
- T4:** Poly ethylene (300G) with 0% ventilation
- T5:** Poly ethylene (300G) with 0.1% ventilation
- T6:** Poly ethylene (300G) vacuum packaging (90%)

Table 14. Sensory evaluation of stored Minimally Processed RTC tend jackfruit

Treatment	Refrigeration temperature							
	Texture		Colour		Flavour		Overall acceptability	
	15	30	15	30	15	30	15	30
T1	8.2	7.1	7.2	7.1	7.8	7.8	7.4	7.1
T2	8.2	7.1	7.1	7.1	7.2	7.0	7.2	7.2
T3	8.2	7.5	8.2	7.5	7.6	7.6	8.1	8.1
T4	8.1	7.1	7.0	7.1	7.1	7.1	7.2	7.1
T5	8.1	7.0	7.3	7.0	7.2	7.0	7.1	7.1
T6	8.5	7.2	8.6	7.2	8.5	8.3	8.4	8.4
F value	NS	NS	NS	NS	NS	NS	NS	NS
SEm ±	-	-	-	-	-	-	-	-
CD at 5%	-	-	-	-	-	-	-	-

T1: Poly propylene (300G) with 0% ventilation

T2: Poly propylene (300G) with 0.1% ventilation

T3: Poly propylene (300G) vacuum packaging (90%)

T4: Poly ethylene (300G) with 0% ventilation

T5: Poly ethylene (300G) with 0.1% ventilation

T6: Poly ethylene (300G) vacuum packaging (90%)

V DISCUSSION

The results of the investigation pertaining to the influence of pretreatment, packaging materials, ventilation and storage conditions on the shelf-life and quality of minimally processed tender jackfruit are discussed in this Chapter.

The minimal processing is a method of preparing convenient fresh products that can be consumed, utilized straight away in less time with two objectives. Firstly, it keeps the produce fresh which is yet to supply in convenient form without losing its nutritional quality. Secondly, the minimally processed products should have a shelf-life acceptable to its intended consumers (Kaur and Kapoor, 2000).

The purpose of this experiment was to control and monitor the level of enzymatic browning of RTC tender jackfruit. Appearance, flavour, texture and nutritional values are the four attributes considered by consumers when making food choices. Appearance which is significantly impacted by colour is one of the first attributes used by consumers in evaluating food quality. Colour may be influenced by naturally occurring pigments such as chlorophylls, carotenoids and anthocyanins in food, or by pigments resulting from both enzymatic and non-enzymatic reactions. Reports suggest that over 50 per cent losses in processed products occur as a result of enzymatic browning. Enzymatic browning is one of the most important colour reactions that affect during minimal processing of fruits and vegetables. It is catalyzed by the enzyme polyphenol oxidase.

Physical and biochemical properties of different genotypes of tender jackfruit

5.1 Physical properties

The physical properties of tender jackfruits were determined and tabulated (Table 4.1). The size (length and diameter) of different genotypes of tender jackfruit was found to be *viz.* Swarna halsu-31.50, 19.50(cm), HV1-43.00, 16.50(cm), HV2-34.00, 21.50 (cm) and PHT varieties was 36.00, 19.00(cm) respectively. The shape of the all four varieties of tender jackfruits resembled the oblong shape. The mean weight of the different genotypes of tender jackfruits was found to be Swarna halasu (1.34) kg, HV1 found to be 1.5 kg, HV2 found to be 1.65 kg and PHT found 1.5 kg. The mean values of texture of different genotypes of tender jackfruit were found to be swarna halasu-4.58N, HV1-7.57N, HV2- 6.77N and PHT-6.52 N.

5.2 Chemical properties

The chemical properties of tender jackfruits of different genotypes were determined and tabulated in the Tables 4.2. Moisture content (w.b) of tender jackfruit was found to be in Swarna halasu-87.62%, HV1-88.01%, HV2- 2.42% and PHT-85.65%. The protein content was found to be Swarna halasu-1.80%, HV1-2.32%, HV2- 2.41% and PHT-2.88%. Fat content of swarna halasu-1.90%, HV1-2.05%, HV2- 2.52% and PHT-1.98% and the fibre contents were swarna halasu-1.5%, HV1-2.53%, HV2- 2.6% and PHT-2.1%. Also, the ash content of different genotypes of tender jackfruits were found to be swarna halasu-1.10%, HV1-1.12%, HV2- 1.16% and PHT-1.25% and finally the

carbohydrate content of different genotypes of tender jackfruit was found to be swarna halasu-6.06%, HV1-3.95%, HV2- 6.04% and PHT-6.64%.

5.3 Pretreatment

In the present study for preventing browning of RTC tender jackfruit, different pre-treatments and nature identical anti-browning agents were used to control excessive browning include blanching (75⁰C), blanching followed by citric acid (0.5%), blanching followed by KMS (0.5%), blanching followed by KMS (1%), brine solution(4%), KMS (0.5%) and blanching followed by brine solution (4-5%).

The effects of different pre-treatments are compared on colour for L^{*}, a^{*}, b^{*} values with control samples of different genotypes of jackfruit viz., swarna halasu (66.86, 5.5, 23.33), HV1 (66.73, 3.6, 26.96), HV2 (76.41, 1.66, 28.06) and PHT (69.4, 5.20, 27.40) indicating more browning. In the present study for retardation of browning seven different pre-treatments are tested. Among seven different pre-treatments blanching followed by KMS (0.5%) and blanching followed by KMS (1%) was found to be good.

5.4 Firmness

Firmness of different genotypes of tender jackfruit found to be swarna halasu-4.58N, HV1-7.57N, HV2-6.77N, PHT-6.52N. With blanching pre-treatment, the firmness of minimally processed RTC tender jackfruit of different genotypes was little bit decreased. Whereas in case of KMS and brine solution pre-treatments hardness of minimally processed RTC tender jackfruit of different genotypes was increased a bit (Table 3).

5.5 Storage

5.5.1 Influence of packaging material and ventilation on intensity of browning of RTC tender jackfruit

Among the different packages studied, vacuum packaging samples delayed browning. Samples in PE and PP vacuum packaging recorded higher L^{*}, a^{*}, b^{*} values for T3 (81.73, -2.73, 12.51) followed by T6 (80.74, -2.1, 12.2) at 21st day of refrigeration storage. The decline in L^{*}, a^{*}, b^{*} values were greater in T5 (69.06, 1.33, 13.62).

The PE and PP packages were observed to maintain the colour intensity for pre-treated minimally processed RTC tender jackfruit. Storage temperature is one of the important factors affecting the shelf-life of minimally processed RTC tender jackfruit. The differences in gas permeability of these packages could be the cause of faster browning in PP packages compared to PE packages.

The low oxygen atmosphere created during vacuum packaging played a major role in terms of anti-browning due to the anti-respiratory activity and lower availability of molecular oxygen required for polyphenol oxidase (PPO) mediated enzymatic browning.

The progress of this enzyme induced reaction is depended on temperature. At low temperature this reaction progress very slowly compared to high temperatures. That might be the reason that refrigerated storage (3-5 °C) was able to prolong shelf-life of the minimally processed RTC tender jackfruit under the both packaging techniques (PE and PP vacuum packaging) employed to 3-4 weeks, whereas at low temperature it was 21 days.

5.5.2 Effect of packaging material and ventilation on nutritional content of RTC tender jackfruit

5.5.2.1 Moisture content

The results indicated that moisture content varied from 84.86 (T5) to 85.43% (T2) at 21st day in low temperature storage, whereas, in refrigerated storage moisture content varied from 85.16 (T2) to 85.51% (T5) at 30th day of storage.

In low temperature storage, PE packages were found to be the best due to higher retention of moisture content whereas in refrigerated temperature PP packages were best.

5.5.2.2 Protein

The protein content varied from 1.50 (T2) to 1.90% (T3) at 21st day in low temperature storage, and in refrigerated temperature it varied from 1.31 (T2) to 1.64% (T6) at 30th day of storage.

5.5.2.3 Fat

The highest fat content in the RTC tender jackfruit was noticed in T3 (0.36) followed by T1 (0.33) and lowest in T4 (0.29) at 21st days in low temperature storage, and it was higher in T2 (0.25) followed by T4 (0.22) and lowest in T3 and T6 (0.20) at 30th day of refrigerated storage.

5.5.2.4 Fibre

The crude fibre content slightly decreased in minimally processed RTC tender jackfruit during storage. Highest fibre content was observed in T6 (2.27%) and lowest in T2 (1.99%) at 21st day in lower temperature storage, whereas at 30th day of refrigerated storage it was higher in T6 (2.38%) and lowest value recorded in T1 (2.09%).

5.5.2.5 Ash

The highest ash content was found in T3 (1.21%) and lowest value in T1 and T4 (1.04%) at 21st day in low temperature storage, while in refrigerated storage, it was highest in T6 (1.28%) and lowest in T5 (1.02%) at 30th day of storage.

5.5.2.6 Carbohydrate

There was a reduction in carbohydrate content of the minimally processed RTC tender jackfruit during storage. Highest Carbohydrate content noticed in T3 (0.36%) followed by T1 (0.33%) and lowest in T4 (0.29%) at 21st days in low temperature

storage. However, at 30th day of refrigerated storage it was higher in T2 (0.25%) followed by T4 (0.22%) and lowest in T3 and T6 (0.20%) treatments.

5.6 Microbial analysis

By visual observation microbial growth is observed in all packaging material at 22nd day in low temperature storage and on 32nd day in refrigeration storage. The low oxygen atmosphere created during vacuum packaging resulted in no microbial growth up to 21st day and on 30th day of refrigerated temperature storage

5.7 Sensory evaluation

The sensory evaluation panel of judges observed that vacuum packaging of minimally processed RTC tender jackfruit was found to be the best. The interaction of pre-treatments and vacuum packaging contributed to towards extended shelf-life of the ready-to-cook tender jackfruit.

5.8 Economic cost analysis

The cost economics was worked out taking into account all aspects of fixed and variable costs involved in investigation. The benefit-cost was found to be 1.00:2.22.

VI SUMMARY

The present investigation was conducted on “**Post harvest management of ready-to-cook (RTC) tender Jackfruit**” at the AICRP on Post Harvest Technology, Gandhi Krishi Vigyan Kendra, University of Agricultural Sciences, Bangalore, and results of the experiments are summarized in this chapter.

Fresh and well developed, healthy, green jackfruits of different genotypes were procured from the Horticulture College, UAS, Bangalore. The selected different genotypes were based on the identification and recommendation of the Department of Biotechnology, UAS, Bangalore. Immediately the selected genotypes were thoroughly washed with KMS solution, then the outer surface portion of spines of green jackfruit was chopped. Peeled green jackfruits were washed with 1% KMS solution, then it was cut into required sizes of cubes.

The main problem in RTC tender jackfruit is browning. Due to browning shelf life has been drastically reducing. For the retardation of browning, different pre-treatments were given to different genotypes to select the best genotype and pre-treatment.

Browning was observed less in HV2 variety compared to other three genotypes studied. Browning was less due to high L^* , a^* , b^* values. For confirmation of further storage studies from among four different genotypes, the HV2 variety was selected.

6.1 Physical and biochemical properties of tender Jackfruit

Among four different genotypes of tender jackfruit HV2 found to be less in moisture content (82.417) and highest protein (2.41), fat (2.52), fibre (2.6) and Ash (1.16) contents.

The L^* , a^* , b^* value of control RTC tender jackfruit of HV2 variety was lower (76.4, 1.66, 28.06) than the samples treated with KMS 1% (86.23, -2.65, 32.93) followed by KMS 0.5% (81.35, -4.95, 31.75).

6.2 Storage of tender Jackfruit

Among the different packages higher L^* , a^* , b^* values were recorded in T3 (81.73, -2.73, 12.51) followed by T6 (80.74, -2.1, 12.2) on 21st day of low temperature storage.

In refrigeration storage higher L^* , a^* , b^* values were recorded in T6 (84.46, -3.8, 15.53) followed by T3 (83.56, -3.038, 15.84) on 30th day of storage.

Maximum retention of moisture content was found in T2 (85.43) followed by T4 (85.18) at 21st day of low temperature storage. While in refrigerated temperature higher moisture content was recorded in T5 (85.51) followed by T1 (85.50) on 30th day of refrigerated storage.

The highest protein content was found in T3 (1.90) followed by T4 (1.81) on 21st day of low temperature storage. In refrigerated storage protein content was found highest in T6 (1.64) followed by T4 (1.61) on 30th day of storage.

The highest fat content noticed was in T3 (0.36) followed by T1 (0.33) on 21st day of low temperature storage, whereas, at 30th day of refrigerated storage the fat content was higher in T2 (0.25) followed by T4 (0.22).

The highest fibre content observed in T6 (2.27) at 21st day of lower temperature storage, whereas at 30th day of refrigerated storage, fibre content was higher in T6 (2.38).

The highest ash content was found in T3 (1.21) at 21st day under low temperature storage, while, the ash content was found to be highest in T6 (1.28) at 30th day in refrigerated storage.

6.3 Microbial analysis

In low temperature storage on 21st day and in refrigeration temperature on 30th day microbial growth were observed. There was no microbial growth observed in PE and PP vacuum packages.

6.4 Sensory evaluation

Sensory evaluation indicated that interaction of pre-treatment and vacuum packaging lead towards higher shelf-life of the ready-to-cook tender jackfruit.

For conducting the experiment post harvest management of RTC tender jackfruit four different genotypes of tender jackfruits are used viz., swarna halasu, HV1, HV2 and PHT. In these four genotypes there were not much differences of physical and chemical parameters were observed. Therefore, browning was considered the main factor to judge the best genotype for storage studies. HV2 variety performed best among other genotypes and it was confirmed by increased L^* , a^* , b^* colour values. Among seven different pre-treatments, KMS 1% and KMS 0.5% showed better results. Because of higher concentration of KMS 1%, KMS 0.5% was used for further storage studies. For evaluating shelf-life of RTC tender jackfruit during storage six different packages and two temperatures were used.

In conclusion, vacuum packaging was found to be the best in extending shelf-life of RTC tender jackfruit. Results indicated that, in low temperature storage KMS 0.5% + Poly propylene (300G) vacuum packaging and in refrigerated storage KMS 0.5%+ Poly ethylene (300G) vacuum packaging was found best and could be used for successful storage of RTC tender jackfruit.

VII. REFERENCES

- A.O.A.C., 1980, Official methods of analysis, 11th edition. Association of official Agricultural chemists, Wahington, D.C., 2004.
- ADA, M. C. N., ROCHA, COULON, E. C., ALCINA, M., BHATIA, M. B. S. AND SIDDAPPA, G. S., 1955, Composition of nutritive value of jackfruit. *Indian J. Agri. Sci.*, **25**: 303-306.
- ADIYAMAN, P., KANCHANA, S., HEMALATHA, G., ANANTHAN, M., GOPAL, N. O. AND M.ILAMARAN, 2013, Influence of Pre- treatments and Pre-packaging on Post Harvest Shelf-Life of Underutilized Fruits (star fruit, egg fruit and fig). *Indian J. Sci. Tech.*, **6(9)**:5263-5270.
- ALOK, S., 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 Engg.*, **87**:455-466.
- AMERINE, M. D., PANGBORN, R. M. AND ROESSTER, E. B., 1965, Principles of sensory evaluation of foods. Academic press, London.
- ANONYMOUS, 2003, Jackfruit processing-Fruitful SSI venture. *Indian Food Industry*, **19(5)**: 323.
- BARWAL, V.S., SHARMA, R. AND SINGH, R., 2005, Preservation of cauliflower by hurdle technology. *J. Food Sci. Tech.*, **42(1)**: 26- 31.
- BERRY, S. K. AND KALRA, C. L., 1989, Chemistry and technology of jackfruit – A review. *Indian Food Packer.*, **4**: 63-73.
- BHATIA, B.S., SIDDAPPA, G. S. AND LAL, G., 1955, Composition and nutritive value of jackfruit, *Indian j. Agri. Sci*, **25(4)**30-36.
- BIEGANSKA-MARECIK AND CZAPSKI, J., 2007, The effect of selected compounds as inhibitors of enzymatic browning and softening of minimally processed apples. *Acta Aci. pole*, **6(3)**: 37-49.
- BUTA, J. G. AND ABBOTT, J. A., 2000, Browning Inhibition of Fresh-cut ‘Anjou’, ‘Bartlett’, and ‘Bosc’ Pears, *J. hort. Sci.*, **35(6)**:1111-1113.
- CHAN, H. T., JOER J. K. AND HEU, R. A., 1974, Identification and determination of sugars in star fruit, green sapota, jackfruit and pineapple. *J. Food. Sci.*, **40**:1329-1330.

- CRANE, J. H., BALERDI, C. AND MAGUIRE, I., 2005, Jackfruit growing in the Florida home landscape. Fact Sheet HS-882, *Florida Cooperative Extension Service*, University of Florida, USA. pp 1-10.
- EXAMA, A., ARUL, J., LENCKI, R.W., LEE, A. AND TOUPIN, C., 1993, Suitability of plastic films for modified atmosphere packaging of fruits and vegetables, *J. Food Sci.*, **58**(6):1365-1370.
- GEETHA, P. AND THIRUMARAN, A. S. 2010, Increasing the shelf-life of papaya through vacuum packing. *Acta Hort.*, **851**: 527-535.
- GHIDELLI, C., ROJAS-ARGUDO, C., MATEOS, M. AND PEREZ-GAGO, M.B., 2013, Effect of antioxidants in controlling enzymatic browning of minimally processed persimmon 'Rojo Brillante'. *J. Postharvest Biol. Technol.*, **86**:487-493.
- GONZALEZ-AGUILAR, G. A., WANG, C. AND BUTA, J., 2001, Inhibition of Browning and Decay of Fresh-cut Radishes by Natural Compounds and their Derivatives. *Lebensm. Wiss. U.Tech.*, **34**: 324-328.
- GONZALEZ-AGUILAR, G. A., WANG, C. AND BUTA, J., 2000, Maintaining Quality of Fresh-Cut Mangoes Using Anti-browning Agents and Modified Atmosphere Packaging., *J. Agric. Food Chem.*, **48**: 4204-4208.
- GOPALAN, C., SASTRI, B. V., RAM AND BALASUBRAMANIAN, S. C., 1985, *Nutritive Value of Indian Foods*, ICMR, New Delhi, India. Pp 88.
- GOSWAMI, C., HOSSAIN, M. A., KADER, H.A. AND ISLAM, R., 2011, Assessment of Physico- chemical properties of Jackfruit (*Artocarpus heterophyllus* Lam) pulp. *J. Hort. Forestry and Biotech.*, **15**(3): 26- 31.
- HE, Q., LUO, Y. AND CHEN, P., 2008, Elucidation of the mechanism of enzymatic browning inhibition by sodium chlorite. *Food Chem.*, **110**: 847–851.
- JACOB, J. P. AND NARASIMHAN, P., 1998, Quality of blast-frozen and cryo-frozen ripe jackfruit bulbs. *J. Fd. Sci. & Technol.*, **35**(1): 59-61.
- KLAIBERA, R. G., BAURA, S., WOLF, G., HAMMESB, W. P. AND CARLE, R., 2005, Quality of minimally processed carrots as affected by warm water washing and chlorination. *Innovative Food Science and Emerging Technologies*, **6**: 351–362.
- KAUR AND KAPOOR, H. C., 2000, Antioxidant activity and quality of minimally processed Indian cabbage (*brassica oleracea var. capitata*). *J. Food Processing and Preservation*, **25**(5): 367-380.

- KRISHNAMURTHY, S. AND RAO, D.V.S., 2001, Status of postharvest management of fruits, *Indian J. of hort.*, **58**(1-2):152.
- LU, S., LUO, Y., TURNER, E. AND FENG, H., 2007, Efficacy of sodium chlorite as an inhibitor enzymatic browning in apple slices. *Food Chem.*, **104**(2): 824-829.
- LUCERA, A., COSTA, C., MASTROMATTEO, M., CONTE, A. AND NOBILE, M. A. D., 2010 Influence of different packaging systems on fresh-cut zucchini (*Cucurbita pepo*). *Innovative Food Sci. Emerging Tech.*, **11**: 361–368.
- MAITI, C. S., WANGCHU, L. AND MITRA, S. K., 2002, Genetic divergence in jackfruit (*Artocarpus heterophyllus* Lam.). *Indian J. Genetics & Plant Breeding*, **62**(4): 369-370.
- MANDHARE, S. K., 2008, Studies on minimal processing of carrot (*Daucus carota* L.). Unpublished *M. Tech. (Agril. Engg) thesis*, University of Agricultural Sciences, Bangalore.
- MANOLOPOULOU, E. AND VARZAKAS, T., 2014, 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. *J. Food and Nutrition Sciences*, **2**: 956-963.
- MARTINEZ-FERRER, M., HARPER, C., PEREZ-MUNOZ, F. AND CHAPARRO, M., 2002, A modified atmosphere packaging (MAP) system for pineapple and mango. *J. Food Sci.*, **67**(9): 3365-3371.
- MATHUR, P.B., SINGH, K.K. AND KAPUR, N.S., 1952, Cold storage of jackfruit. *J. indian. Soc. Refrig. Engineers*, **3**(1):40-46.
- MONTERO-CALDERONA, M., ROJAS-GRAUB, M. A. AND MARTIN BELLOSOB, O., 2008, Effect of packaging conditions on quality and shelf-life of fresh-cut pineapple (*Ananas comosus*). *J. Postharvest Biology and Technology*, **50**: 182-189.
- MOZUMBER, N.H.M.R., RAHMAN, M.A., KAMAL, M.S., MUSTAFA, A.K.M. AND RAHMAN, M.S, 2012 Effects of pre-drying chemical treatments on quality of cabinet dried tomato powder. *J. Environ. Sci and Natural Resources*, **5**(1): 253-265.
- NANJUNDASWAMY, A. M., 1990, Processing of untapped indigenous fruits. *Proceedings of National seminar on Production, Processing, Marketing and Export of untapped Indigenous Fruits and Vegetables*, 7th April, Indian Agricultural Research Institute, New Delhi, pp 84-87.

- PADMANABAN, G., SINGARAVELU, K. AND ANNAVI, S. T., 2014, Increasing the shelf- life of papaya through vacuum packing, *J. Food Sci. Tech.*, **51**(1):163-7.
- PAVLOS TSOUVALTZIS, ANGELOS DELTSIDIS, JEFFREY, K. AND BRECHT, 2011, Hot water treatment and pre-processing storage reduce browning development in fresh-cut potato slices. *Hort. Sci.*, **46**(9):1282-1286.
- PIETRO, R., FEDERICO, G. G., FENANDO, M., LARS, W., SANTINA, R., MARCO, D. AND INGENGED, S., 2007, Effect of the application of anti-browning substances on the metabolic activity and sugar composition of fresh cut potatoes. *J. Post-Harvest Biol. Tech.*, **43**(1): 151-157.
- PURSEGLOVE, J. W., 1968, Tropical Crops: Dicotyledons-2. *John Wiley and Sons Inc.*, New York. pp 384-387.
- QIANG HE, A.B., YAGUANG LUO, B. AND PEI CHEN, 2007, Elucidation of the mechanism of enzymatic browning inhibition by sodium chlorite. *Food Chem.*, **110**: 847–851.
- RAHMAN, M. A., NAHAR, N., JABBAR, M. A. AND MOSIHUZZAMAN, M., 1999, Variation of carbohydrate composition of two forms of fruit from Jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic conditions. *Food Chem.*, **65**: 91–97.
- RANGANNA, B., MUNISHAMANNA, K.B. AND SUBRAMANYA, S., 2008, Development of MAP technology for guava for long distance transportation. *Mysore J. Agri. Sci.*, **43**(4):749-753.
- RATHOD, A., SHOBA, H. AND CHIDANAND, D.V., 2011, A Study on Shelf life Extension of Carambola Fruits., *International Journal of Scientific & Engineering Research*, **2**(9): 2-7.
- REDDY, B. M., PATIL, P., SHASHIKUMAR, S. AND GOVIDARAJU, L. R., 2004, Studies on physico-chemical characteristics of jackfruit clones of south Karnataka. *Karnataka J. Agric. Sci.*, **17**(2): 279-282.
- SALLY, K. M., 2011, Packaging and storage of minimally processed jack fruit bulbs. Unpublished *M. Tech thesis*, University of Agricultural Sciences, Bangalore.
- SAMADDAR, H. N., 1985, Jackfruit. In: Bose T.K. (Ed.), *Fruits of India: Tropical and Subtropical*. Mitra Naya Prokash Publishers, Calcutta, India. pp 487–497, 638-649.
- SANDHU, K.S. AND PARHAWAK, B., 2002, Studies on the preparation of dehydrated potato cubes. *J. Food Sci. Tech.*, **39**(6): 594-602.

- SANDHYA, 2009, Modified atmosphere packaging of fresh produce: Current status and future needs. *Food Science and Technology*, **43**: 381-392.
- SAXENA, A. K., MANA, J. K. AND BERRY, S. K., 1987, Pomegranate Post harvest Technology. Chemistry and Processing. *Indian Food Packer.*, **41**(4): 43-59.
- SHAFIQ ALAM, BALJINDER KAUR, KALIKA GUPTA AND SUNILKUMARAN, 2013, Studies on refrigerated storage of minimally processed papaya (*carica papaya* L.) *Agri. Engg. Int.*, **15**(4): 275-280.
- SONDE, 1989, Comparative study on the preservation of jackfruit, M.Sc. (Agri.) thesis, UAS, Dharward, pp120.
- SUTTIRAK, W., MANURAKCHINAKOR, S. AND WALAILAK, J., 2010, Potential application of ascorbic acid, citric acid and oxalic acid for browning inhibition in fresh-cut fruits and vegetables, *Sci. Technol.*, **7**(1), 5-14.
- TEIXEIRA, G., DURIGAN, J., ALVEN, R. AND OHAEC, T., 2007, Used of modified atmosphere to extend shelf life of fresh weight carambola (*Averrhoa carambola* L.). *Postharvest Biol. Technol.*, **44**(1): 80-85.
- TSOUVALTZIS, P., DELTSIDIS, A. AND BRECHT, K. K., 2011, Hot water treatment and pre-processing storage reduce browning development in Fresh-cut Potato slices. *J. Hort. Sci.*, **46**(9):1282–1286.

List of Abbreviations

Abbreviations/Symbols	Description
%	Per cent
µg	Micro gram
°C	Degree celsius
AOAC	Association of Analytical Chemists
Cfu	Colony forming units
Cm	Centimetre
CO ₂	Carbon dioxide
<i>et al.</i>	And others
gm	Gram
G	Gauge
g/L	Gram per litre
h	Hour
Ha	Hectare
HCl	Hydrochloric acid
HDPE	High density poly ethylene
<i>i.e.</i>	Id est (That is)
IU	International unit
k cal	Kilo calories
k p _a	Kilo Pascal
Kg	Kilogram
KMS	Potassium meta bisulphate
L	Litre
LDPE	Low density polyethylene
MAP	Modified atmosphere package
mg	Milligram
min	Minute
mm	Millimetre
N	Newton
N ₂	Nitrogen
NaCl	Sodium chloride
O ₂	Oxygen
OD	Observing density
pH	Negative logarithm of hydrogen
PLW	Physiological loss weight
PP	Poly propylene
PE	Poly ethylene
PPO	Poly phenol oxidase enzyme
RTC	Ready-to-cook
r	Radius
TSS	Total soluble solid
w.b	Wet basis
Π	Pie

ANNEXURE II

SCORE CARD FOR THE SENSORY EVALUATION

Name:

Date:

Instructions:

- Please evaluate each of the following samples using scoring system given below.
- Write the preferred number score in the column as per evaluation.
- Rinse your mouth in between evaluating each sample.

Sample	Appearance	Texture/ Consistency	Colour	Aroma	Taste	Overall acceptability

Scoring system:

9-like extremely: 6-like slightly: 3-dislike moderately:
8-like very much: 5-neither like nor dislike: 2-dislike very much:
7-like moderately: 4-dislike slightly: 1-dislike extremely:

Remarks:

Signature

ANNEXURE III

Economic analysis of the minimally processed RTC tender jackfruit

I] Operation cost of refrigeration

- Cost of Refrigerator (C) = Rs. 24,000/-
- Salvage value (S) @ 10% of original cost =Rs. 2400/-
- Annual usage (U) (Expected operational hours (365×24) =8760 h
- Expected life (L) 15 years

a) Fixed cost

i. Depreciation (D) for Refrigerator

$$\begin{aligned} D &= \frac{C-S}{UL} \\ &= \frac{24000 - 2400}{8760 \times 15} \\ &= \text{Re. } 0.16/\text{h} \end{aligned}$$

ii. Interest on capital investment @ 12% per annum an average price (I1)

$$\begin{aligned} I1 &= \frac{C+S}{2U \times 0.12} \\ &= \frac{24000 + 2400 \times 0.12}{2 \times 8760} \\ &= \frac{26400 \times 0.12}{17520} \\ &= \text{Re. } 0.18/\text{h} \end{aligned}$$

iii. Insurance and housing cost @ 2% per annum an average price (I2)

$$\begin{aligned} I2 &= \frac{C+S}{2U \times 0.02} \\ &= \frac{24000 + 2400 \times 0.02}{2 \times 8760} \\ &= \text{Rs. } 0.03/\text{h} \end{aligned}$$

iv. Repairs/maintenance cost @ 6% of refrigerator cost (R)

$$\begin{aligned} R &= \frac{C}{UL \times 0.1} \\ &= \frac{24000 \times 0.04}{8760 \times 15} \\ &= \text{Rs. } 0.0072/\text{h} \end{aligned}$$

Total fixed cost A = (D + i1+ ii2 +R)

$$\begin{aligned} \text{Re.} &= 0.16+0.18+0.03+0.0072 \\ &= 0.3772/\text{h} \end{aligned}$$

B. Operation cost of vacuum packaging machine

- Cost of vacuum packaging machine (C) Rs. 85,000/-
- Salvage value (S) @ 10% of original cost Rs. 8500/-
- Annual use (U) (Expected operational hours (200×5) = 1000 h
- Expected life (L) 15 years

a) Fixed cost

i. Depreciation (D) for refrigerator

$$\begin{aligned} D &= \frac{C-S}{UL} \\ &= \frac{85000-8500}{1000 \times 15} \\ &= \text{Re. } 5.1/\text{h} \end{aligned}$$

ii. Interest on capital investment @ 12% per annum an average price (I1)

$$\begin{aligned} I_1 &= \frac{C+S}{2U \times 0.12} \\ &= \frac{85000 + 8500 \times 0.12}{2 \times 1000} \\ &= \text{Re. } 5.61/\text{h} \end{aligned}$$

iii. Insurance and housing cost @ 2% per annum an average price (I₂)

$$\begin{aligned}
 I_2 &= \frac{C+S}{2U \times 0.02} \\
 &= \frac{85000 + 8500 \times 0.02}{2000} \\
 &= \text{Rs. } 0.935/\text{h}
 \end{aligned}$$

iv. Repairs/maintenance cost @ 6% of refrigerator cost (R)

$$\begin{aligned}
 R &= \frac{C}{UL \times 0.1} \\
 &= \frac{85000 \times 0.04}{1000 \times 15} \\
 &= \text{Re. } 0.22/\text{h}
 \end{aligned}$$

Total fixed cost B = (D + i₁ + i₂ + R)

$$\begin{aligned}
 &= \text{Rs. } 5.1 + 5.61 + 0.93 + 0.22 \\
 &= 11.86/\text{h}
 \end{aligned}$$

Total fixed cost = A+B = 12.24

v. Variable cost

ii. Minimal processing cost for 10 kg green jackfruit

- Cost of raw tender jackfruit @ Rs. 15/kg for 10 kg Rs. 150
- Chemical cost Rs. 5
- Packaging cost of polyethylene covers (300 gauge) Rs.9
- Labour cost Rs.150.00
- Transportation cost Rs. 10
- Total variable cost for minimally processed RTC tender jackfruit = 324.48 Rs
- Total cost for minimally processed RTC tender jackfruit = Total fixed cost + Total variable cost
-

$$=12.24+324.48$$

$$=336.72$$

C] Cost: benefit ratio

- Assumed market sale price for minimally processed RTC tender jackfruit (50 packages of 300g @ Rs.15) Rs. 750/-

- Cost: benefit ratio
$$\frac{\text{Rs. 750}}{\text{Rs. 336.72}}$$
$$= 2.22$$
$$1.00:2.22$$