DEVELOPMENT OF SHELF STABLE JACKFRUIT VARATTY BY THERMAL PROCESSING IN RETORT POUCH

By

NITHA N

SANURAJ S

SHABARI SREENIVAS

TARUNA VARGHESE

KERALA AGRICULTURAL UNIVERSITY

Department of Food & Agricultural Process Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR - 679 573, MALAPPURAM
KERALA, INDIA

2015

DEVELOPMENT OF SHELF STABLE JACKFRUIT VARATTY BY THERMAL PROCESSING IN RETORT POUCH

By

NITHA N

SANURAJ S

SHABARI SREENIVAS

TARUNA VARGHESE

PROJECT REPORT

Submitted in partial fulfilment of the

Requirement for the degree

Bachelor of Technology

In

Food Engineering

Faculty of Food Engineering and Technology

KERALA AGRICULTURAL UNIVERSITY

Department of Food & Agricultural Process Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR - 679 573, MALAPPURAM
KERALA, INDIA

2016

DEVELOPMENT OF SHELF STABLE JACKFRUIT VARATTY BY THERMAL PROCESSING IN RETORT POUCH

By

NITHA N

SANURAJ S

SHABARI SREENIVAS

TARUNA VARGHESE

ABSTRACT

Submitted in partial fulfilment of the

Requirement for the degree

Bachelor of Technology

In

Food Engineering

Faculty of Food Engineering and Technology

KERALA AGRICULTURAL UNIVERSITY

Department of Food & Agricultural Process Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR - 679 573, MALAPPURAM
KERALA, INDIA

2016

DECLARATION

We hereby declare that this thesis entitled "DEVELOPMENT OF SHELF STABLE JACKFRUIT VARATTY BY THERMAL PROCESSING IN RETORT POUCH" is bonafide record of research work done by us during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Nitha N (2012-06-006)

Sanuraj S (2012-06-013)

Shabari Sreenivas (2012-06-014)

Taruna Varghese (2012-06-017)

Place:Tavanur

Date: 11-02-2016

CERTIFICATE

Certified that this project report entitled **"Development of Shelf Stable Jackfruit Varatty by Thermal Processing in Retort Pouch"** is a record of project work done jointly by **Nitha N (2012-06-006), Sanuraj S (2012-06-013), ShabariSreenivas (2012-06-014), Taruna Varghese (2012-06-017)**under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship ,fellowship to them.

Place - Tavanur

Date -11-02-2016

Dr.Rajesh G K

Assistant Professor

Dept. of FAPE

K.C.A.E.T, Tavanur

ACKNOWLEDGEMENT

With profound and reverence, we would like to express my sincere gratitude and thanks to our Project guide, **Dr. Rajesh G.K**, Assistant Professor, Department of FAPE, KCAET, for his valuable guidance, profound suggestions, constant backing, encouragement and advice throughout the project work.

With deep sense of gratitude and due respect, we acknowledge our gratitude to **Dr.Hajilal. M S**, Dean, KCAET, Tavanur.

We express our deep sense of gratitude to **Dr.Santhi Mary Mathew**, Professor and Head, Department of FAPE, KCAET, Tavanur and Member of Advisory Committee, for her valuable advice and moral support provided during the project work.

We are immensely thankful to **Dr.Sudheer K P**, Associate Professor, Department of FAPE, KCAET, and Tavanur for his constant support, encouragement and guidance that helped us to complete our Project successfully. We also extend our sincere thanks and gratitude to **Dr. Prince M V**, Associate Professor, and Department of FAPE for his support and encouragement.

We are extremely thankful to **Smt.Sreeja R**, Assistant Professor, Department of FAPE, KCAET, and Tavanur for her constant help, support, valuable suggestions and guidance that helped in the completion of our Project successfully.

We also thank **Er.Ranasalva**, PhD student, Department of FAPE, KCAET, Tavanur for her constant help, support, encouragement and valuable guidance throughout the Project.

We would also like to thank Lab Assistants **Mr.Radhakrishnan, Mr.Sreenish,** and Research Assistant**Mrs.Vimitha T** for their constant support, valuable assistance throughout the Project.

We would also like to thank **Mrs.Jayashree**, Friends Agro Processing Centre, Naduvattom, and Edappal for providing us with the raw material for the Project.

Also I thankfully remember the services of **Mr.Lenin**and **Mr.Pradheep**, Technicians, KCAET, Tavanur for their immense help. We would also like to thank our parents for their constant support throughout the Project.

We also extend our sincere thanks to all the faculties of **Library**, KCAET, and Tavanur for their help and support.

Last but not the least, we thank our sincere **friends** for their ever willing help, support and cooperation that helped us to complete the Project successfully.

Above all, I bow my head to God Almighty who had been a part of our efforts, invigorating, enlightening and making me confident and optimistic.

Nitha N

Sanuraj S

ShabariSreenivas

Taruna Varghese

DEDICATED TO ALL

FOOD ENGINEERS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS

%	Percentage
^{o}C	Degree Celsius
^{o} F	Degree Fahrenheit
&	And
/	Per
$<$	Less than
=	equal to
$>$	Greater than
±	Plus or minus
≈	Approximate
ALP	Aluminium laminated polypropylene
ANOVA	Analysis of variance
AO	Antioxidant
BOPP	Biaxial oriented polypropylene
CA	Controlled atmospheric
CD	Critical Difference
cfu	colony forming unit
C.	Clostridium
CRD	Completely Randomized Design
DF	Dilution Factor
eg	Example
et al.,	and others
etc.	etcetera
F	Thermal death time (pasteurization)
F_0	Thermal death time (sterilization)
FDA	Food and Drug Administration

ft	feet
Fig.	Figure
G	gram(s)
g $^{-}$1	per gram
h	hour
HP	High pressure
H_2SO_4	Sulphuric acid
Ha	hectare
HCl	Hydrochloric acid
HMF	Hydroxyl Methyl Furfural
HTST	High Temperature Short Time
i.e.	That is
IS	Indian Standard
ISO	International Organization for Standardisation
IU	International Units
KCAET	Kelappaji College of Agricultural Engineering and Technology
KAU	Kerala Agricultural University
Kg	kilogram
Kgcm-1	kilogram per square centimetre
kJ	kilo Joules
KMS	Potassium met bisulphite
kW	kilo Watt
L	Litre (s)
L^{-1}	per litre
LTLT	Low Temperature Long Time
M	metric
MCPP	Metalized co-extruded polypropylene

mg	milligram
min	minute(s)
ml	millilitre
mt	million tonnes
mT	Metric tonnes
N	Normality, Newton
NaOH	Sodium hydroxide
NIST	National Institute of Science and Technology
No.	Number
NS	Non Significant
P	Probability
PPs	Polyphenols
PFA	Prevention of Food Adulteration
Ppm	parts per million
PO	peroxidase
PPO	Polyphenol oxidase
PLS	Partial Least Squares
RH	Relative Humidity
RTU	Ready-to-Use
Sec	second(s)
S	Significant
SD	Standard Deviation
TBA	Thiobarbituric acid
TPA	Texture Profile Analysis
TSS	Total soluble solids
UV	Ultra Violet
UK	United Kingdom

UTM	Universal Testing Machine
viz.,	namely
via	by way of
V	Volt
Wt.	Weight

INTRODUCTION

CHAPTER 1

INTRODUCTION

India is blessed with wide range of agro climatic zones, fertile soil and large cultivable area and it has a rich diversity of horticultural crops. The total production of horticultural crops in India during the year 2013-14 including fruits, vegetables, spices and plantation crops is estimated as 268.9 MT from a cropped area of 23.69 Mha. Fruits and vegetables together contributed 90.5 per cent of the total production and 62.4 per cent of the total area (Anon 2014).

Jackfruit (*Artocarpus heterophyllus* L.*)* belongs to the Moraceae family is widely found in tropical humid climate regions of the world. It is widely grown in tropical regions of India, Bangladesh, Nepal, Srilanka, Thailand, Malaysia, Philippians, Africa, Brazil etc. In India, it is grown in southern and eastern states viz., Kerala, Karnataka, Tamilnadu, West Bengal, Bihar etc. It is the largest edible fruit in the world and is the national fruit of Bangladesh. It is called as *chakka* in Malayalam, *kathhal* in Hindi, *pala* in Tamil and *panasapandu* in Telugu. It grows well from sea level up to an elevation of 3800 feet at an optimum temperature of 22-35°C. Being grown without any management practices, the fruit has the potential to be identified as the organic fruit of Kerala. Jackfruit is a rich source of carbohydrates, protein, potassium, calcium, iron, vitamins viz., A, B, C and offers numerous health benefits. The flesh of the jackfruit is starchy and fibrous, and is a source of dietary fibre. The presence of isoflavones, antioxidants, and phytonutrients in the fruits indicate that jackfruit has cancer-fighting properties. In spite of such a vast potential and usefulness, jackfruit remains an underutilized fruit species and deserves to be given more prominence.

Jackfruit is available mainly during the months of March to August. Jack trees are classified into two type's viz., firm flesh (kappa) and soft flesh (rassal) based on the firmness of the bulb. Jackfruits mature 3 to 8 months from flowering. When mature, there is usually a change of fruit colour from light green to yellow-brown. Spines, closely spaced, yield to moderate pressure, and there is a dull, hollow sound when the fruit is tapped. People consumed it mostly as a fruit when ripe but also as vegetable in the unripe stage.

Every year, a considerable amount of jackfruit, specially obtained in the glut season (June-July) goes waste both in quality and quantity due to lack of proper harvesting, insufficient cold chain facilities and proper storage. Proper postharvest technology for prolonging shelf life is, therefore, necessary. The two main goals of post-harvest technology are loss prevention and value addition to the raw food commodities through preservation and processing. A substantial amount of post-harvest losses of jackfruit can be prevented through proper value addition.

Jackfruit has a wide potential for value addition. Various delicious products can be prepared from jackfruit. Various products like chips, papad, pakoda, pickle, cutlets etc are prepared from matured jackfruit and products such as halwa, gulab jamun, unni appam, wine, cake, varatty etc are prepared from ripened jackfruit.

The most prevalent processed form of jackfruit during olden times was the jackfruit varatty. Jackfruit varatty is a prominent traditional jackfruit processed product of Kerala. It is prepared generally from the varikka variety of jackfruit. For its preparation the fruit pulps are removed from the seeds and pureed. It is then cooked with jaggery and ghee and made into a paste.

It is consumed as such or it is used as the base for several traditional dishes like *chakkayada, chakkaprathaman, chakkayappam, chakkapayasam* etc. It is not easily available in the urban areas and have high demand even in the off seasons.

Jackfruit varatty has a comparatively medium shelf life at ambient conditions. But storage for longer periods of time demands cold storage and freezer facilities which are cumbersome. Various technologies have applied to preserve and process jackfruits including canning, minimal processing, jam, candy, preserve, cold storage etc. But these technologies have been unable to get widespread acceptance from the consumers.

Thermal processing in retort pouch has proven to be highly successful in extending the shelf life of food products. It is one among the most widely used methods for preservation of perishable products. These hermetically sealed pouches when thermally processed at 121^{o}C for 30 minutes provides an extremely high shelf life and are easy to handle, transport and store. Jackfruit varatty in retort pouch will provide a traditional ready to eat food which can be revived into its fresh form by just dipping it in hot water. Jackfruit varatty in a ready to eat (RTE) or ready to use form also has a great market potential mainly among the Keralites living abroad.

Owing to the immense wastage of jackfruit in the country, a study on "Development of shelf stable jackfruit varatty by thermal processing in retort pouch" will provide a new dimension for preserving jackfruit. It not only increase the sales and meet the requirements of the consumer, but also helps to reduce the post-harvest losses in jackfruit and increase the availability of nutrient rich food to the consumer at least cost. Current study focuses on the shelf life study of retort pouch processed jackfruit varraty and the various parameters affecting it. It produce a safe and high quality product at a price affordable to the consumer.

With this point of view, a project was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to study the thermal processing of jackfruit varatty in retort pouch with the following objectives.

- Development of shelf stable jackfruit varatty by retort processing.
- Optimization of process parameters for the production of thermally processed jackfruit varatty.
- Shelf life study and quality evaluation of retort pouch packed jackfruit varatty.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

The review of work done by the early researchers and literature collection related to jackfruit, its composition, value added products, thermal processing of jackfruit varatty and its storage studies are compiled and presented in this chapter.

2.1 Jackfruit

2.1.1 Origin

Jackfruit (*Artocarpus heterophyllus*.) tree belongs to the family Moraceae. It grows abundantly in India, Bangladesh, and in many parts of Southeast Asia (Rahaman *et al.)*. It is one of the most significant evergreen trees in tropical areas and widely grown in Asia including India. It is a medium-size tree typically reaching 28 to 80 ft in height that is easily accessible for its fruit. The fruit is borne on side branches and main branches of the tree. Average weight of a fruit is 3.5 to 10 kg and sometimes a fruit may reach up to 25 kg. In general, the fresh deseeded sweet bulbs are consumed as such by the people and the bulbs cannot keep it for long time because of high perishability and as a result there are huge post-harvest losses (30-35%) occurring during the season and also the usefulness of the seeds and rind is not known to the growers and consumers (Lakshmana*et al.,*2007). Spoilage begin within a week after ripening, leading to significant wastage of jackfruit. Now the commodity has lost its status and is treated as one of the under exploited fruits of the state

2.1.2 Variety

The two main varieties of jackfruit available are ‘Koozha’ and ‘Varikka’. The variety ‘Koozha’ is thin, fibrous and has mushy edible pulp, usually very sweet and emitting strong odour. But ‘Varikka’ is thick, firm, crisp and has less fragrant pulp.

Thamarachakka, Nadavalamvarikka, Vakathanamvarikka, Muttomvarikka, then varikka, Aathimathuramkoozha, Rudrakshi, Ceylon varikka, Then varikka, Thengavarikka are the main jackfruit varieties in Kerala. (Priya *et al*., 2012).

2.1.3 Harvesting

Jackfruit is used as a vegetable after 50 - 70 days of fruit formation. It is used as a fruit when colour changes from pale green to a darkish green brown, the spines flatten out and there is a characteristic aroma (Priya *et al*., 2014).

2.1.4 Nutritional and medicinal value

The fruit provides about 2 MJ of energy per kg/wet weight of ripe perianth (Ahmed *et al.,* 1986). Jackfruit has been reported to contain high levels of protein, starch, calcium, and thiamine (Burkill 1997). Jackfruit is reported to possess many medicinal properties. The phenolic compounds isolated from jackfruit are reported to exhibit anti-inflammatory effect (Prakash *et al.,* 2009) the phenyl flavones present in jackfruit had shown strong antioxidant properties and is expected to act against lipid peroxidation of biological membranes (Cheng *et al.,* 1998). The hot water extract of mature leaves are utilised in ayurvedic treatment for hyperglycaemia and diabetes. The flavonoids present in the extract have been identified to be responsible for the non-toxic hypoglycaemic action (Wedage*et al.,* 2006). Lectins present in the seeds have shown antifungal properties while the crude methanolic extracts from root bark and stems have shown broad spectrum antibacterial activity.

Raw jackfruit flesh is regarded as a good source of carbohydrate (25%), vitamin A and a fair source of protein (1.6%). The postprandial glycaemic response to raw and ripe jackfruit elicits low glycaemic index.

Table 2.1 Composition of jackfruit (100g)

Sl No	Composition	Young fruit	Ripe fruit	Seed
A	Proximate analysis			
1	Water(g)	76.2 - 85.2	72.0 - 94.0	51.0 - 64.5
2	Protein(g)	2.0 - 2.6	1.2 - 1.9	6.6 - 7.04
3	Fat(g)	0.1 - 0.6	0.1 - 0.4	0.40 - 0.43
4	Carbohydrate(g)	9.4 - 11.5	16.0 - 25.4	25.8 - 38.4
5	Fibre(g)	2.6 - 3.6	1.0 - 1.5	1.0 - 1.5
6	Total sugars(g)	-	20.6	-
B	Minerals and vitamins			

1	Total minerals(g)	0.9	0.87 - 0.9	0.9 - 1.2
2	Calcium(mg)	30.0 - 73.2	20.0 - 37.0	50.0
3	Magnesium(mg)	-	27.0	54.0
4	Phosphorus(mg)	20.0 - 57.2	38.0 - 41.0	38.0 - 97.0
5	Potassium(mg)	287 - 323	191 - 407	246
6	Sodium(mg)	3.0 - 35.0	2.0 - 41.0	63.2
7	Iron(mg)	0.4 - 1.9	0.5 - 1.1	1.5
8	Vitamin A(IU)	30	175 - 540	10 - 17
9	Thiamine(mg)	0.05 - 0.15	0.03 - 0.09	0.25
Sl No	Composition	Young fruit	Ripe fruit	Seed
B	Minerals and vitamins			
10	Riboflavin(mg)	0.05 - 0.2	0.05 - 0.4	0.11 - 0.3
11	Vitamin C(mg)	12.0 - 14.0	7.0 - 10.0	11.0

Source: Arkroyd *et al.,* (1966), Narasimham (1990), Gunasena*et.al.,* (1996),Azad (2000).

2.2 Thermal processing

Joy *et al. (*2007) studied the nutritional comparison of fresh, frozen and canned fruits and vegetables. It was concluded that thermal processing increased the extractability of phenolic compounds.

Goh*et al. (*2012) studied the effect of thermal and ultraviolet treatments on the stability of antioxidant compounds in single strength pineapple juice throughout refrigerated storage. It was concluded that thermal treatment provided better stability to flavonoids and carotenoids.

Veronica *et al.* (2002) found that thermal processing enhanced the nutritional value of tomatoes by increasing the bio accessible lycopene content and total AO activity and were against the notion that processed fruits and vegetables have lower nutritional value than fresh produce.

Liesbeth*et al*. (2012) demonstrated that the potential benefit of HP over thermal processing of carrots is largely dependent on the processing intensity applied. Mild and severe thermal pasteurization, mild and severe HP pasteurization and HP sterilization resulted in a comparable overall quality than thermal sterilization. Quality of carrot is mostly affected by the thermal sterilization method.

Pritty *et al.* (2013) optimized the thermal process time temperature combination for safe canned tender 'Varikka' jackfruit in context of increasing shelf life by considering microbiological and quality aspect of product. The thermal processing at temperature 90°C for 19 minutes (F value 10) and at temperature 121°C for 38 minutes (Fo value one) were chosen as the better time temperature combination for pasteurization and sterilization. Based on the combined result of microbiological quality, characteristic variability and sensory perception; pasteurizing tender jackfruit at 90°C for 19 minutes was chosen as the optimum thermal process treatment for enhancing the shelf life.

Nair *et al. (*2002) studied a comparison on the thermal processing in retort pouches and canning. It has been found that among thermal processing retort pouch processing has several advantages over canning. Presently, consumption of canned foods is declining due to high cost of tin for making cans acceptable to the market .Retort pouch can be imprinted, its size and shape are flexible, and it can be displayed on shelves. Foods can be cooked faster in flexible pouches than in cans and it also helps to reduce the cost of delivery and storage.

Gould (1995) found that the thermal process design is adopted to maximize microbiological inactivation with minimal collateral degradation to product quality.

Mansour *et al.* (2006) conducted a study on the heat treatment of mango and it was found that fruits treated with heat increased shelf life up to 8 days without appreciable change in TSS/Vitamin C.

2.3 Retort pouch processing

Ramaswamy *et al.* (2014) conducted a study on process optimization and shelf life study of retort processed rose flavoured milk. It was found to be stored at ambient temperature without any appreciable loss in terms of physiochemical, microbiological and sensory attributes and could be used as a potential means of product diversification in the dairy industry.

Siddharth *et al.* (2014) performed retort processing of Omega-3 enriched kulfi concentrates. It was found that wholesome, safe and shelf stable control kulfi and fish powder kulfi concentrate could be produced by processing them in flexible non transparent, transparent pouches at F_0 value of 3.8 to 4.4.

Mohammedali*et al.* (2013) conducted a study on the retort pouch processing of Thari Kanchi Payasam. The overall acceptability score of the Tharikanchipayasamremained in good during storage period, which would be commercially useful. The microbiological analyses revealed that the product remained commercially sterile during the entire storage at ambient (27-30^{0}C) and elevated conditions (45^{0}C) and hence the product was safe for consumption. The changes in peroxide value and free fatty acid content during storage did not affect the acceptability of the product and well within the limits. In view of the acceptability of the product both in terms of physico- chemical and sensory properties, it could prove to be a means of value addition, product diversification and export promotion for traditional ethnic dishes.

Alok *et al.* (2012) found that F_0 and nisin values used in product formulation of shelf stable dairy desert dahlia had pronounced effect on thiobarbituric acid (TBA), hydroxyl methyl furfural (HMF) content, and pH and colour values.

Awuah (2007) pointed that new processing concepts such as the application of variable retort temperature have received attention from processing experts and promises to improve both the economy and quality of thermally processed foods.

Varalakshmi *et al.* (2014) studied the economic analysis of a retort pouch processing plant. Based on the cost effective analysis and sensitivity analysis, it was found to be economically feasible. It was also found to be effective in terms of institutional catering.

Cynthia *et al.*(1989) investigated the retort pouch advantages over conventional metal can. Conduction and convection heating products were selected for this study. i.e. pureed pumpkin (conduction heating products), peas in brine and pineapple in juice (products using conduction/convection heating). It was reported that pouches yield greatly less process times for product with conduction heating. Less processing time only was required for agitated cooking of cans than the thinner still - cooked pouches, for particulates in a liquid medium.

Cluter *et al.* (1994) evaluated the shelf life of cling peaches in retort pouches. Fruit source (fresh and frozen) and syrup pH (3.85 and 3.25) were taken as processing variables and 4, 21 and 38°C were selected as the storage temperature. It was reported that sensory colour, texture, acceptability, instrumental colour and sugar composition were greatly affected by pH. Frozen and fresh source peaches at pH 3.85 met shelf life requirements at 21 and 38°C. .

Taiwo *et al.* (1997) studied the production aspects of cow pea in tomato sauce and economic comparison of packaging in retort pouch system and canning. The study reveals that cost of cans be accounted for a larger percentage of the raw material cost than the pouch.

Tatsioni *et al.* (2003) studied the ready to eat retort pouch processed coconut kheer and observed that the fat content of the product was found to be reduced during storage whereas no significant changes in protein content observed till the end of 12 months storage. Similarly, no significant changes noticed in fibre, ash and carbohydrates content during storage under ambient condition.

Lampi R *et al.* (1977) studied that the effect of retort processing on physico-mechanical and barrier properties of multilayer retort pouch is that there is a significant reduction in tensile, tear, % elongation and seal strength after retort processing. The reduction in these properties may be due to heat induced changes in the polymer matrix. Further, there were no significant changes in gas and water vapour transmission rates before and after processing. This is mainly due to the presence aluminium foil as barrier layer

Stumbo *et al.* (1975) studied that a minimum Fo value of 3.0 min is necessary to ensure adequate inactivation of anaerobic spore formers, particularly *C. botulinum* in low-acid foods.

Sabapathy *et al.* (2001) found that retort pouch processing technology has been widely recognized as one of the alternatives to metal cans for producing thermally processed shelf stable foods.

Sabapathy *et al.* (2003) found that flexible retortable pouches are a unique alternative packaging method for sterile shelf stable products. The retort pouch has many advantages over canned and frozen food packages for both the customers as well as food manufactures.

Kumar *et al.*(2007) found the advantages of retort pouch are pouch profile, storage and preparation efficiency, savings in transportation, package cost, improved flavour and savings of energy.

The retort pouch is a packaging type that allows faster heat transfer than the traditional metal or glass containers, owing to their slimmer profile, or more specifically, the higher surface area to volume ratio (Awuah *et al*., 2007; Rodríguez *et al*., 2002).

The same microbiological lethality can be achieved with a 30-50 % shorter processing time in retort pouches compared to retorting of metal cans. (Snyder & Henderson, 2007).

Before sealing the packages, the amount of air inside should be minimized to avoid negative effects on sensory properties and nutrient levels (Rodríguez *et al*., 2002). The risk of adverse effects from oxidation during processing and storage can be minimized by removing oxygen by vacuum (non-liquid products) or steam flushing.

Removal of air has been shown to increase the shelf-life of retort products (Bindu *et al*., 2007).

Minimizing the residual gas increases the heating rate of the product substantially and reduces the risk of pouch damage from gas expansion during heating (Rodríguez *et al.,* 2002).

2.4. Storage studies:

Alok*et al.* (2012) found that retorted dahlia desert of F_o value 4.15 min and nisin 375 IU/g was found to be acceptable after storage up to 72 days.

Ramaswamy*et al.* (2014) found that in-pouch-processed product had a shelf-life of 3 months without refrigeration with no appreciable loss in terms of physiochemical, microbiological and sensory attributes.

Mohammedali*et al.* (2013) found that traditional thari kanji payasam in retort pouches remained commercially sterile during the entire storage of 12 months at ambient (27-30^{0}C) and elevated conditions (45^{0}C) and hence the product was safe for consumption.

Patricia *et al.* (2012) pointed that at ambient storage conditions, shelf life end- points of the products range from 0 to 96 months, depending on the product formulation.

Effects of atmosphere composition and temperature on quality of stored Jujube fruit was done by Lin *et al.,* (2004). The results indicated that the contents of ethyl acetate and ethanol, degradation of anthocyanin, and chlorophyll were significantly lower in the fruits stored in controlled atmospheric (CA) at -1°C than those in air at -1°C. Short term high O_2

(70%) treatment was the most effective in maintaining peel colour, anthocyanin and chlorophyll contents and preventing peel browning compared to other treatments.

Jan and Rab (2012) investigated the influence of storage duration on physico - chemical properties of apple fruits. The per cent weight loss, TSS, pH, total sugar, TSS/Acid ratio, bitter pit incidence and soft rot increased with increase in storage duration while starch score, juice content, titratable acidity, vitamin C, density and firmness of fruit decreased with increase in storage duration.

Shelf life study and quality evaluation of retort pouch packed tender jackfruit curry was done by Nadanasabapathi *et al.,* (2013). The curry was acceptable and stable with good texture and sensory qualities up to 12 months of storage

2.5 Quality parameters:

2.5.1 Total soluble solid (TSS)

Sindumathi*et al.* (2014) showed that the TSS of coconut jam showed an increase from 68.50°brix to 72.00°brix and 73.00°brix when packed in glass bottles and plastic container stored at room temperature and also increased to 70.00 °brix and 71.00 °brix under refrigeration temperature.

Koli*et al.* (2004) showed that the gradual increase in total soluble solids from 69.32 °brix to 70.31°brix observed in sapota jam during storage period.

Fruit quality changes in pears during CA storage was investigated by Anna *et al.,* (2006) There were no significant changes in soluble solids at the time of harvest and after storage.

Dinesh *et al.* (2014) studied the effect of TSS during storage of litchi fruits under different temperatures. It was observed that the TSS (^{0}Brix) of litchi fruits increased with the storage period. TSS, reducing sugar, non-reducing sugar and total sugar increased up to first 10 days of storage and there after declined.

Increase in TSS during storage may be due to acid hydrolysis of polysaccharides especially gums and pectin (Luh and Woodroof, 1975).

Singh *et al.* (1984) observed that TSS of fruits under controlled atmosphere decreased with increase in carbon dioxide concentration and storage period.

Naik *et al.* (1993) observed that TSS of tomatoes increased up to 14 days of storage in polyethylene bags and thereafter, gradually decreased. The control showed very rapid decrease in TSS.

2.5.2 Microbiological quality

Commercial sterility for low acid foods may be defined as that condition in which all *clostridium botulinum* spores and all other pathogenic bacteria have been destroyed as well as more heat resistant organisms if present, could produce spoilage under normal conditions of storage and distribution (Denny, 1970).

Microbiological quality of food indicates the amount of microbiological contaminants it has a high level of contamination indicates low quality of food storage and its handling more likely to transmit diseases (Oranusi *et al.,* 2013).

Bacterial count in prepared food and water is a key factor in assessing the quality and safety of food. It also reveals the level of hygiene adopted by food handlers in the course of preparation of such foods. Food and water in particular have been described as vehicle for the transmission of microbiological disease among which are those caused by coliforms (Nkere *et al*., 2011).

Ghani*et al.* (2002) observed that the common causes of spoilage are pre-process spoilage, under-processing, inadequate cooling and contamination resulting from package leakage

Aruna and Poonam (2013) conducted microbiological studies and found out negligible plate count (cfu/g) of mould, bacteria and yeast in processed tomato salsa packed in glass jars, cans and retort pouches during four months of storage analysis.

Typically the most problematic microorganism is Clostridium botulinum, as it can thrive in the anaerobic conditions inside food containers and produce the very dangerous botulinum toxin (Awuah*et al*., 2007). For thermal processing of food with a pH above 4.6, the generally accepted limit below which C .botulinum cannot grow, special attention is given to this bacteria.

2.5.3 Texture

Textural properties may serve as an indicator of maturity or process ability to the food processor and that of eating quality to the consumer. It includes those qualities that can be felt with the fingers, tongue, palate or teeth. The textural change of softening of the tissue is caused by enzymatic degradation and solubilisation of pectin materials leading to cell separation and decreased resistance to applied forces. The principle of texture profiling has been applied to instrumental texture measurements with universal testing machine using the classification and definition of textural characteristics as the sensory profiling method. In order to predict consumer response to texture via an objective test, correlation of sensory evaluation results with the results of objective test is necessary.

Jacob *et al.* (1992) conducted studies to improve the texture and sensory qualities of raw jackfruit and showed that the firmness of fried dice increased significantly as measured by peak force of 11.06 and 11.49 kg cm-2 compared to 0.33 kg cm-2 of steam cooked dice.

Lakshmana*et al.* (2013) conducted a study on Development and Evaluation of Shelf Stable Retort Pouch Processed Ready- to-Eat Tender Jackfruit (*Artocarpusheterophyllus*) Curry. The hardness of the tender jack fruit reduced significantly after retort processing due to the heat induced thermal softening of tissues. Further, the changes in cohesiveness, springiness, gumminess and chewiness were significant in fresh, blanched and retort processed samples. However, the overall texture of retort processed tender jack fruit curry was acceptable.

Guillermo *et al.* (2014) evaluated the effects of freezing, blanching and frozen storage (five months at 18°C) on the physico - chemical qualities of broad beans at milk maturity stage. In sensory evaluation of cooked beans, a significant increase in texture was found in unblanched beans compared with over blanched beans.

Texture Profile Analysis (TPA) of raw tender jack fruit, blanched and retort processed was carried out using Universal Testing Machine(UTM) equipped with TPA software by Kumaraswamy*et al.,*(2000) and found that the hardness of the tender jack fruit reduced significantly after retort processing due to the heat induced thermal softening of tissues. Further, the changes in cohesiveness, springiness, gumminess and chewiness were significant in fresh, blanched and retort processed samples. However, the overall texture of retort processed tender jack fruit curry was acceptable.

2.5.4 Colour

Colour characteristic of foods are an important quality attribute resulting from both pigmented and originally non-pigmented compounds. The major causative factor of colour in most foods is due to the presence of a broad array of natural pigments. There are some notable exceptions, such as caramelisation and browning reaction that occur in the food. Natural pigments in foods are determined not only as an index of economic value but also to control colour during processing and storage. Visual perception of colour can be described by three variables namely, hue, value and chroma. Value (lightness) distinguishes between light colour and dark colour, hue distinguishes among red, yellow, green and blue and chroma (saturation or purity) distinguishes between vivid and dull colours. The visual perception of colour is represented by three axes value (L), hue (a) and chroma (b) of hunter calorimeter (Yeshajahu *et al.,* 1996).

According to Irwin (1998) colour is critically important in many dimensions of food choice and influence the perception of other sensory characteristics by the consumer. Colour is actually different wavelengths of white light and is the stimulus that result from the detection of light after it has interacted with an object. A colorimeter quantifies colour by measuring three primary colour components of light viz., red, green and blue. This is usually done by preparing a sample according to directions and comparing its colour against a reference or series of references.

Segini *et al.* (2004) compared the relationship between instrumental and sensory analysis of texture and colour of potato chips. Parameters like fracture force, deformation and stiffness were measured by a puncture test using an Intron Universal testing machine. The instrumental colour quantification was done by computerised video image analysis technique and the colour was expressed as L*a*b* values. Sensory evaluation of texture and colour was performed by a sensory panel specially trained in evaluating potato chips.

Pua *et al.* (2008) conducted an experiment on storage stability of jackfruit powder packaged in aluminium laminated polyethylene and metalized co- extruded biaxially oriented poly propylene. The total colour difference (ΔE), rates of adsorbed moisture and sensory attributes of drum-dried jackfruit powder packaged in aluminium laminated polyethylene (ALP) and metalized co-extruded biaxially oriented polypropylene (BOPP/MCPP) pouches stored at accelerated storage (38°C, with 50°C, 75°C and 90% relative humidity (RH)) were determined over 12 weeks period. The changes in total colour followed zero order reaction kinetics. The powder packaged in ALP significantly ($P < 0.05$) reduced total colour change, rates of adsorbed moisture, lumpiness intensity of jackfruit powder and was rated higher in terms of overall acceptability over BOPP/MCPP.

Study on retort processed rose flavoured milk was done by Prem*et al.,* (2014). The various colour indices L^*, a^* and b^* was found to decrease during the storage and it had been concluded that the degradation of colour was due to Maillard reactions, increasing storage temperature and non-enzymatic spoilages.

Guillermo *et al.* (2014) evaluated the effects of freezing, blanching and frozen storage (five months at 18°C) on the physico - chemical qualities of broad beans at milk maturity stage. Five months frozen storage caused 34% and 31% degradation in total chlorophyll in, over blanched beans and minimally blanched beans, respectively. Maximum colour values variation was observed for fresh beans followed by blanched beans and frozen beans.

Gomez *et al*. (2010) studied the effect of ultraviolet-C light dose on quality of cut-apple, microbiological quality, colour and compression behaviour. They reported that the colour and compression parameters were found to be dependent on UV-C dose, storage time and type of pre-treatment. At the end of storage, samples exposed to only UV-C light turned darker (lower 'L' values) and less green (higher 'a' value) when compared to fresh-cut-apple slice.

2.5.5 Moisture content

Free water in products is jointly responsible for the growth of undesirable organism such as bacteria or fungi, which produce "toxins" or other harmful substances. Bat also chemical/biochemical reactions (e.g. the Maillard reaction) increasingly takes place and possibly change the following factors of a product: Microbiological stability, Chemical stability, Content of proteins and vitamins, Colour, taste and nutritional value, Stability of the compound and durability, Storage and packing, Solubility and texture (Banu*et al.,* 2002; Nicola*et al.,*2006)

Mohammedali*et al.* (2013) found a decrease in the percent moisture during retort pouch processing of tharikanjipayasam in retort pouches. Moisture content of the product was reduced by 2.19 and 3.25% in ambient temperature (27-30^{0}C) and accelerated temperature (45^{0}C), respectively.

Ashaye*et al.* (2009) the moisture content of Roselle jam from dark-red Roselle calyx under cold storage was significantly higher than other Roselle jam samples at 2nd, 4thand 6weeks of storage. The dry matter content of stored Roselle jams was less than 72% with that processed from light red variety and stored under cold temperature being significantly higher than other jam samples at 2^{nd} and 4^{th} week of storage. There was also no definite pattern in the dry matter content of the jams.

Ashaye *et al*. 2006 concluded that fluctuations in the moisture and dry matter contents are due to the activity of microorganisms and catabolic enzymes produced by them

2.5.6 Water activity

In the bound state water is not available to participate in these reactions as it is bound by water soluble compounds such as sugar, salt gums, etc.(osmotic binding), and by the surface effect of the substrate matrix binding (Gustavo *et al.,*2007).

Chemical/biochemical reactions (e.g. the Maillard reaction) increasingly takes place and possibly change the following factors of a product: Microbiological stability, Chemical stability, Content of proteins and vitamins, Colour, taste and nutritional value, Stability of the compound and durability, Storage and packing, Solubility and texture (Banu*et al.,* 2002; Nicola*et al.,*2006).

2.5.7 Total sugars

Sulphuric acid in anthrone reagent hydrolyses di and oligosaccharides into monosaccharides and dehydrates all monosaccharides into furfural or furfural derivatives. These two compounds react with a number of phenolic compounds and one such is anthrone which produces a complex coloured product. The intensity of which is proportional to the amount of saccharides present in the sample. (Roe, 1995)

Sindumathi*et al.* (2014) studied the processing and quality evaluation of coconut based jam. There was decrease in the total quantum sugar which was due to the breakdown of total sugar into simple sugars. The actual decrease in the total sugar content was more in room temperature stored the sample than in refrigeration stored samples.

Siddharth*et al.* (2014) evaluated the total solids of the retort processing of Omega- 3 Enriched Kulfi Concentrates and there was a decrease in the total solids due to breakdown into simple sugars.

2.5.8 Sensory evaluation

According to ISO (5492) 1992, sensory evaluation is the examination of organoleptic attribute of a product by the sense organ

Effect of storage on sensory score of badamflavoured milk was studied by Prem*et al.,* *(*2014). There was decrease in colour, flavour and overall acceptance of the product during the course of storage.

Sensory Evaluation of Retort Processed *Tharikanchipayasam*(by 9 point Hedonic Scale) was done by Mohammedali*et al.,* (2013). There was decrease in the colour, flavour, taste, texture and overall acceptance of the product under ambient and elevated temperature. There was greater decrease in the scores for elevated temperature than ambient storage.

Costell and Dursan (2012) explained that texture is a primary attribute that, together with taste, visual appearance and aroma comprises the sensory quality of food. The only way to evaluate sensory quality or some of its attributes (i.e., result of sensation experienced by human when consuming food) is to ask the opinion of the consumer, since sensory quality is not an intrinsic food characteristic, but the result of interaction between human kind and food.

Aruna and Poonam (2013) reported sensory score for processed tomato salsa packed in glass jars, cans and retort pouches during four months of storage analysis. The score was in the order of glass jars (refrigeration temperature) > cans > glass jar (room temperature) > retort pouch (refrigeration temperature) > retort pouch (room temperature).

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The experimental set up and techniques used for the production of retort processed jackfruit varatty are discussed in this chapter. Quality evaluation and storage studies of the retort processed jackfruit varatty are also presented.

3.1 Sample Collection

Prepared jackfruit varatty, procured from M/s Friends Agro Processing Unit, Naduvattam, Malapuram were used for the experiments. The prepared jackfruit varraty was brought and kept in cool chamber at $10^{o}C$ for further studies.

3.2 Estimation of Physico-Chemical Characteristics

3.2.1 Total soluble solid

Total soluble solids (TSS) was measured using hand refractrometer (ERMA INC Tokyo Japan). TSS is the sugar content of an aqueous solution and is expressed as degree Brix. It. One degree Brix is 1 gram of sucrose in 100 grams of solution and represents the strength of the solution as percentage by mass.Small quantity of jackfruit varatty was placed on hand refractrometer and TSS was measured. (Ranganna, 1995).

3.2.2 Colour

Hunter Lab colour flex meter was used for the measurement of colour of prepared jackfruit varatty. It works on the principle of collecting the light and measures energy from the sample reflected across the entire visible spectrum. The meter uses filters and mathematical models which rely on "standard observer curves" that defines the amount of green, red and blue primary lights required to match a series of colour across the visible spectrum. It provides a reading in terms of 'L^*', 'a*' and 'b*', the'L*' coordinate measures the value or luminance of a colour and ranges from black at 0 to white at 100. The 'a*' coordinate measures red when positive and green when negative and 'b' measures yellow when positive and blue when negative. All the three standard colour parameters 'L*', 'a*' and 'b*' were observed for day light colour. The colour meter was standardized using black and white ceramic calibration tiles. Readings were observed from three replicates of each sample and the mean values of 'L*', 'a*' and 'b*'were reported.

Plate 3.1 Colorimeter **Plate 3.2 Texture Analyser**

3.2.3 Texture analysis

Textural properties of processed jackfruit varatty were evaluated using a texture analyser (TAHDi, Stable Microsystems, and England). Cylindrical probe of 5 mm diameter was used. The detailed experiment conditions of textural analyser are as follows:

Load cell: 5 kg

Test Mode: Measure force in compression

Test option: Return to start

Pre-test Speed: 2 mm·s-1

Test Speed: 1 mm·s-1

Post-test Speed: 2 mm·s-1

Distance: 5 mm

Test probe: P 4

The peak force under the force-deformation curve was represented as hardness/ firmness. The force that is required to overcome the force of adhesion between the probe and the sample is calculated for stickiness

3.2.4 Water Activity

Water activity is important in determining product safety and quality maintenance in a particular storage environment. An automated instrument (M/s Aqua lab, USA) model XT-2i, was used to determine the water activity of processed jackfruit varatty.

Water activity is measured by equilibrating the liquid phase water in the sample with the vapour phase water in the headspace and measuring the relative humidity of the headspace. The water activity meter is provided with a sample cup which is sealed against a sensor block. Inside the sensor block there is a fan, a dew point sensor, a temperature sensor and an infrared thermometer. The dew point sensor measures the dew point temperature of the air and the infrared thermometer measures the sample temperature. From these measurements, the relative humidity of the headspace computed as the ratio of saturation vapour pressure of air to the saturation vapour pressure of the sample. The measurement of the headspace humidity gives the water activity of the sample. The purpose of the fan is to speed up the equilibrium process and to control the boundary layer conductance of the dew point sensor.

Water activity was measured by placing the sample in a container which placed in a sealed chamber and then the knob is closed to read the water activity of the sample. The water activities of the samples were recorded with respect to atmospheric temperature.

3.2.5 Moisture Content

The moisture content of the sample was estimated by hot air oven method (AOAC, 1990). About 5 to 10 g of sample was weighed accurately and dried in a hot air oven at 70°C. The drying was continued till a constant weight was obtained. The moisture content was expressed as percentage.

$$\text{Wet Basis\% } w_b = \frac{M_i - M_f}{M_i}$$

$$\text{Dry basis \% } d_b = \frac{M_i - M_f}{M_f}$$

Where, M_i - Initial weight of sample

M_f - Final weight of sample

3.2.6 Total Sugar Content

The total sugar content is estimated by calculating the amount of carbohydrate present in the sample. They exist as free sugars and polysaccharides. The basic units of carbohydrates are the monosaccharides which cannot be split by hydrolysis into simpler sugars. The carbohydrate content can be measured by hydrolysing the polysaccharides into simple sugars by acid hydrolysis. Phenol-sulphuric acid method (Sadasivam and Manickam, 1992) was used to estimate the total sugar content of jackfruit varatty. In hot acid medium, glucose is dehydrated to hydroxyl methyl furfural. This forms a colored product with phenol and has an absorption maximum at 530 nm. The reagents used were 80 per cent ethanol, 5 per cent phenol, conc. sulphuric acid and working standard glucose solution (100mg/ml).

500 mg of jackfruit varatty was taken and ground nicely with 10 ml of hot 80 percent ethanol and transferred to a 100 ml test tube. The test tube was then placed in a boiling water bath for about 10 minutes and made up to 10 ml. From this 1 ml of the sample was pipetted into a test tube and kept on the boiling water bath until it dried completely. Ten ml of distilled water was added to the test tube.

Half and one ml of the ethanol extract was pipetted into two test tubes containing 0.0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard glucose solution was pipetted into six test tubes. The volume was made up to 1 ml in all test tubes by adding distilled water. One ml of 5 per cent phenol solution was added to all test tubes. Concentrated sulphuric acid of 5 ml was added quickly into all tubes. The solution was mixed and allowed to stand at room temperature for 20 minutes. The absorbance at 530 nm was read with the use of standard graph, and the amount of sugar present in 100 mg of sample was calculated.

The standard graph was drawn with concentration in x-axis and optical density in y-axis. The sugar present in 100 mg vegetable was calculated from the sugar present in 0.5 and 1 ml solution.

3.3 Thermal Process Optimization

Thermal processing was done in retort pouches (15 cm × 20 cm). It is a flexible laminated package that can withstand thermal processing temperature. It combines the advantages of both metal cans and plastic packages. This three layers consist of exterior polyester (12.5 µm), middle aluminium foil (12.5 µm) and interior cast polypropylene (75 µm) layer. Physical properties of retort pouch are listed in Table 3.1

Table 3.1 Properties of retort pouch

Properties		Values
Thickness(µm)	Total	100
	Polyester	12.5
	Al Foil	12.5
	Cast PP	75
Tensile strength (kg/cm2)	Machine direction	460
	Cross Direction	430
Tensile strength (kg/cm2)	Machine direction	45
	Cross Direction	35
Heat seal strength (kg/cm2)	Machine direction	390
	Cross Direction	380
Bond strength (g /10 mm)		180
Pouch burst strength (psig)		30
OTR (ml/m2/ 24 h at 1 atm. & at 25°C)		0.35
WVTR (g/m2/24 h at 370C & 90%RH)		0.02
Global migration residue (mg/dm^2)(maximum limit value:10 mg/dm2)	Water extractives at 121°C for 2h	0.60
	3% Acetic acid extractives at 121°C for 2h	0.25
	n-heptane extractives at 66°C for 2h	1.7

3.3.1 Pouch filling, exhausting and sealing

One hundred gram jackfruit varatty pieces was filled manually in the retort pouch. After filling the retort pouch, the sealing was done using a sealing machine at a pressure of 1 bar and voltage of 38V.The sealing time required is 6 sec and a cooling time of 15 sec.

Plate 3.3 Sealing Machine

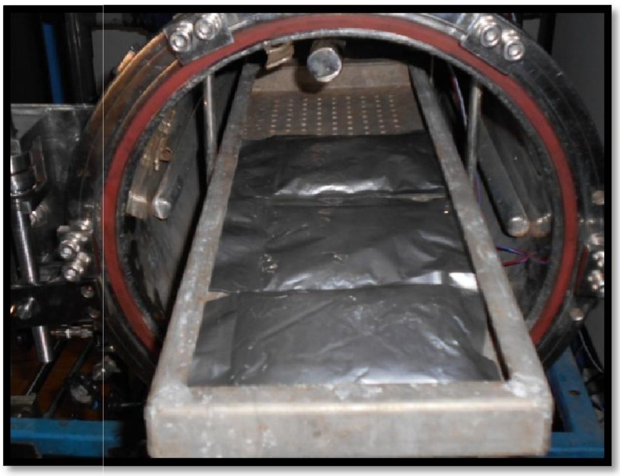

Plate 3.4 Filling of pouches in retort

3.3.2 Positioning of thermocouple in retort pouch

The hermetically sealed retort pouches were loaded into the perforated aluminium trays and placed into retort processing chamber. One of the pouches was fixed with a thermocouple sensor. The sensor tip was inserted into the jackfruit varatty for recording core temperatures.

3.3.3 Thermal processing

The retort unit consisted of a steam generator at the bottom, retort processing chamber in the middle and water storage tank at the top. All these units along with control panel were mounted on a stainless steel frame. The steam generator or boiler is internally divided into two portions and a pressure gauge is attached to it. One portion is to boil water and produce steam with a capacity is 30 kg and the other one is to store steam for retort processing. A glass tube is attached to one side of the boiler to indicate the water level in the boiler. The retort or processing chamber is made up of 3 mm thick stainless steel plate having a diameter of 350 mm and 400 mm length. The chamber contained four spraying rods: One at the top to spray water, two on either side to spray steam and one at the bottom to release compressed air. Two temperature measuring probes are inserted into the processing chamber through the provision at the top to measure the temperature of processing chamber and the temperature of the product inside the pouch. Removable stainless steel loading tray with thirteen aluminium molds occupies the chamber. The retort is fitted with safety valve, pressure gauge and manually operated air vent outside the chamber. An overhead stainless steel tank with a capacity of 200 litres of water, used for various processing operations, is provided with the lid to cover the tank.

F value is defined as the time needed to reduce microbiological numbers by a multiple of D value. F0 value is used to describe process that operate at 121.1°C which are based on the microorganism with Z value of 10°C. (Donald and Ricardo, 2007). Pritty *et al*. (2014) optimized the thermal processing for canned ‘Varikka’tender jackfruit for both pasteurization and sterilization (Sterilization was done at F0 =1 and pasteurization at F = 10). The same F0 and F values were considered for this research. Retort pouch processing was done in the lab scale retorting machine in the food processing lab of FAPE department. Process times were determined using the cold point method with the help of valsuite software that optimize a suitable combination of time and temperature. The cooling mode cools the product. After thermal processing in retort chamber, the hermetically sealed pouches were surface dried and stored for shelf life studies at ambient temperature as well as refrigerated conditions.

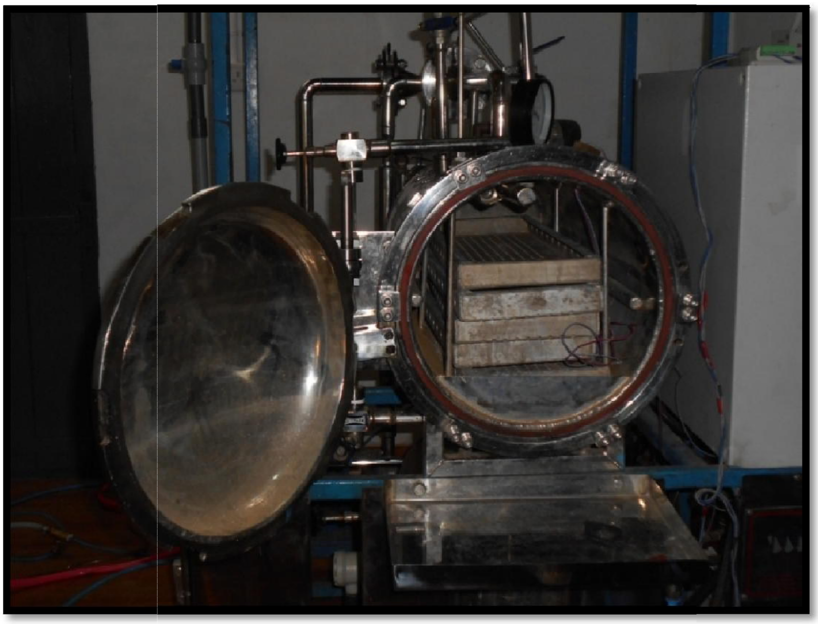

Plate 3.5 Retort

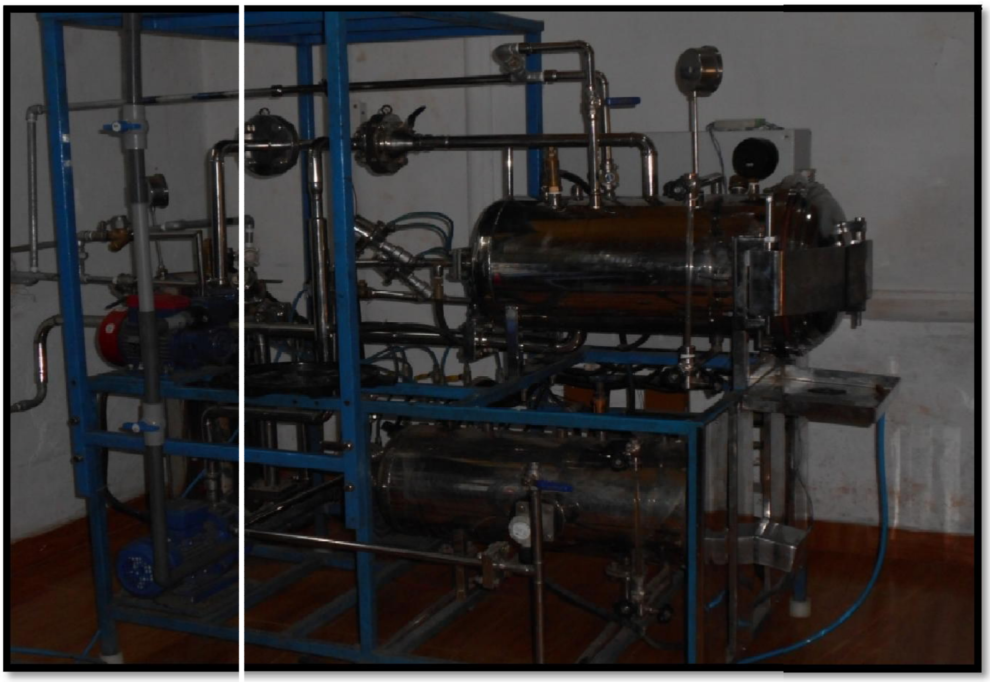

Plate 3.6 Retort

3.3.4 Standardization of time - temperature combination for thermal processing of jackfruit varatty

The different F value- temperature combinations selected for the standardization of jackfruit varraty are shown in Table 3.2. Upon this Time Temperature combinations studies are conducted and the analysis is done. The current temperature were taken as 100^{o}C,110^{o}C and 121^{o}C .The flow chart for the production of thermally processed jackfruit varatty is placed in Fig 3.1

Table 3.2 Standardisation of time-temperature combinations for thermal processing of jackfruit varatty

Sample	Treatment
T1	Pasteurised at 100^{o}C for F_1 stored at ambient condition
T2	Pasteurised at 100^{o}C for F_2stored at ambient condition
T3	Pasteurised at 110^{o}C for F_1stored at ambient condition
T4	Pasteurised at 110^{o}C for F_2 stored at ambient condition
T5	Sterilised at 121^{o}C for F_0 stored at ambient condition
T6	Pasteurised at 100^{o}C for F_1 stored at refrigerated condition
T7	Pasteurised at 100^{o}C for F_2 stored at refrigerated condition
T8	Pasteurised at 110^{o}C for F_1 stored at refrigerated condition
T9	Pasteurised at110^{o}C for F_2 stored at refrigerated condition

T10	Sterilized at 121°C for F_0 stored at refrigerated condition

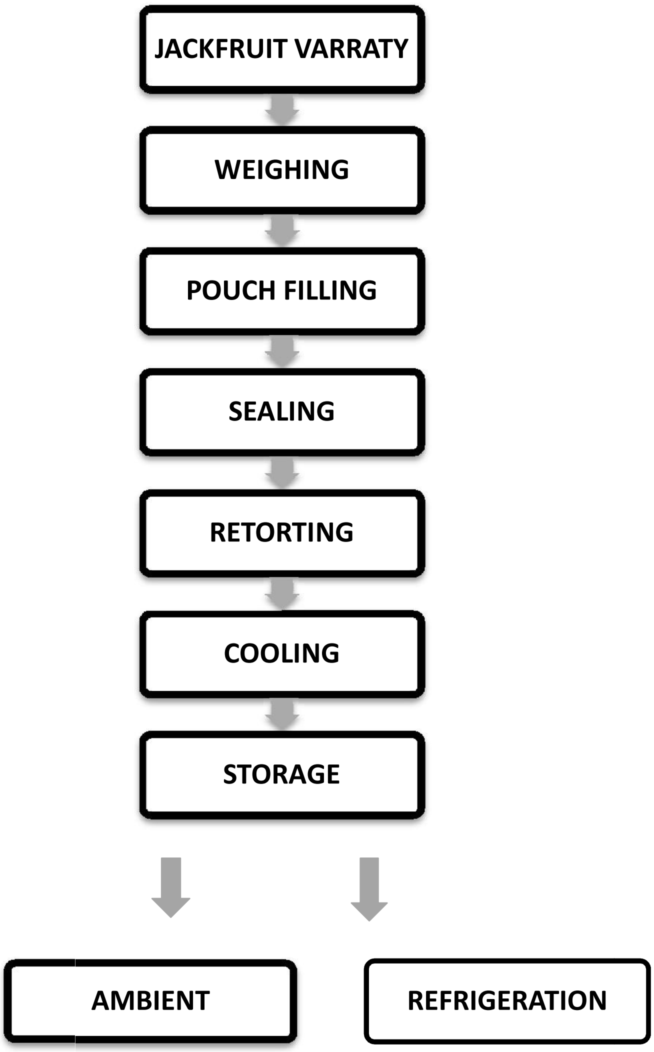

Fig 3.1 Flow chart for the production of thermally processed jackfruit varatty

3.4 Physico-chemical and microbiological analysis of retort pouch packed jackfruit varatty

Physico-Chemical Characteristics viz., total soluble solids (TSS), colour, textural properties, water activity, moisture content, total sugar content etc of jack fruit varatty were estimated according to procedures explained in section 3.1. Microbiological analysis was performed using standard plate count method. Microbiological analysis was performed for the quantification and identification of microorganisms. Detection of bacteria was done using total plate count method. Enumeration of bacteria, yeast and fungus were done by serial dilution and plating method outlined by Anon. (1967). Nutrient agar was used for bacteria culture.

3.4.1 Standard plate count method

This method allowed the growth of microorganism in nutrient culture petriplate and the colonies developed were counted.1 g of sample was mixed in 100 ml of distilled water. From the prepared sample 1ml (W_s) was then added to 90 ml of sterile water (10-1 dilution) and shaken well for 10 - 15 minutes to assure uniform distribution of microorganisms.1ml of this diluted sample was transferred to sterile petri plate with a sterile micro pipette. Molten and cooled nutrient medium (15 – 20 ml) at 45°C conducive for the growth of the specific organism were added to respective petri plates. The plates were rotated clockwise and anticlock wise for the thorough mixing of dilutent and the medium. Then the petri plates were incubated at 37°C for one to two days, for the bacterial growth (Rao, 1986). After the incubation period, the colonies (cfu) were counted and the number of microbiological organisms per gram of sample (Ns) for dilution factor (DF) was calculated as given below

$$N_s = \frac{(Ncfu \times DF)}{W_s}$$

3.4.2 Storage Studies

The thermally processed jackfruit varatty in retort pouches were stored for three months and shelf life studies were conducted. The jackfruit varatty samples in sterilized pouches were stored in ambient condition (temperature at 37^{o}C) and in refrigerated condition (15°C). The following parameters were tested in every 1 month interval up to two month and final analysis was done after three months of storage.

(1) TSS

(2) Water Activity

(3) Moisture Content

(4) Total Sugar Content
(5) Colour
(6)Texture
(7) Microbiological Analysis

3.5Experimental Design

The independent and dependent variable considered in this study are as follows

Independent variables

- Ambient temperature
- Refrigerated temperature
- Processing temperature
- Processing time

Dependent variables

- Colour
- Total soluble solids
- Total sugar content
- Water activity
- Moisture content
- Texture

3.6 Statistical analysis

The data obtained were statistically analysed by completely randomized block design (CRBD) using the statistical package AGRES. The Analysis of variance (ANOVA) and mean table for different process parameters were tabulated and the level of significance was reported

3.7 Sensory analysis

Sensory analysis is a scientific approach that analyses and measures human responses to the composition of food, comprising colour, flavour, texture and overall acceptability. It is combination of experimental design and statistical analysis to use the human senses for the purpose of evaluation. Sensory evaluation of jackfruitvaratty was done by 5 point hedonic scale. The 5 points in the hedonic scale are:

5-Like very much; 4-Like; 3-Neither like nor dislike; 2: Dislike; 1: Dislike very much

3.7 Cost economics

The cost of production of thermally processed jackfruit varatty was estimated by considering the fixed and variable costs. Fixed costs was calculated based on depreciation cost of machines and capital interest of investment. The variable cost of unit was calculated by considering electricity charges, repairs and maintenance, raw materials and cost of labour. Cost analysis is given in Appendix D

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

This chapter deals with the results obtained on the characteristics of thermally processed jackfruit varatty. Shelf life studies of jackfruit varatty stored at ambient and refrigerated conditions are also presented in this chapter. The results are critically analysed in comparison with published literature and are discussed.

4.1 Physico -Chemical Characteristics of fresh jackfruit varatty

The composition of fresh jackfruit varatty is shown in Table 4.1. Jackfruit varatty was light yellow in colour having an L^* value of 26, a^* value of 8.48 and b value of 22.35. It had a water activity of 0.771. The TSS and total sugar content of jackfruit varatty were 71.8°Brix and 86 per cent, respectively. The hardness and stickiness of the fresh jackfruit was estimated to be 0.0121N and 0.196N, respectively. The initial microbiological load of the sample was 14×10^2 cfu/ml.

Table 4.1 Physico –Chemical and Microbiological Characteristics of fresh jackfruit varatty

Sl No	**Physico-chemical parameters**		**Value**
1	Water activity		0.771
2	TSS(^{0}brix)		71.8
3	Moisture Content (d_b)		26.5
4	Microbiological Analysis (10^2cfu/ml)		1400
5	Total Sugar Content(% carbohydrate)		87.5
Sl No	**Physico-chemical parameters**	**Value**	**Sl No**
6	Colour	L^*	26
		a^*	8.48
		b^*	13.6
7	Texture	Hardness(N)	0.0121
		Stickiness(N)	0.196

8	Microbiological load (x10^2cfu/ml)	14

4.2 Optimization of Thermal Processing

The temperature values were recorded by inserting a thermocouple at the centre of the jackfruit varatty filled retort pouch. Temperature of the retort and the corresponding core temperature (product temperature) were recorded. Using the time temperature data, heat penetration curve (graph) was plotted in a semi log paper as shown in Fig 4.1, 4.2, 4.3, 4.4 and 4.5. In the present study, two pasteurization temperatures(100°C and 110°C) and a sterilization temperature(121°C) were selected. Based on the Ball's formula and heat penetration curve, the total process time for pasteurization at 100°C to reach F value 1 and F value 2 were 39 min and 58 min, ,respectively. Similarly the total process time for pasteurization at 110°C to reach F1 and F2 were 25 min and 36 min, ,respectively. Also, the total process time required for sterilization at 121°C for attaining F_O value was 22 min. Ravishankar*et al.* (2002) processed fish curry in cans and reported a process time of 48.94 minutes. The thermal processing time- temperature combination was optimized based on the storage studies.

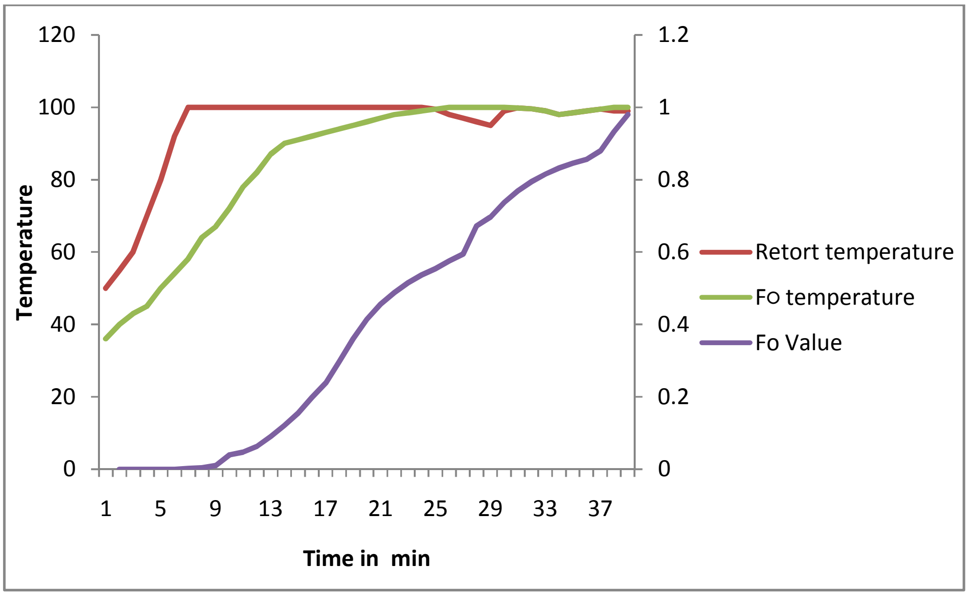

Fig 4.1.Heat penetration characteristics for pasteurisation (100° C F_1)

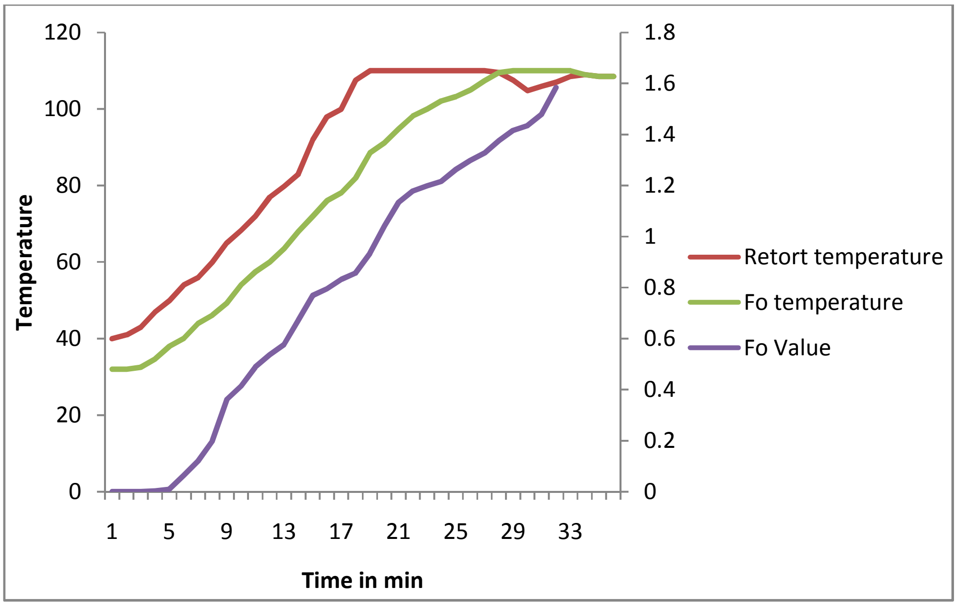

Fig 4.2 Heat penetration characteristics for pasteurisation (100^0C F_2)

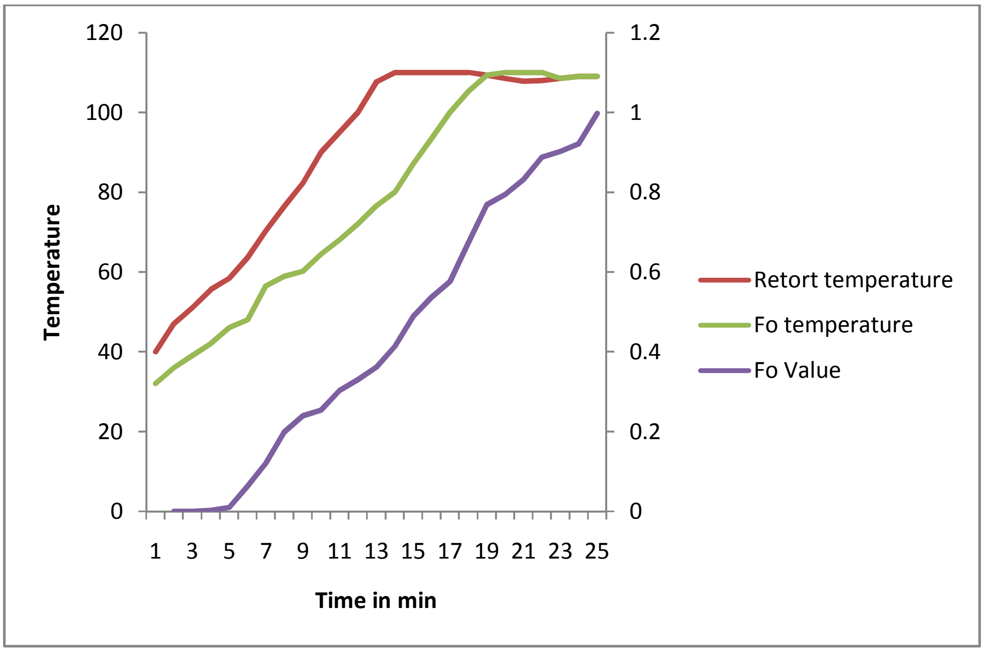

Fig 4.3 Heat penetration characteristics for pasteurisation (110^0C F_1)

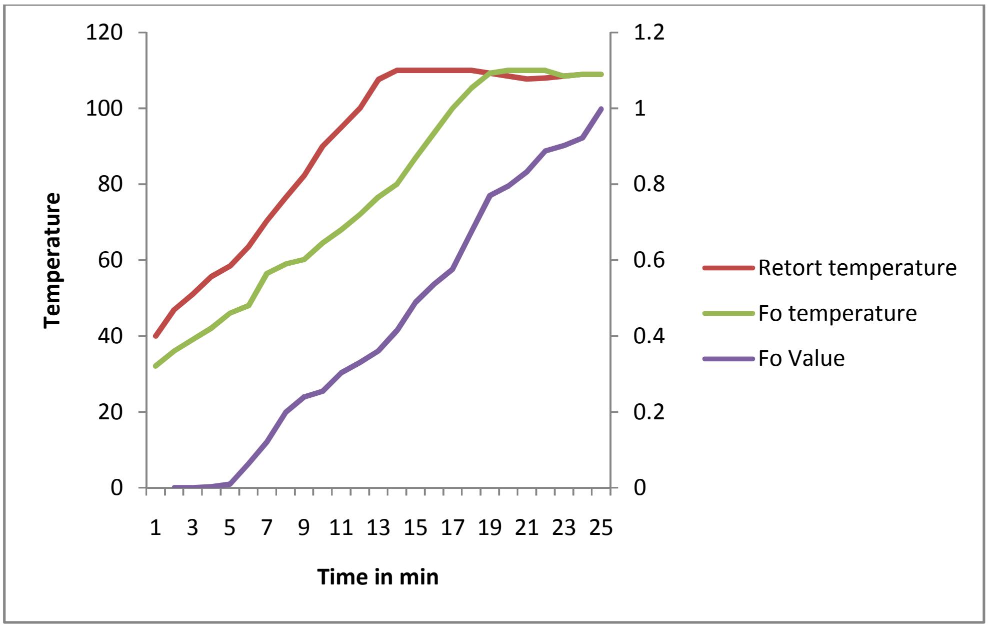

Fig 4.4 Heat penetration characteristics for pasteurisation (110^{0}C F_2)

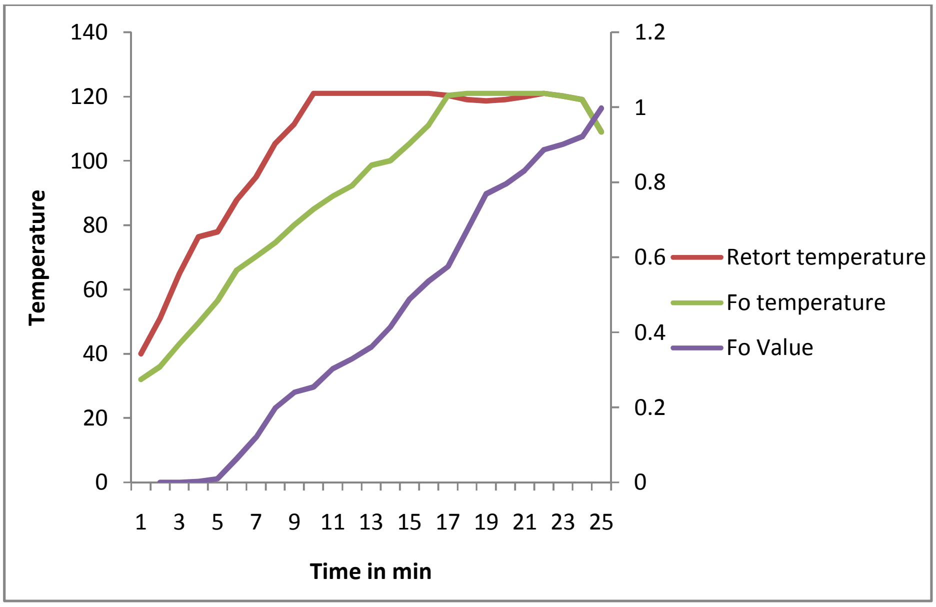

Fig 4.5 Heat penetration characteristics for sterilisation (T121^{0}C F_0)

4.3 Physico chemical and microbiological characteristics of thermally processed jackfruit varatty

The physic-chemical and microbiological characteristics of thermally processed jackfruit varatty are presented in Table 4.2.

Water activity of the processed jackfruit varatty decreased with increase in process temperature. The a_w of samples processed at 100°C, 110°C and 121°C were 0.78, 0.76 and 0.76, ,respectively. The TSS of processed samples was 71.8°Brix for all treatments. The microbiological load of the thermally processed sample was found to be nil for all treatments. The total sugar content of the samples processed at 100°C, 110°C and 121°C were 86.6, 86.5 and 85.3 per cent, ,respectively

Table 4.2 Physico chemical and microbiological characteristics of processed jackfruit varatty

Sl No	Particulars		T100^{0}C F_1	T100^{0}C F_2	T110^{0}C F_1	T110^{0}C F_2	T121^{0}C F_0
1	Water activity		0.78	0.77	0.76	0.756	0.76
2	TSS(^{0}brix)		71.8	71.8	71.8	71.8	71.8
3	Moisture Content (d_b)		25	24.1	24.9	23.9	23.7
4	Microbiological Analysis (10^1cfu/ml)		0	0	0	0	0
5	Total Sugar Content(% carbohydrate)		86	86.6	86.4	86.5	85.3
6	Colour	L^*	25.2	23.05	22.1	19.2	16
		a^*	13	9.8	11.5	13.6	15.57
		b^*	16	17.2	19	20.9	21.7
7	Texture	Hardness(N)	0.006	0.075	0.087	0.076	0.09
		Stickiness(N)	0.106	0.112	0.123	0.135	0.17

. L* value decreased with increase in process temperature whereas a* and b* value increased with increase in process temperature.The reduction in L* value may due to caramellisation of the jaggery present in the sample (Loathar, 1994).The sample subjected to sterilization temperature was found to be more darker than pasteurized samples. The hardness and stickiness value of sterilized sample was found to be higher than the pasteurized samples.

4.4 Quality evaluation of thermally processed jackfruit varatty during storage

4.4.1 Effect of TSS on storage

The effects of storage period on total soluble solids of thermally processed jackfruit varatty under ambient and refrigerated conditions are shown in Table 4.4. The effect of TSS value during storage for all treatments were statistically analysed.The effect of TSS during storage was found to be non-significant for all treatments. From the Table 4.3, it was found that TSS value increased with storage period for all treatments.

4.3 Effect of TSS during storage of thermally processed jackfruit varatty

Treatment		Storage Period			
		Month0	Month1	Month 2	Month 3
Ambient	T1	71.8	71.8	72	72
	T2	71.8	71.8	72	72
	T3	71.8	71.8	72	72
	T4	71.8	71.8	71.8	72
	T5	71.8	71.8	72	72
Refrigerated	T1	71.8	71.8	72	72
	T2	71.8	71.8	72	72
	T3	71.8	71.8	72	72
	T4	71.8	71.8	72	72
	T5	71.8	71.8	71.8	72

But there were no appreciable changes in TSS during storage. TSS value of jackfruit varatty during the initial day of storage was 71.8. After 90 days of storage, the TSS value of jackfruit varatty stored at ambient temperature and refrigerated storage was increased to 72 for all treatments. With reference to the study conducted on coconut jam, we could infer that the slight increase in TSS value during storage may be due to the breakdown of complex sugars into simple sugars (Sindhumati*et al.,* 2014)

4.4.2 Effect of colour during storage of thermally processed jackfruit varatty

Change in food colour is associated with heat treatment of the food. Retention of food colour after thermal processing may be used to predict the extent of quality deterioration of food resulting from exposure to heat (Seonggyun and Santi, 1995).

4.4.2.1 Effect of storage on L^* value

The effect of storage period on L* value of stored thermally processed jackfruit varatty under ambient and refrigerated conditions are presented in Fig 4.6 and 4.7. The effect of L* value during storage and treatments were statistically analysed and the variables were found to behighly significant ($p<0.1$).

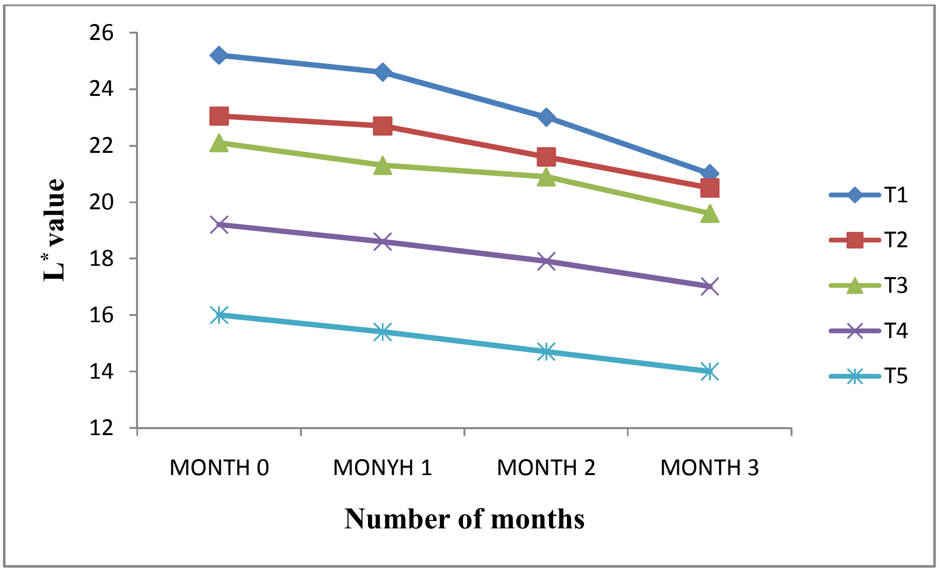

Fig 4.6 –Effect of L^* value during storage at ambient conditions

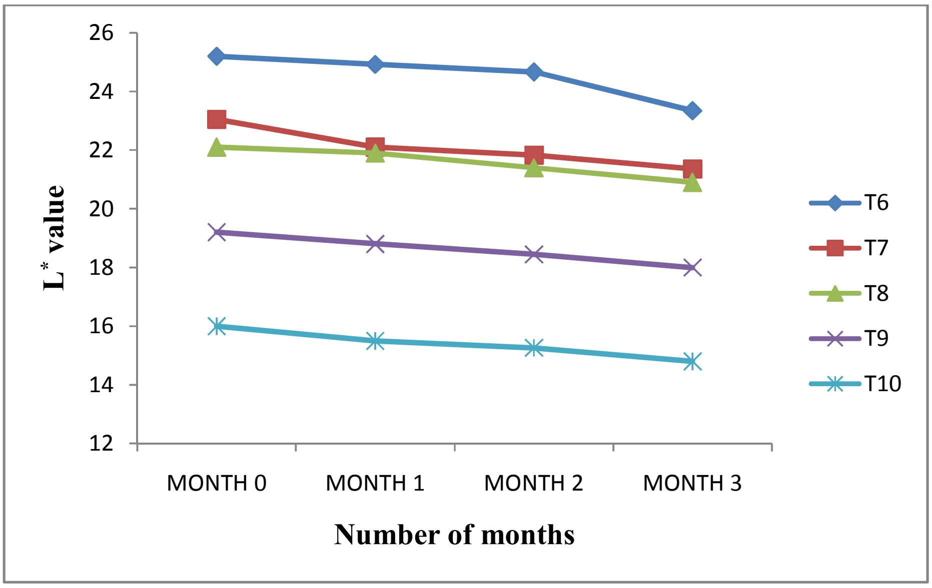

Fig 4.7-Effect of L^* value during storageat refrigerated conditions

From the figure it is observed that the L* value of the samples decreased with storage period. Also, the sample stored at refrigerated conditions showed less decrease in L* value as compared to ambient storage. It may be due to less reaction rate at lower temperature. The L* value of the thermally processed jackfruit varatty during the initial day of packaging for treatments T1, T2, T3, T4 and T5 were 25.2, 23.05, 22.1, 19.2 and 16 ,respectively.After 90 days of storage the L* values obtained for jackfruit varatty stored at ambient temperature for treatments T1, T2, T3, T4and T5 was 20.9, 14.1, 21.3, 17.2 and 23.1, ,respectively. Similarly, the L^* values at refrigerated storage for various treatments were 23.8, 17.1, 21.3, 23.7 and 20.4, respectively.

With reference to the study concluded in the process optimization of rose flavoured milk, the observed decreasing trend of L^* value may be due to Maillard's reactions, which start with binding of aldehyde group of lactose with amino group of the Lysol – residues (amino-acid radical, or residue of amino-acid lysine) from different milk proteins (Prem *et al.,*2014).

4.4.2.2 Effect of storage on a^* value

The effect of storage period on a value of thermally processed jackfruit varatty under different treatments and storage conditions are presented in Fig 4.8 and Fig 4.9. The effect of a* value and treatments were statistically analysed and the variables were found to be highly significant (p<0.1).

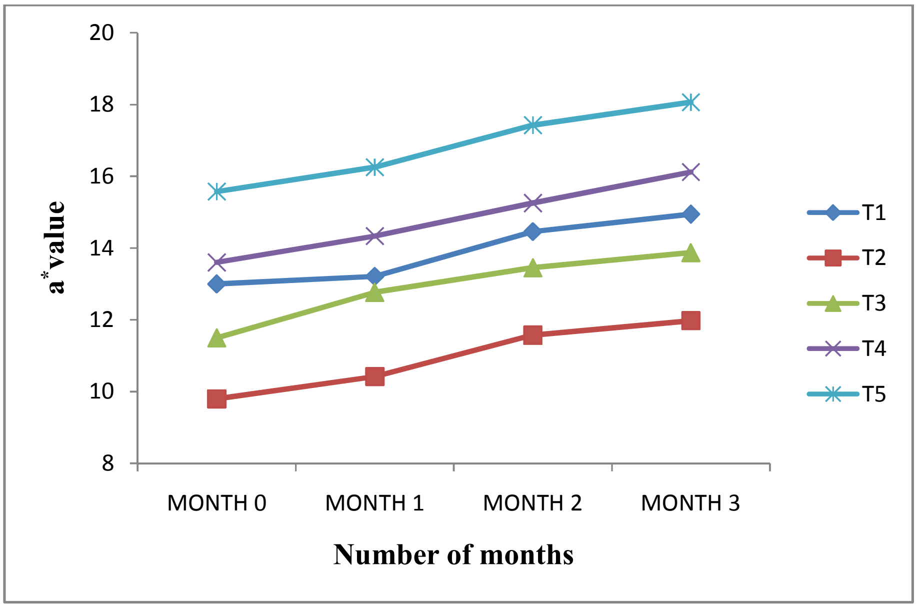

Fig 4.8- Effect of a^* value during storage at ambient conditions

It was observed that storage of the samples resulted in increase of the redness. It may be due to non-enzymatic reactions, especially Maillard reaction in the sample (Prem *et al.,* 2014).The increase in a* value was higher at ambient storage than at refrigerated storage for all treatments. The a^* value of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 and T5 were 13, 9.8, 11.5, 13.6 and 15.5 ,respectively After 90 days of storage the a value of jackfruit varatty stored at ambient temperature for different treatments T1, T2, T3, T4and T5 were 14.34, 11.01, 13.04, 14.9 and 17.3 ,respectively. Similarly, the* value at refrigerated storage for different treatments are 14.94, 11.98, 13.87, 16.12 and 18.06, respectively.

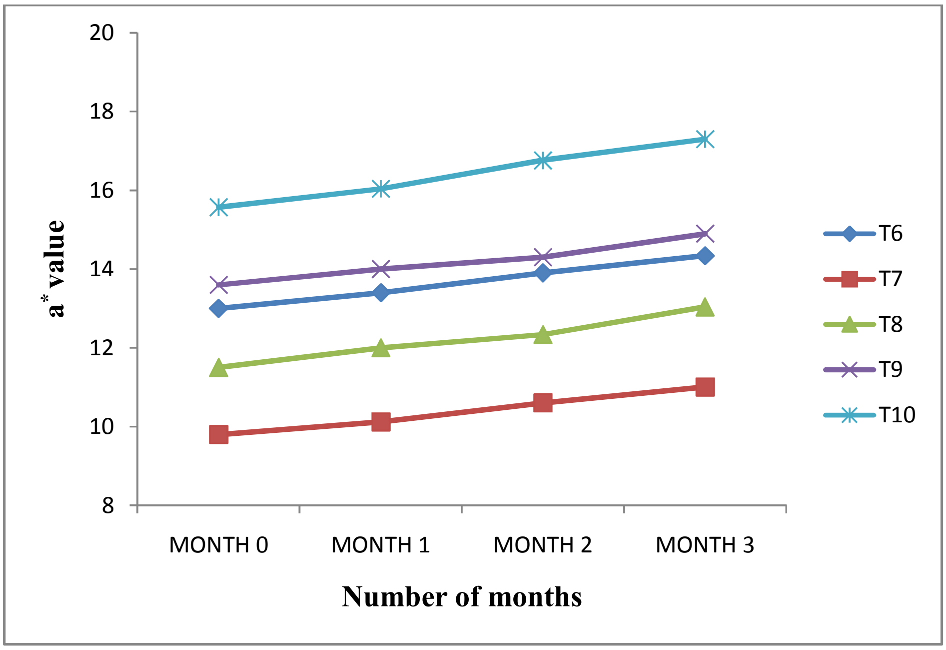

Fig 4.9 – Effect of a* value during storage at refrigerated conditions

.

4.4.2.3 Effect of storage on b^* value

The effect of storage period on b^* value of thermally processed jackfruit varatty under different treatments and storage conditions are shown in Fig 4.10 and Fig 4.11. The effect of b value for all treatments were statistically analysed and the variables were found to be significant ($p<0.5$).

It was observed that there was an increase in b* value for both ambient and refrigerated stored jackfruit varatty during storage. The b*value of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 andT5 were 16, 17.2, 19, 20.9 and 21.7,,respectively. After 90 days of storage the b* values of jackfruit varatty stored at ambient temperature for different treatments T1, T2, T3, T4and T5 were 22.1, 22.8, 24.5, 25.5 and 26.7 ,respectively. Similarly, the b values at refrigerated storage for different treatments were 17.89, 19.4, 21.8, 23 and 24.5 ,respectively. This change is in accordance with the colour change observed in storage of orange jam (Kopjar*et al.,* 2010).

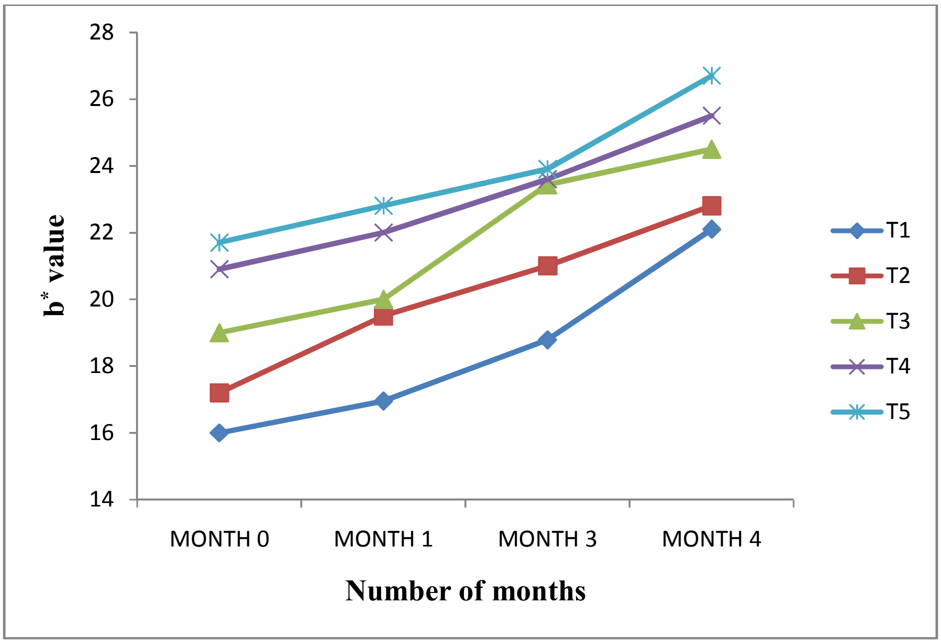

Fig 4.10-Effect of b* value during storage at ambient conditions

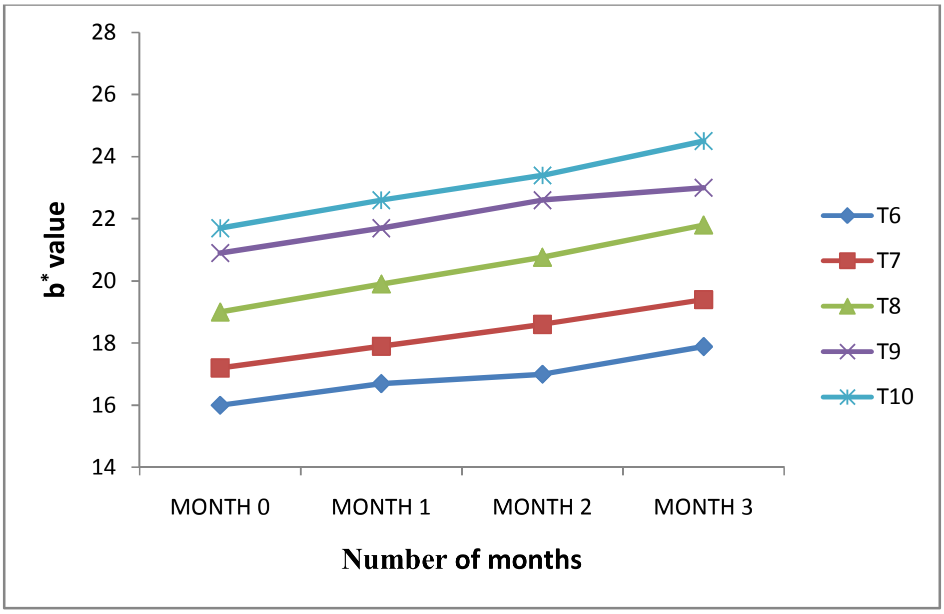

Fig 4.11-Effect of b* value during storage atrefrigerated conditions

4.4.3 Effect of texture on storage

4.4.3.1. Effect of hardness during storage

The effect of storage period on hardness value of stored jackfruit varatty under different storage conditions are shown in Fig 4.12 and Fig 4.13. The effect of hardness value and treatments were statistically analysed and the variables were found to be highlysignificant ($p<0.1$).

Refrigerated sample showed more pronounced increase as compared to the ambient sample. The hardnessvalue of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 andT5 were 0.006, 0.075, 0.087, 0.076 and 0.09N.After 90 days of storage, the hardness value of stored jackfruit varatty stored at ambient temperature was increased to 0.501, 0.497, 0.571, 0.498 and 0.653, respectively for treatments T1, T2, T3, T4 and T5. This could be attributed to the continuous reduction in moisture content and consequent increase in total solids mainly contributed by sucrose. This is in accordance with the findings of Gupta *et al.* (1990) and Suresh and Jha (1994) who have reported that the increased hardness of *khoa* correlated with the increase in total solids, and by increasing the total solids in *khoa,* hardness also increased. Similarly, the harness of jackfruit varatty stored at refrigerated storage was increased to 1.023, 0.958, 0.875, 0.793 and 0.953 ,respectively. The increase in the initial hardness as a consequence of the frozen storage, may be due to the damage of the constituents of the sample produced during frozen storage. It was in accordance with the findings of Fik*et al*., 2002.

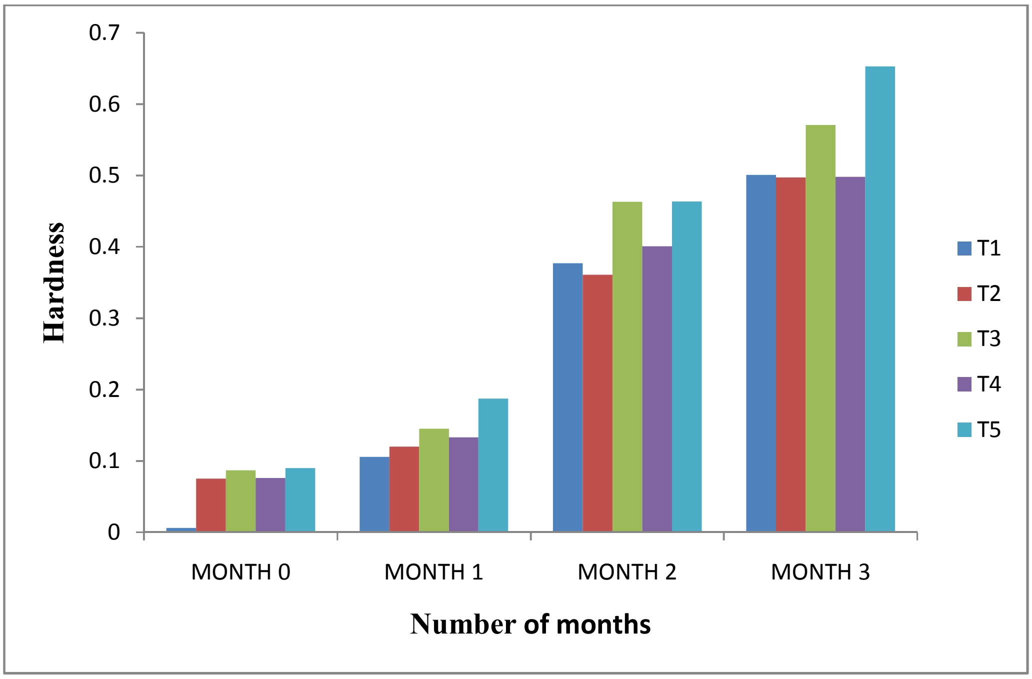

Fig 4.12-Effect of hardness during storage at ambient conditions

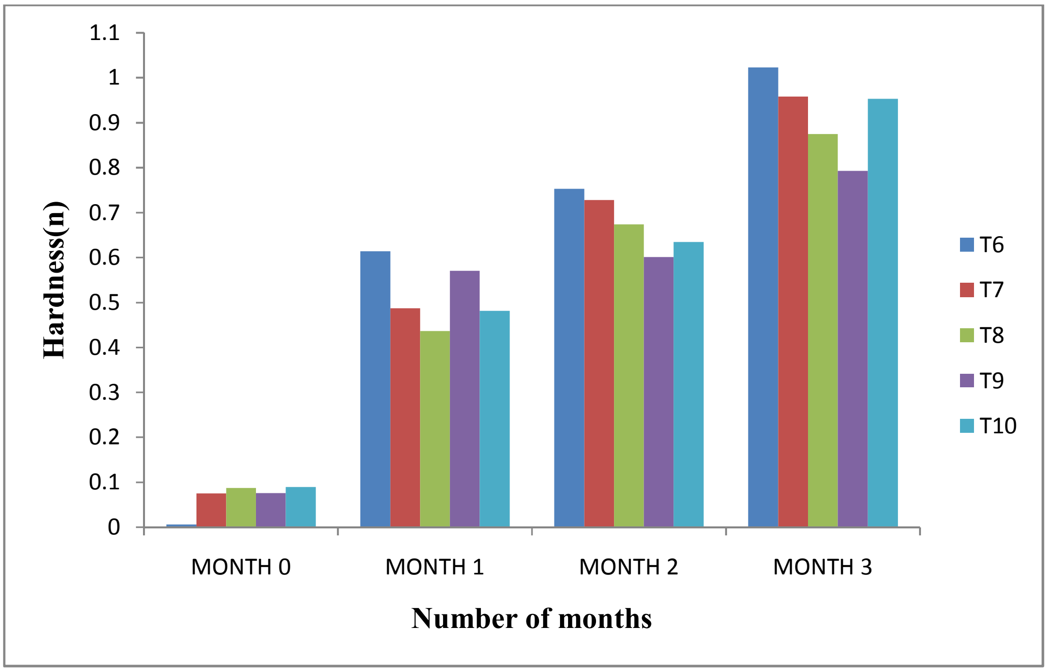

Fig 4.13- Effect of hardness during storage at refrigerated conditions

4.4.3.2. Effect of storage on stickiness

Fig 4.14 and Fig 4.15 shows the effect of storage period on stickiness value of stored jackfruit varatty under different storage conditions. Stickiness values for each of the treatment of stored jackfruit varatty were found to be highly significant ($p<0.1$).

The stickiness value for jackfruit varatty decreased with storage period for both ambient and refrigerated stored product. Ambient stored sample was found to be stickier than refrigerated stored samples.The stickiness value of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 and T5 were 0.110, 0.115, 0.123, 0.135 and 0.175N, ,respectively. After 90 days of storage, the stickiness of stored jackfruit varatty stored at ambient temperature was reduced to 0.023, 0.039, 0.023, 0.028 and 0.021N for treatments T1, T2, T3, T4 and T5. Similarly, the stickiness of jackfruit varatty stored at refrigerated storage was decreased to 0, 0.021,0.006,0.002,0.018N .

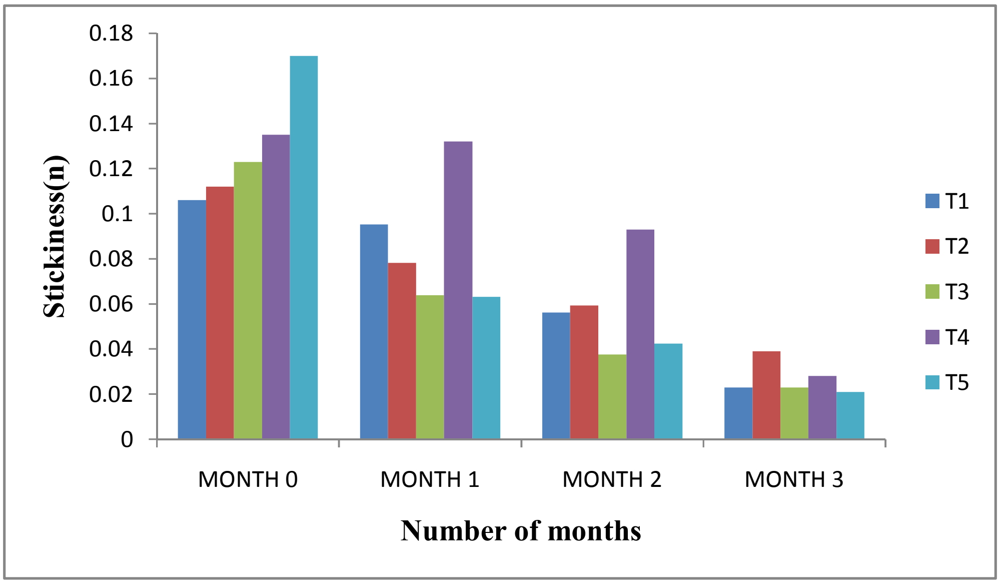

Fig 4.14- Effect of stickiness during storage at ambient conditions

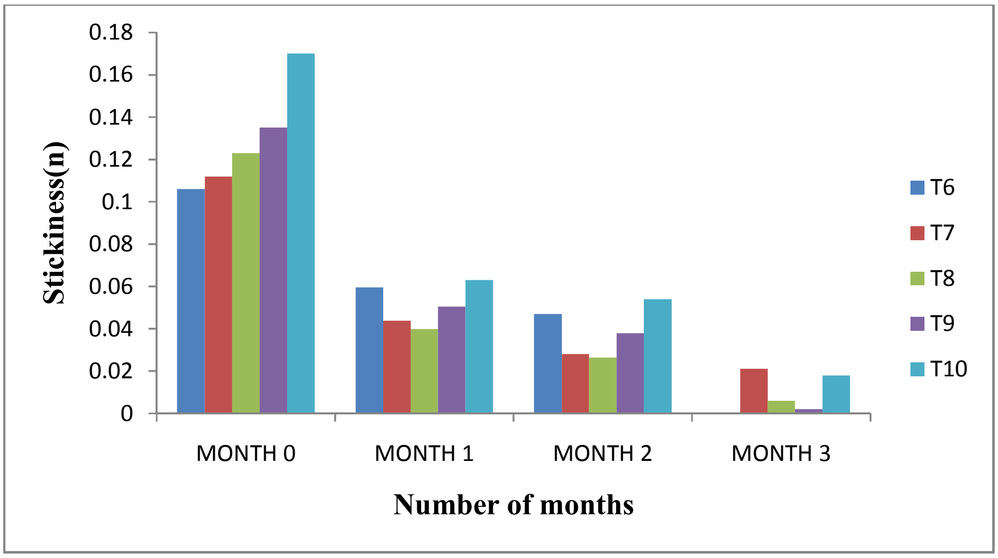

Fig 4.15-Effect of stickiness during storage at refrigerated conditions

Interactions between amylase and amylopectin were found to decrease during storage and is responsible for the decrease in stickiness during storage (Gustavo *et al.,* 2006). Increase in temperature results in lower viscosity, lower surface tension and as a result increase in stickiness (Yrjo*et al.,* 2015).

4.4.4 Effect of water activity during storage

Fig 4.16 and Fig 4.17 depicts the effect of storage on water activity of jackfruit varatty under ambient and refrigerated conditions, respectively. Water activity for each treatment of stored jackfruit varatty were found to be highlysignificant ($p<0.1$). The water activity of processed jackfruit varatty decreased with storage period for both ambient and refrigerated stored product.The decrease in water activity was more pronounced in ambient sample than refrigerated sample.The water activity of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 and T5 were 0.78, 0.77, 0.76, 0.756 and 0.76, respectively.

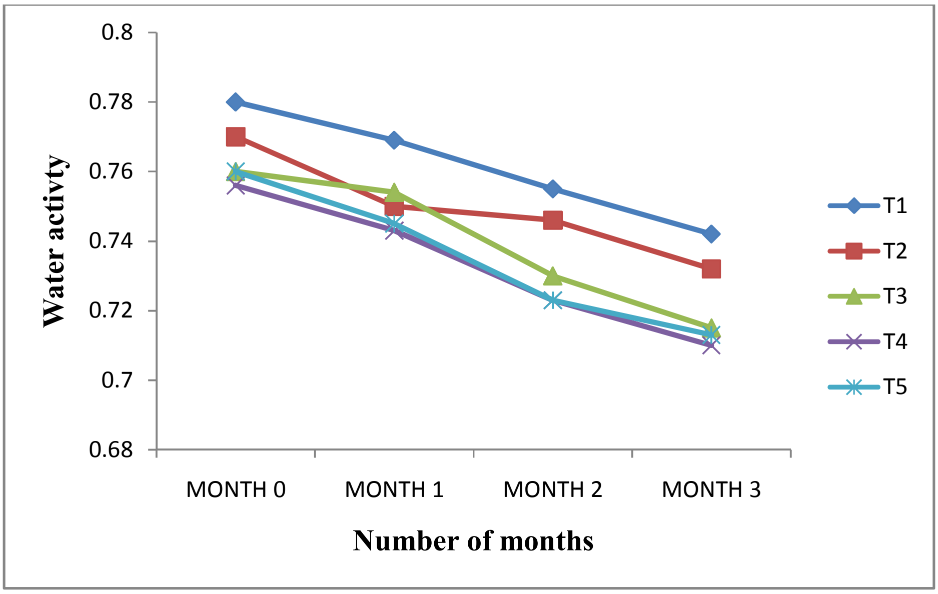

Fig 4.16-Effect of water activity during storage at ambient conditions

After 90 days of storage, the water activity of stored jackfruit varatty stored at ambient temperature was decreased to 0.75, 0.73, 0.73, 0.72 and 0.72 for treatments T1, T2, T3, T4 and T5. Similarly, the water activity of jackfruit varatty stored at refrigerated storage was decreased to 0.74, 0.72, 0.75, 0.73 and 0.69, respectively.The water activity of the sample during storage which confers more storage stability. This may be due to loss of water during storage and increase in solid content which results in increase in water activity (Len *et al.,* 2010).

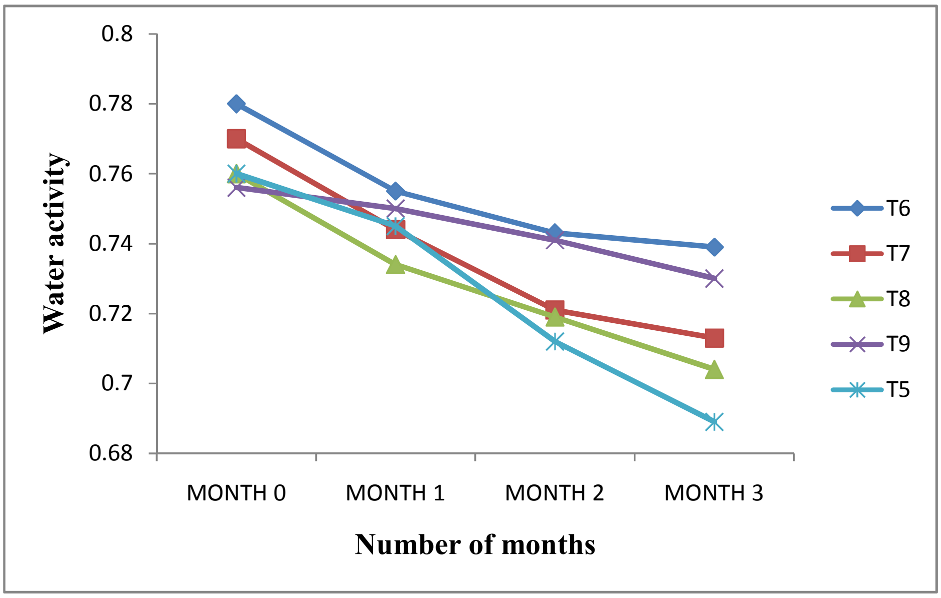

Fig 4.17-Effect of water activity during storage at refrigerated conditions

4.4.6 Effect of total sugar content during storage

Table 4.5 depicts the effect of storage on sugar content of jackfruit varatty under ambient and refrigerated conditions. Statistical analysis showed that there is no significant difference between the sugar content during storage for all treatments.

Table 4.4 Effect of total sugar content during storage of thermally processed jackfruit varatty

Sl no	Storage condition	Treatment	Conc.	Carbohydrate %			
				No. of months			
				0	1	2	3
1	Ambient	T1	0.5	86	83.61	83.42	83.26
			1	85.9	84.11	83.95	83.92
2	Ambient	T2	0.5	86.45	82.78	82.53	82.15
			1	86.12	83.46	83.31	82.04
3	Ambient	T3	0.5	84.5	83.50	83.39	84.72
			1	84.2	84.57	84.42	83.92
4	Ambient	T4	0.5	86.6	82.91	82.83	81.69
			1	86.5	83.87	83.23	82.75
5	Ambient	T5	0.5	85.5	83.95	82.46	82.13
			1	85.2	84.06	83.97	83.82
6	Refrigerated	T6	0.5	86	85.29	85.22	85.05
			1	85.9	84.87	84.81	84.76
7	Refrigerated	T7	0.5	86.45	85.67	84.61	83.58
			1	86.12	85.14	84.10	83.03
8	Refrigerated	T8	0.5	84.5	83.85	83.77	83.71
			1	84.2	83.54	83.49	83.41

9	Refrigerated	T9	0.5	86.6	85.56	85.51	85.48
			1	86.5	85.69	85.66	85.63
10	Refrigerated	T10	0.5	85.5	84.86	84.81	84.77
			1	85.2	85.17	85.14	85.09

From the table it is observed that the total sugar content of processed jackfruit varatty decrease during the course of storage. The decrease was more pronounced in ambient storage than refrigerant storage. The total sugar content of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 and T5 were 85.95, 86.34, 84.35, 86.55 and 85.35 percent.After 90 days of storage, total carbohydrates of ambient stored sample T1, T2, T3, T4 and T5 were 83.58, 82.095, 84.32, 82.22 and 82.975 percent,respectively. Similarly, total sugars of refrigerated storage T6, T7, T8, T9 and T10 were 84.9, 83.31, 83.56, 85.55 and 84.93 percent respectively. This may be due to the breakdown of total sugar into simple sugar would have decreased the quantum of total sugar as observed in coconut jam (Sindhumati*et al.,* 2014).

4.4.7 Effect of moisture content during storage

Fig 4.18 and Fig 4.19depicts the loss in moisture content of the retort packaged jackfruit varatty during storage. Statistical analysis showed that there is no significant difference between moisture content during storage for all treatments.There was decrease in the moisture content during ambient and refrigerated storage of processed jackfruit varatty. The moisture content of processed jackfruit varatty at the initial day of packaging for various treatments T1, T2, T3, T4 and T5 were 25, 24.1, 24.9, 23.9 and 23.7 per cent(db),respectively.

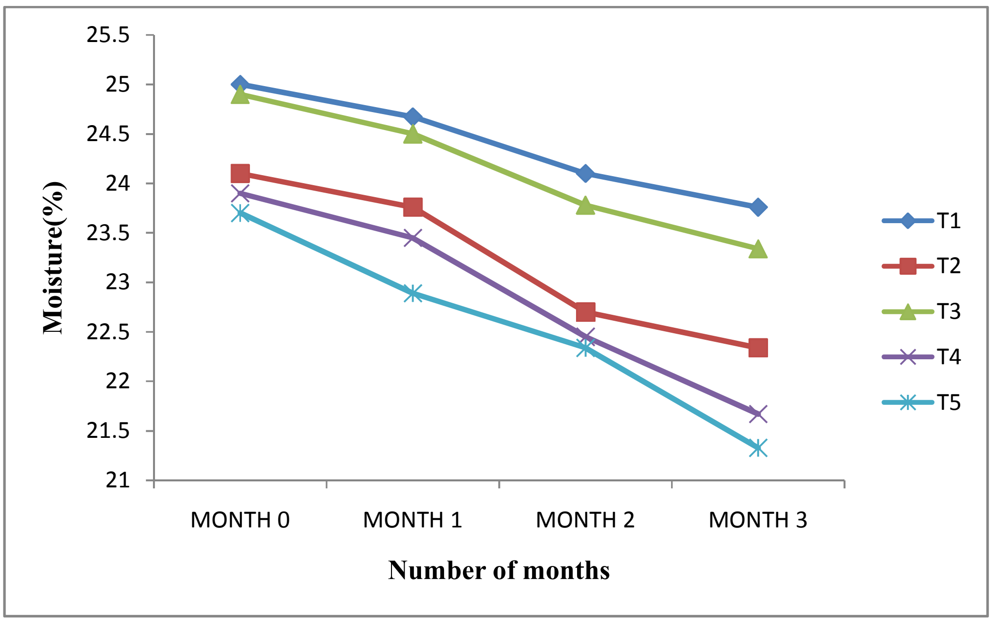

Fig 4.18- Effect of

moisture content during storage at ambient conditions

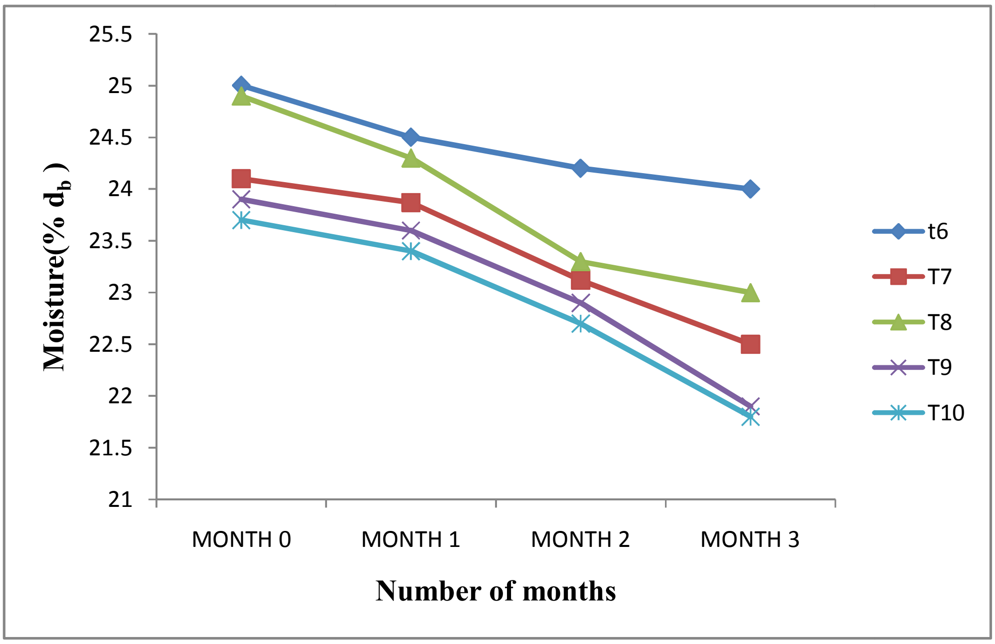

Fig 4.19-Effect of moisture content during storage at refrigerated conditions

After 90 days of storage, moisture content of ambient stored samples T1, T2, T3, T4 and T5 were found to be 23.76, 22.34, 23.34, 21.67 and 21.33 per cent(db), ,respectively and that of refrigerated samples at T6, T7, T8, T9 and T10 were 24, 22.5, 23, 21.9 and 21.82 per cent(db), ,respectively. The decrease in moisture was more pronounced in refrigerated storage than at ambient storage.

4.4.8 Effect of microbiological load during storage

Retort processed jackfruit varatty was examined for its microbiological load at regular intervals and the results are given in Table 4.5 .It is observed that the number of colony forming units was found to be nil up to first 30 days of storage in all treatments except T1 under refrigerated condition. After 90 days of storage, the observed microbiological counts were within the permissible limit. For control sample, the microbiological count was within the permissible limit for 30 days of storage. But, after 60 days of storage, the microbiological count was found to be exceed the permissible limit. The results revealed that the thermally processed samples under ambient and refrigerated storage were microbiologically safe. Effect of storage on microbiological load is illustrated in table 4.6 for three months

Plate 4.1 Microbiological analysis of stored jackfruit varatty

Table 4.5 Effect of microbiological load during storage of thermally processed jackfruit varatty

Temperature		Storage Period			
		Month 0	Month 1	Month 2	Month 3
Ambient	T1	0	0	1	2
	T2	0	0	0	0
	T3	0	0	1	1
	T4	0	0	0	1
	T5	0	0	0	0
Refrigerated	T1	0	1	1	2
	T2	0	0	0	1
	T3	0	0	0	0
	T4	0	0	0	1
	T5	0	0	0	0
Control		26000	TNC	TNC	TNC

Retort pouch processing could prove to be a means of value addition, product diversification and export promotion for traditional ethnic dishes (Mohammed Ali*et al*., 2012).

4.4.9 Sensory evaluation of the sample:

The retort processed jackfruit varatty was stored for 5 months at ambient and refrigerated conditions and the organoleptic characteristics was evaluated using 5 point hedonic scale and the score values are presented in Fig 4.20, 4.21, 4.22 and 4.23. Sensory evaluation of various parameters such as colour, taste, texture and overall acceptability was conducted. From the fig, it is understood that the treatment T6(Pasteurised at 100°C for F1 stored at refrigerated condition) was the best among all treatments followed by T1(Pasteurised at 100°C for F1 stored at ambient condition).

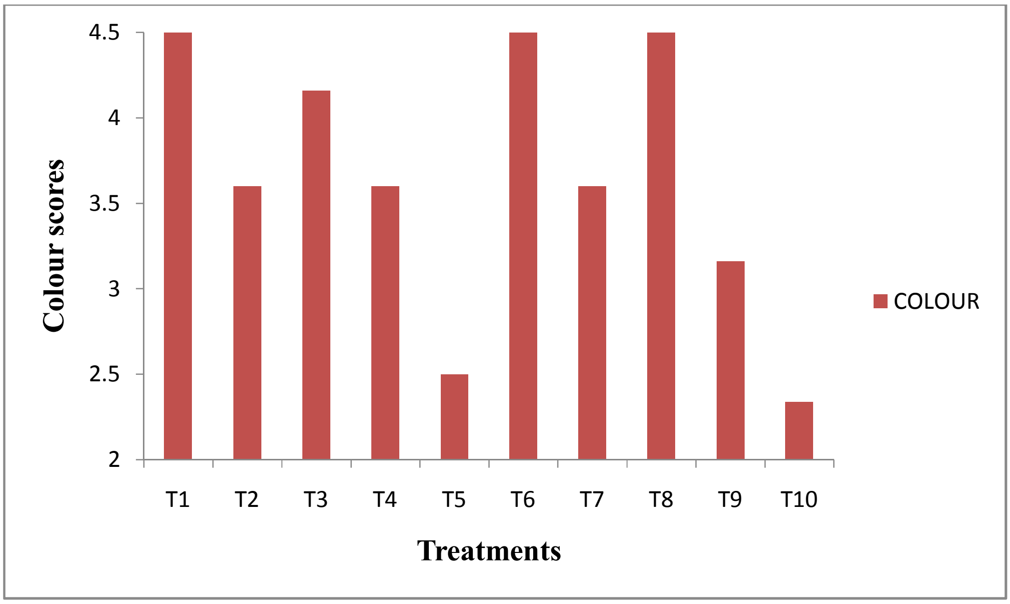

Fig 4.20- Sensory score values (Colour) of thermally processed jackfruit varatty during storage

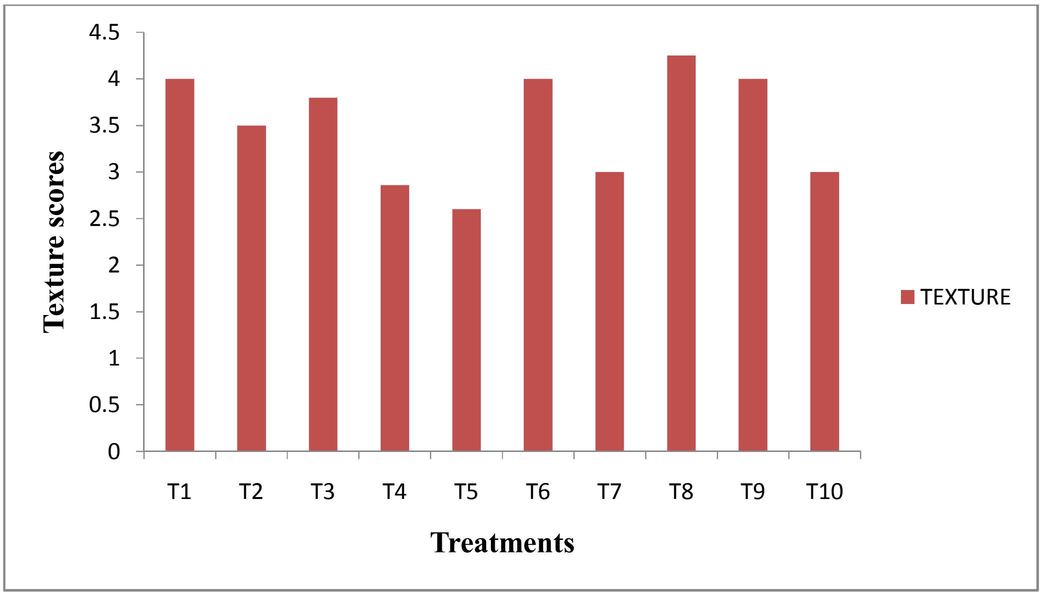

Fig 4.21-Sensory score values (Texture) of thermally processed jackfruit varatty during storage

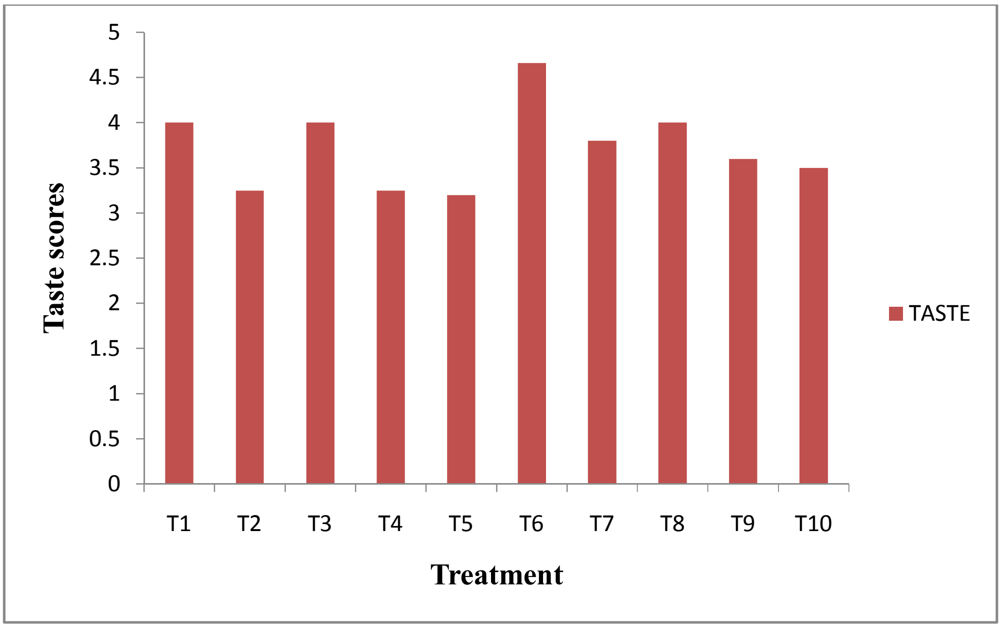

Fig 4.22- Sensory score values (Taste) of thermally processed jackfruit varatty during storage

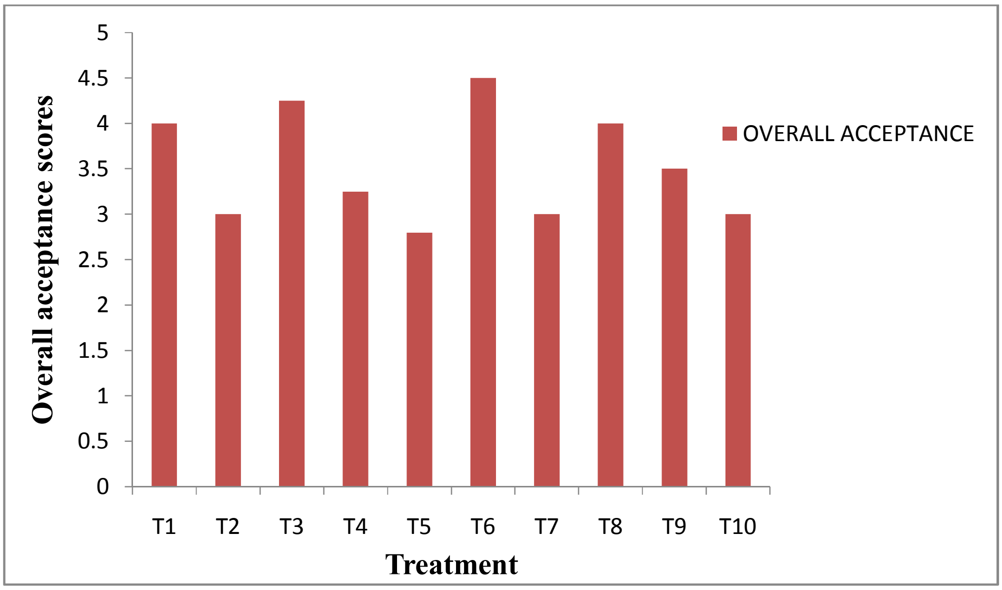

Fig 4.23-Sensory score values (Overall Acceptance) of thermally processed jackfruit varatty during storage

Cost Economics

Cost economics of the thermally processed jackfruit varatty in retort pouch was calculated and is given in Appendix D. The cost of production of retort pouch contains 100g varatty was found to be Rs.14.

SUMMARY AND CONCLUSIONS

CHAPTER 5
SUMMARY AND CONCLUSIONS

Jackfruit (*Artocarpus heterophyllus L*) belongs to family Moraceae, grows widely in tropical countries of south east Asia especially India and Bangladesh. It is a seasonal organic fruit which has very less shelf life. This under exploited fruit is considered as heavenly fruit by the ancient people in Kerala because of its nutritive composition. The edible portion is considered as a good source of carbohydrate, proteins, vitamins and minerals. The presence of isoflavones, antioxidants, and phytonutrients in the fruits indicate that jackfruit has cancer-fighting properties. Various delicious products can be prepared from jackfruit. Various products like chips, papad, pakoda, pickle, cutlets etc are prepared from matured jackfruit and products such as halwa, gulabjamun, unniappam, wine, cake, varattyetc are prepared from ripened jackfruit.

Jackfruit varatty is a prominent traditional jackfruit processed product of Kerala. It is consumed assuch or it is used as the raw material for several traditional dishes like chakkayada, chakkaprathaman, chakkayappam, chakkapayasam etc. Jackfruit varatty has a comparatively medium shelf life at ambient conditions. But storage for longer periods of time demands cold storage and freezer facilities which are cumbersome. Thermal processing of jackfruit varatty in retort pouch has proven to be highly successful in extending the shelf life in case of various products. It is one among the most widely used methods for preservation of perishable products. Current study entitled 'Development of shelf stable jackfruit varatty by thermal processing in retort pouch' focuses on the shelf life study of the retort pouch processed jackfruit varraty and the various parameters affecting it. The objectives of the project work are a) development of shelf stable jackfruit varatty by retort processing .b) Optimization of process parameters for the production of thermally processed jackfruit varatty and c) Shelf life studies and quality evaluation of retort pouch packed jackfruit varatty.

Prepared jackfruit varatty, procured from M/s Friends Agro Processing Unit, Naduvattam, Malapuram were used for the experiments. The physico-chemical and microbiological studies of raw jackfruit varatty were conducted. Jackfruit varatty was light yellow in colour having an L* value of 24.15, a value of 11.81 and b value of 22.35. It had a water activity of 0.771. The TSS and total sugar content of jackfruit varatty were 71.8°brix and 86 per cent, respectively. The hardness of the fresh jackfruit was estimated to be 0.0121N.

Thermal processing was done in retort pouches (15 cm × 20 cm). It is a flexible laminated package that can withstand thermal processing temperature. One hundred gram jackfruit varatty pieces was filled manually in the retort pouch. After filling the retort pouch, the sealing was done using a sealing machine at a pressure of 1 bar and voltage of 38V. The hermetically sealed retort pouches were loaded into the perforated aluminium trays and placed into retort processing chamber. One of the pouches was fixed with a thermocouple sensor. The sensor tip was inserted into the jackfruit varatty for recording core temperatures. The retort unit consisted of a steam generator at the bottom, retort processing chamber in the middle and water storage tank at the top. All these units along with control panel were mounted on a stainless steel frame. The steam generator or boiler is internally divided into two portions and a pressure gauge is attached to it. One portion is to boil water and produce steam with a capacity is 30 kg and the other one is to store steam for retort processing. The different F value- temperature combinations selected for standardization of jackfruit varraty are a) T1- Pasteurised at 100^{o}C for F_1 stored at ambient condition, T2- Pasteurised at 100^{o}C for F_2stored at ambient condition, T3- Pasteurised at 110^{o}C for F_1stored at ambient condition, T4- Pasteurised at 110^{o}C for F_2 stored at ambient condition, T5- Sterilised at 121^{o}C for F_0 stored at ambient condition, T6- Pasteurised at 100^{o}C for F_1 stored at refrigerated condition, T7- Pasteurised at 100^{o}C for F_2 stored at refrigerated condition, T8- Pasteurised at 110^{o}C for F_1 stored at refrigerated condition, T9- Pasteurised at110^{o}C for F_2 stored at refrigerated condition and T10- Sterilized at 121^{o}C for F_0 stored at refrigerated condition

The thermally processed jackfruit varatty in retort pouches were stored for three months and shelf life studies were conducted. The jackfruit varraty samples in sterilized pouches were stored in ambient condition (temperature at 37^{o}C) and in refrigerated condition (15°C). The parameters viz., TSS, water activity, moisture content, total sugar content, colour, texture and microbiological analysis weretested in every 1 month interval up to two month and final analysis was done after three months of storage.

TSS value increased with storage period for all treatments. But there is no appreciable changes in TSS during storage. TSS value of jackfruit varatty during the initial day of storage was 71.8. After 90 days of storage, the TSS value of jackfruit varatty stored at ambient temperature and refrigerated storage was increased to 72 for all treatments.

The effect of L^* value and treatments were statistically analysed and the variables were found to be highly significant ($p<0.1$). The 'L*' value showed a gradual decrease with increase in storage period, for all treatments under ambient and refrigerated conditions. The reduction of L^* value was more at ambient storage than at refrigerated stored jackfruit varatty for all treatments. There was increase in and b value for both ambient and refrigerated stored jackfruit varatty. It may be due to non-enzymatic reactions, especially Maillard reaction in the sample.

The effect of hardness value during storage were statistically analysed and the variables were found to be highlysignificant ($p<0.1$). The hardness value was higher for refrigerated sample as compared to ambient sample. The hardness value at the initial day of storage of jackfruit varatty was 0.0121N. After 90 days of storage, the hardness value of stored jackfruit varatty stored at ambient temperature was increased to 0.5, 0.5, 0.55, 0.5 and 0.65N for treatments T1, T2, T3, T4 and T5. Similarly, the harness of jackfruit varatty stored at refrigerated storage was increased to 1.0, 0.95, 0.88, 0.8 and 0.95, respectively.

Water activity for each treatment of stored jackfruit varatty were found to be highlysignificant ($p<0.1$). Water activity of jackfruit varatty decreased with storage period for all treatments.

The water activity at the initial day of storage of jackfruit varatty was 0.776. After 90 days of storage, the water activity of stored jackfruit varatty stored at ambient temperature was decreased to 0.75, 0.73, 0.73, 0.72 and 0.72 for treatments T1, T2, T3, T4 and T5. Similarly, the water activity of jackfruit varatty stored at refrigerated storage was decreased to 0.74, 0.72, 0.75, 0.73 and 0.69, respectively.

Retort processed jackfruit varatty was examined for its microbiological load at regular intervals. The number of colony forming units was found to be nil up to first 30 days of storage in all treatments except T1 under refrigerated condition. After 90 days of storage, the observed microbiological counts were within the permissible limit. For control sample, the microbiological count was within the permissible limit for 30 days of storage. But, after 60 days of storage, the microbiological count was found to be exceed the permissible limit. The results revealed that the thermally processed samples under ambient and refrigerated storage were microbiologically safe.

Sensory evaluation was done after 6 months. Various parameters such as colour, texture, taste and overall acceptance were evaluated by a 5 point hedonic scale. Based on the sensory evaluation, samples processed at 100^0C F_1 and stored at refrigerated condition was found to be the best.

Based on the physico-chemical analysis, the samples stored at refrigerated conditions was found to be better than the ambient storage for all treatments. But microbiological analysis revealed that the thermally processed samples under ambient and refrigerated storage were microbiologically safe for 90 days. Hence, by considering the economy, it is concluded that thermally processed jackfruit at a pasteurization temperature of 100°C, F1 (Pasteurised at 100°C for F1 stored at ambient condition) can be stored safe at ambient temperature for a period of 90 days.Cost economics of the thermally processed jackfruit varatty in retort pouch was calculated and the cost of production of retort pouch contains 100g varatty was found to be Rs.14.

REFERENCES

REFERENCE

AlokJha., Murli., Ashok Ambalel Patel., TeralandurKrishnaswamy., ChandragiriNagarajaraoRavishankar. 2012. *LWT- Food Science and Technology.* 4980:88

Anna, W., Krzysztof, P.R., and Dorota, E.K. 2006. Changes in fruit quality in pears during CA storage. *J. Fruit Ornamental Plant Res.* 14 (2): 77-84.

Arkroyd, W.R., Gopalan, C., and Balasubramanuyam, S.C. 1966. *The Nutritive Value of Indian Food and the Planning of Satisfaction Diet*. Indian Council of Medical Research, New Delhi

Aruna, K.Y. and Poonam, A.S. 2013. Development of fresh and processed tomato salsa with herbs. [On-line]. Available*:* http://www.omicsonline. org/scientific-reports/2157-7110-SR-689.pdf. [02 DEC. 2014].

Ashaye, O.A., Taiwo, O.O. and Adegoke, G.O. 2006. Effect of local preservatives AframomumDanielle) on the chemical and sensory properties of stored warakanshi. *African Journal of Agricultural Research* 1 (1):10-16.

Awuah, G.B., Ramaswamy, H.S., and Economides, A. 2007. Thermal processing and quality: Principles and overview. *J. Chem. Eng. Processing.* 46: 584– 686

Azad, A.K. 2000. *Genetic diversity of jackfruit in Bangladesh and development of propagation methods*. Ph.D. thesis, University of Southampton. UK.

Banu, C., ş.a. 2002. Calitateaşicontrolulcalităiiproduseloralimentare, Agir. *Bucureşti*. 547p.

Benjamin, C., Paul, M.F and Fidel, T. 2016. *Encyclopedia of Food and Health*: *Vol. 1*Elsevier Inc., USA. 435pp.

Bindu, P.O. 1995. Suitability of osmotic drying technique for product development in jackfruit (*Artocarpus heterophyllus Lam.*). MSc (Ag) thesis. Kerala Agricultural University, Thrissur, 153p.

Booth, I.R. and Kroll, R.G. 1998. The preservation of foods by low pH. In: Gould, G.W. (ed.), *and Mechanism of Action of Food Preservative Procedures*. Elsevier Press, London, pp.119–160.

Burkill M M.1999, *Useful crops of West Africa* (4th Ed.) 2160-161

Chandra, U.G., Wedage, W.S., Wickramasinghe and Fernando, WS. 2006. Hypoglycaemic action of the flavonoid fraction of Artocarpus heterophyllus leaf. *African Journal of Traditional, Complementary and Alternative Medicine*; 3: 42-50.

Chowdhury, M.G.F., Miaruddin, M., Rahman, M.M., Islam, M.S. and Tariqul, I.A.F.M. (2009). Study on the effect of preservative on the storage quality of spiced papads. *J. Innovative Dev. Strategy*. 2(3): 30-33.

Cluter, R.A., Nattress, D.T., Dunne, C.P., and Popper, A.D. 1994. Shelf life evaluation of cling peaches in retort pouches. *J. Food Sci.* 59(4): 849-854.

Costell, E. and Duran, L. 2012. Food texture; Sensory evaluation. [On-line] Available: http://www.eolss.net/Sample-Chapters/C10/E5-10-03-09.pdf [15 Dec2014].

Cynthia, S.J. and Jerald, H.M. 1989. A preliminary study of heating characteristic and quality attributes of product packed in retort pouch compared with conventional can. *J. Food Process Eng.* 11(3): 221-236.

Denny, C.B. 1970. Collaborative study of a method of determination of commercial sterility of low acid canned foods. *J. Assoc. Off. Chem.* 55(1): 613-616.

Dinesh, R., Sharma, P.D., and Kumar, S. 2014. Effect of total soluble solid during storage of litchi fruits under different temperatures. *Adv. Appl. Sci. Res.* 5(2): 117-121.

Fik, M and Surowka, K. 2002. Effect of frozen storageon the sensory quality and instrumental texture of sweet peda. *Journal ofthe Science of Food and Agriculture*, 82:1268–1275.

Gomez, J.B., Bates, P.R., and Ahammed, E.M. 1980. Flexible pouch process development and evaluation of pasteurized-refrigerated mango slices. *J. Food Sci.* 45(6): 1592-1594.

Guillermo, P., Marisa, C. and Jorge, M. 2014. Influence of blanching, Freezing and frozen storage on physico – chemical properties of broad beans. *Int. J. Refrigeration.* 40: 429-434.

Gunasena, H.P.M., Ariyadasa, K.P., Wikramasinghe, A., Herath, H.M.W., Wikramasinghe, P., and Rajakaruna, S.B. 1996. *Manual of jack cultivation in Sri Lanka.* Forest Information Service, Forest Department. 48p.

Gupta, S.K.,Patil, G.R., Patel, A.A., Garg, F.C., Rajorhia, G.S.1999.Instron texture profile parameters of *khoa* as influenced by composition. *J Food Sci Tech*. 27:209–213.

Gustavo, V. and Barbosa Canovas. 2007. *Water activity in foods: fundamentals and applications.* Blackwell Publishing and Institute of Food Technologists. USA. 313p.

Irwin, A.T. and Paul Singh, R. 1998. *Food storage stability*. CRC press LLC. New York. 524p.

Jan and Rab 2012 Storage studies of apple *J. Food Sci.* 5:90-99

Jha, Y.K and Singh, S. 1977. Effect of antioxidants and anti-microbiological substances on keeping quality of *khoa*. *Indian J Dairy Sci.* 30:1–6.

Joy, C.R., Christine, M.B., and Diane, M.B. (2007). Nutritional comparison of fresh, frozen, and canned fruits and vegetables II. Vitamin A and carotenoids, vitamin E, minerals and fibre. *J. Sci. FD Agric*. 87(7): 1185- 1196.

Joy, C.R., Christine, M.B., and Diane, M.B. 2007. Nutritional comparison of fresh, frozen, and canned fruits and vegetables II. Vitamin A and carotenoids, vitamin E, minerals and fibre. *J. Sci. Food Agric.* 87(7): 1185-1196.

Ko, F.N., Cheng, Z.J., Lin, C.N and Teng C.M. 1998. Scavenger and antioxidant properties of phenyl flavones isolated from *Artocarpus heterophyllus. Free Radical Biology and Medicine*. 25: 160-8.

Kumar, R., Natarajan, S., Jayaprahash, C., Sabhapathy, S.N and Bawa A.S. 2007. Development and evaluation of retort pouch processed ready-to-eat coconut kheer. *Indian Coconut Journal* 37: 2-6.

Lakshmana JH, Jayaprakash C, Kumar R, Kumaraswamy M.R, Kathiravan T and Nadanasabapathi. 2013. Development and Evaluation of Shelf Stable Retort Pouch Processed Ready- to-Eat Tender Jackfruit (*Artocarpusheterophyllus*) Curry. *J. Food Process Technology*, 4:10

Lampi R.A. 1977. Flexible Packaging for Thermo processed Foods. *Adv. Food Res* 23: 305-428. 19.

Liesbeth, V., Iesel, V.P., Tara, G., Philippe, V., Ariette, M., Marc, H., and Ann, V.L. 2012. Thermal versus high pressure processing of carrots: A comparative pilot-scale study on equivalent basis. *Innovative Food Sci. Emerging Technol.* 15: 1–13.

Luh, B.S. and Woodroof, J.G. 1975. *Commercial Vegetable Processing.* The AVI Publishing Company, Westport, Connecticut, USA, pp.649- 650.

Mohammed Ali Shihab, C.P., Hafeeda, P., Kumar, R., Kathiravan, T. and Nadanasabapathi, S. 2013. Development and evaluation of shelf stable retort processed ready-to-drink (RTD) traditional ThariKanchipayasam in flexible retort pouches. *International Food Research Journal* 20(4): 1765-1770.

Naik, D.M., Mulekar, V.G., Chandel, G.C., and Kapse, B.M. 1993. Effect of pre-packaging on physico-chemical changes in tomato during storage. *J. Indian Fd Packer.* 42(2): 9-13.

Nair, B. and Elmore, A.R. 2003. Final report on safety assessment of sodium sulphite, potassium sulphite, ammonium bisulphate, sodiumMeta bisulphate and potassium Meta bisulphate. *Int. J. Toxicol.* 22(2): 63-88.

Narasimham, P. 1990. Breadfruit and jackfruit. In: Nagy, S., Shaw, P.E. and Wordowski, W.F. (Eds*.). Fruits of Tropical and Sub-tropical origin - Composition, Properties and Uses.* Florida Science Source Inc.: 193- 259.

Patricia, A.D., Patricia, A.K., Yohan, Yoon and John, N.S. 2007. Influence of modified blanching treatments on inactivation of Salmonella during drying and storage of carrot slices. *Fd Microbiological*. 24: 500-507.

Pedreshchi, F., Segini, S and Dejmek, P. 2004. Evaluation of texture of fried potato. *J. Texture Stud.* 35(3): 277-291.

Prakash, O., Kumar, R., Mishra, A and Gupta R. 2009. *Artocarpus heterophyllus (*jackfruit): an overview. *Pharmacognosy Review*; 3: 353-8. 2.

PremAnandh, C., Ramasamy1, D., Surendraraj, A and K.S. Gnanalakkshmi. 2014. Process Optimization and Shelf Life Study of Retort Processed Rose Flavoured MilkInternational*Journal of Food, Agriculture and Veterinary Sciences*. 4 (1): 2277

Pritty, S.B. 2013. Development and quality evaluation of thermally processed jackfruit (*Artocarpus heterophyllus L.*). Unpublished M.Tech thesis. Kerala Agricultural University, Thrissur, 165p.

Priya, S.D., Devisunetra, T., Mathala, J.G., Thangam, M., and Singh, P.N. 2014. *A guide on jackfruit cultivation and value addition.* Technical BulletinNo.41, ICAR (RC), Goa

Pua, C.K., Tan, C.P., Mirlosseini, H., Abdul, R.R., and Russel, G. 2008. Storage stability of jackfruit (*Artocarpus heterophyllus*) powder packaged in aluminium laminated polythene and metalized co extruded biaxially oriented polypropylene during storage. *J. FdEngg.* 89: 419-428.

Rahman, M A, Nahar, N., Misan, A J and Mossaahuzain, N. 1999. Variation of carbohydrate composition of two types of fruits from jackfruit tree, *J. Food Chem*. 65:91-99.

Rodriguiz, A.C. and Teixeira, A.A. 1988. Heat Transfer in Hollow Cylindrical Rods Used as Bio Indicator Units for Thermal Process Validation. *Trans. of ASAE*. 21(4): 1237-1237

S.A.Koli., T.T.Kolker., L. Kate and I.K.Chavan. 2004. Preparation of storage of sapota jam. *Beverage and Food world,* 31(2): 32.

Sabapathy, S.N and Bawa., AS. 2003. Retort processing of RTE foods. *Food Nutrition World* 1: 28-29.

Sabapathy, S.N., Ramakrishna, A and Srivastava. AN. 2000. Current Status and Potentials for Retort Processed Foods in India. *Indian Food Industry* 20: 78-79.

Seonggyun, S. and Santi, R.B. 1995. Thermal kinetics of colour changes in pea puree. *J. FdEngg.* 24(1): 77-86.

Siddharth. M., Divya, S and D. Ramasamy.2014. Retort Processing of Omega- 3 Enriched Kulfi Concentrates. *Trends in Biosciences.* 4 (1): 3617-3621

Singh, R., Joshi, M.C., Ram, H.B., and Bisht, N.S. 1984. Effect of wax coating and pre-packaging on the storage behaviour of vegetables. *J. Indian Fd Packer*. 10: 80-85

Taiwo, K.A., Akabi, C.T., and Ajibola, O.O. 1997. Production of cowpea in tomato sauce; Economic comparison of packaging in canning and retort pouch systems. *J. Food Process Eng.* 20(1): 337-348

Tatsioni, A., Gerasi, E., Charitidou, E., Simou, N and Mavreas V. 2003. Important drug safety information on the internet: assessing its accuracy and reliability. *Drug Safety*. 26: 519-527.

Varalakshmi K, Prince Devadason, Babji Y, Rajkumar. 2014. Retort Pouch Technology for Ready to Eat Products – An Economic Analysis of Retort Processing plant *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS).*7(1): 2319-2380.

Veronica, D., Xianzhon, W.U., Kafui, K.A., and Rui, H. 2002. Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. *J. Agric. Food Chem.* 50(1): 3010-3014.

Wei, B.L., Weng, J.R., Chiu, P.H., Hung, C.F., Wang, J.P., and Lin, C.N. 2005. Anti-inflammatory flavonoids from *Artocarpusheterophyllus* and *Artocarpuscommunis*. *J. Agric. Fd Chem.* 53: 3867-3871.

Yeshajahu, P. and Clifton, E.M. 1996. *Food Analysis Theory and Practice* (3rd Ed.). Chapman and Hall Inc. New York, 778p.

Yrjo H Roos and Stephan Drusch. 2015.*Phase Transitions in Foods*(2th Ed.).Elsevier Inc.,USA,228pp.

APPENDICES

APPENDIX A

A. Composition of Nutrient Agar Medium

Peptone	- 5 g
Yeast extract	- 2 g
Beef extract	- 1 g
Sodium chloride	- 5 g
Agar	- 15 g
pH	- 6.5 -7.5
Distilled water	- 1000 ml

APPENDIX B

B. Sensory Evaluation Chart

Treatment	Mean Scores			
	Colour	Texture	Taste	Overall Acceptance
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				

5 - Like very much 4- Like 3-Neither like nor dislike 2- Dislike
1 - Dislike very much

Name of examiner: Signature of the examiner:

Date-

B.1 Colour scores of the samples.

Treatment	Color
T1	4.5
T2	3.6
T3	4.16
T4	3.6
T5	2.5
T6	4.5
T7	3.6
T8	4.5
T9	3.16
T10	2.34

B.2 Texture scores of the samples.

Treatment	Texture
T1	4
T2	3.5
T3	3.8
T4	2.86
T5	2.6
Treatment	Texture
T6	4
T7	3
T8	4.25
T9	4
T10	3

B.3 Taste scores of the samples.

Treatment	Taste
T1	4
T2	3.25
T3	4
T4	3.25
T5	3.2
T6	4.66
T7	3.8
T8	4
T9	3.6
T10	3.5

B.4 Overall acceptance scores of the samples.

Treatment	Overall Acceptance
T1	4
T2	3
T3	4.25
T4	3.25
T5	2.8
T6	4.5
T7	3
T8	4
T9	3.5
T10	3

APPENDIX C

C.1 Effect of storage on TSS (^{0}Brix) of the retort processed jackfruit varatty.

Treatments	Month 0	Month 1	Month 2	Month 3
T1	71.8	71.8	72	72
T2	71.8	71.8	72	72
T3	71.8	71.8	72	72
T4	71.8	71.8	71.8	72
T5	71.8	71.8	72	72
T6	71.8	71.8	72	72
T7	71.8	71.8	72	72
T8	71.8	71.8	72	72
T9	71.8	71.8	72	72
T10	71.8	71.8	72	72

C.2 Effect of storage on colour of the retort processed jackfruit varatty.

C.2.2 Effect of L^* value during storage of thermally processed jackfruit varatty.

Treatments	Month 0	Month 1	Month 2	Month 3
T1	25.2	24.6	23	21
T2	23.05	22.7	21.6	20.5
T3	22.1	21.3	20.9	19.6
T4	19.2	18.6	17.9	17.01
T5	16	15.4	14.7	14
T6	25.2	24.92	24.66	23.34

T7	23.05	22.1	21.83	21.36
T8	22.1	21.9	21.4	20.9
T9	19.2	18.8	18.45	18
T10	16	15.5	15.26	14.8

C.2.2 Effect of a* value during storage of thermally processed jackfruit varatty

Treatments	Month 0	Month 1	Month 2	Month 3
T1	13	13.21	14.46	14.94
T2	9.8	10.42	11.57	11.98
T3	11.5	12.76	13.45	13.87
T4	13.6	14.33	15.25	16.12
T5	15.57	16.25	17.42	18.06
T6	13	13.4	13.9	14.34
T7	9.8	10.12	10.6	11.01
T8	11.5	12	12.34	13.04
T9	13.6	14	14.3	14.9
T10	15.57	16.04	16.76	17.3

C.2.3 Effect of b* value during storage of thermally processed jackfruit varatty.

Treatments	Month 0	Month 1	Month 2	Month 3
T1	17.2	16.7	17	17.89
T2	19	17.9	18.6	19.4
T3	20.9	19.9	20.76	24.5
T4	20.9	22	23.6	25.5
T5	21.7	25.8	23.9	26.7
T6	16	16.7	17	17.89
T7	17.2	17.9	18.6	19.4
T8	19	19.9	20.76	21.8
T9	20.9	21.7	22.6	23
T10	21.7	22.6	21.66	24.5

C.3 Effect of storage on texture.

C.3.1 Effect of storage on hardnessofjackfruitvaratty.

Treatments	Month 0	Month 1	Month 2	Month 3
T1	0.06	0.106	0.3768	0.501
T2	0.075	0.1201	0.361	0.497
T3	0.087	0.1452	0.463	0.571

T4	0.076	0.1328	0.401	0.498
T5	0.09	0.1874	0.464	0.653
T6	0.006	0.614	0.887	0.99
T7	0.075	0.487	0.687	0.958
T8	0.087	0.437	0.674	0.875
T9	0.076	0.571	0.6014	0.793
T10	0.09	0.482	0.635	0.953

C.3.2 Effect of storage on stickiness of jackfruit varatty.

Treatments	Month 0	Month 1	Month 2	Month 3
T1	0.106	0.0952	0.0562	0.023
T2	0.112	0.0782	0.0593	0.039
T3	0.123	0.0638	0.463	0.571
T4	0.135	0.132	0.093	0.028
T5	0.17	0.0632	0.0425	0.021
T6	0.106	0.0596	0.0469	0
T7	0.112	0.0438	0.0281	0.021
T8	0.123	0.0398	0.0264	0.006
T9	0.135	0.0505	0.0379	0.002
T10	0.17	0.0631	0.0539	0.018

C.4 Effect of storage on water activity of jackfruit varatty.

Treatments	Month 0	Month 1	Month 2	Month 3
T1	0.78	0.769	0.755	0.742
T2	0.77	0.75	0.746	0.732
T3	0.76	0.754	0.73	0.715
T4	0.756	0.743	0.723	0.71
T5	0.76	0.745	0.723	0.713
T6	0.78	0.755	0.743	0.739
T7	0.77	0.744	0.721	0.713
T8	0.76	0.734	0.719	0.704
T9	0.756	0.75	0.741	0.73
T10	0.76	0.745	0.712	0.689

C.5 Effect of storage on moisture content of jackfruit varatty. (d_b)

Treatments	Month 0	Month 1	Month 2	Month 3

T1	25	24.6	24.1	23.76
T2	24.1	23.76	22.7	22.34
T3	24.9	24.5	23.78	23.34
T4	23.9	23.45	22.45	21.67
T5	23.7	22.89	22.34	21.33
T6	25	24.5	24.2	24
T7	24.1	23.87	23.12	22.5
T8	24.9	24.3	23.3	23
T9	23.9	23.6	22.9	21.9
T10	23.7	23.4	22.8	21.8

C.8 ANOVA table for changes in TSS of thermal processed retort packed jackfruit varattykept in ambient condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	0.004953	0.001238	0.9036	0.488	NS
M	2	0.250327	0.125163	91.3284	0.000	**
TM	8	0.011107	0.001370	1.013	0.469	NS
Err	14	0.019187	0.001370	1.000		

T-Temperature M- No of Months

C.9 ANOVA table for changes in TSS of thermal processed retort packed jackfruit varatty kept in refrigerated condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	0.015953	0.003988	3.8279	0.026	*
M	2	0.233327	0.116663	111.9712	0.000	**
TM	8	0.062107	0.007763	7.4511	0.001	**
Err	14	0.014587	0.001042	1.0000		

T-Temperature M- No of Months

C.10 ANOVA table for changes in L* value of thermal processed retort packed jackfruitvaratty kept in ambient condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	285.956726	71.489181	65075.2417	0.000	**
M	2	13.107206	6.553603	5965.6202	0.000	**
TM	8	7.135536	0.891942	811.9178	0.000	**
Err	14	0.015380	0.001099	1.0000		

T-Temperature M- No of Months

C.11 ANOVA table for changes in L* value of thermal processed retort packed jackfruitvaratty kept in refrigerated condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	176.957353	44.239338	59060.7823	0.000	**
M	2	3.638180	1.819090	2428.5372	0.000	**
TM	8	0.706687	0.088336	117.9309	0.000	**
Err	14	0.010487	0.000749	1.0000		

T-Temperature M- No of Months

C.12 ANOVA table for changes in a* value of thermal processed retort packed jackfruit kept in ambient condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	112.237841	28.059460	96642.5022	0.000	**
M	2	11.777928	5.888964	20282.7932	0.000	**
TM	8	0.315506	0.039438	135.8335	0.000	**
Err	14	0.004065	0.000290	1.0000		

T-Temperature M- No of Months

C.13 ANOVA table for changes in a* value of thermal processed retort packed jackfruit kept in refrigerated condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	26.247713	6.561928	9935.1474	0.000	**

M	2	27.308607	13.654303	20673.4225	0.000	**
TM	8	9.997927	1.249741	1892.1815	0.000	**
Err	14	0.009247	0.000660	1.0000		

T-Temperature M- No of Months

C.14 ANOVA table for changes in b* value of thermal processed retort packed jackfruit kept in refrigerated condition.

Source	Df	SS	MS	F	PROB	Signi
T	4	26.247713	6.561928	9935.1474	0.000	**
M	2	27.308607	13.654303	20673.4225	0.000	**
TM	8	9.997927	1.249741	1892.1815	0.000	**
Err	14	0.009247	0.000660	1.0000		

T-Temperature M-No of Months

C.15 ANOVA table for changes in b* value of thermal processed retort packed jackfruit kept in ambient condition.

Source	df	SS	MS	F	PROB	Signi
T	4	825.536233	206.384058	20567.8874	0.000	**
M	2	134.443487	67.221743	6699.2056	0.000	**

TM	8	8.402147	1.050268	104.6680	0.000	**
Err	14	0.140480	0.010034	1.0000		

T-Temperature M-No of Months

C.16 ANOVA table for changes in water activity of thermal processed retort packed jackfruit kept in ambient condition.

Source	Df	SS	MS	F	PROB	Signi
T	5	0.013897	0.002779	182.4302	0.000	**
M	2	0.001776	0.000888	58.2875	0.000	**
TM	10	0.003293	0.000329	21.6161	0.000	**
Err	17	0.000259	0.000015	1.0000		

T-Temperature M-No of Months

C.17 ANOVA table for changes in water activity of thermal processed retort packed jackfruit kept in refrigerated condition.

Source	Df	SS	MS	F	PROB	Signi
T	5	0.010634	0.002127	679.3470	0.000	**
M	2	0.004995	0.002497	797.7223	0.000	**
TM	10	0.001091	0.000109	34.8624	0.000	**
Err	17	0.000053	0.000003	1.0000		

T-Temperature M- No of Months

C.18 ANOVA table for changes in moisture content of thermal processed retort packed jackfruit kept in ambient condition

Source	Df	SS	MS	F	PROB	Signi
T	5	478.579792	95.715958	7913.2950	0.000	**
M	2	4.01375	2.006875	165.9179	0.000	**
TM	10	223.977083	22.397708	1851.7254	0.000	**
Err	17	0.205625	0.012096	1.000		

T-Temperature M- No of Months

C.18 ANOVA table for changes in moisture content of thermal processed retort packed jackfruit kept in refrigerated condition

Source	df	SS	MS	F	PROB	Signi
T	5	141.053333	28.210667	28.210667	0.000	**
M	2	399.790467	199.859233	199.859233	0.000	**
TM	10	16.791000	1.679100	1.679100	0.000	**
Err	17	0.970800	0.057106	0.057106		

T-Temperature M- No of Month

C.19 ANOVA table for changes in microbial load of thermally processed jackfruit varatty under ambient condition

Source	df	SS	MS	F	PROB	Signi

T	4	4.133333	1.033333	31.0000	0.000	**
M	2	1.400000	0.700000	21.0000	0.000	**
TM	8	2.266667	0.283333	8.5000	0.000	**
Err	14	0.466667	0.033333	1.0000		

T-Temperature M- No of Months

C.19 ANOVA table for changes in microbial load of thermally processed jackfruit varatty under ambient condition

Source	df	SS	MS	F	PROB	Signi
T	4	4.133333	1.033333	31.0000	0.000	**
M	2	1.400000	0.700000	21.0000	0.000	**
TM	8	2.266667	0.283333	8.5000	0.000	**
Err	14	0.466667	0.033333	1.0000		

T-Temperature M- No of Months

APPENDIX D

1. Cost of operation of plant/hr Cost of machineries
2. i) Retorting autoclave and other accessories : Rs.9,00,000/- Initial cost (C) : Rs. 9,00,000/-

Assumptions

Useful life (L) : 15 years

Annual working hours, T : 1800 hours

Salvage value, S : 10% of initial cost

Interest on initial cost, r : 12% annually

Repairs and maintenance : 5% of initial cost

Insurance and taxes : 2% of initial cost Electricity charge : Rs. 5.2/unit

Labour wages (8 working hours/day) : Rs.300/day

Cost of a pouch : Rs.4/-

Fixed cost

Depreciation : C−S/ L

: Rs.54,000/year

Interest on average investment : Rs.59,400/year

Insurance and taxes : Rs.18,000/year

Total fixed cost : **Rs.1,31,400/year**

Variable Cost

Repair and maintenance : Rs 45000

Electricity cost Total Power consumption : 8HP=6KW

Cost of energy consumption/year :(Power x Duration xCost of one unit)/1000

: Rs 62400

Annual labour cost :Rs75000/year

Total Variable Cost :Rs 182400/year

Total Cost : Fixed cost+variable cost

:Rs 313800/year

Cost of operation of plant/hr (C_{oper}) : (Total Cost)/T

:Rs 174.5

Number of batches required for retorting 100 pouches (n) : 5

Time required for retorting under sterilization temperature (t_s) :30min

Total cost of packing operation (C_{pouch}) : (C_{oper} x n x t_s)/60

:Rs 436.5

Labour cost :Rs 420

Total expenditure for retorting

100 pouches of jackfruit varatty : $C_L + C_P + C_{JACKFRUIT\ VARATTY} + C_{POUCH}$

: 420+400+80+436.5

: 1336.5

Total expenditure for a retort pouched jackfruit varatty: Rs 14

ABSTRACT

ABSTRACT

Jackfruit (*Artocarpus heterophyllus*) belongs to family Moraceae, is one the most significant evergreen trees in tropical areas and widely grown in south east Asia especially India and Bangladesh. It isan important nutritious tropical fruit of India. Its availability is seasonal and could not be stored as such for longer periods under ambient or refrigerated conditions which results in its wastage. Preparation of value added products is one of the traditional methodsto extend its shelf life.Chakkavaratti is a prominent traditional jackfruit processed product of Kerala. It is consumed assuch or it is used as the raw material for several traditional dishes like chakkayada, chakkaprathaman, chakkayappam, chakkapayasam etc. But jackfruitvaratty stored at ambient condition was found to be less shelf life. Thermal processing of jackfruit varatty in retort pouch has proven to be highly successful in extending the shelf life in various products. Hence the present study on "Development of shelf stable jackfruit varatty by thermal processing in retort pouch" was undertaken with specific objectives – 1) Development of shelf stable jackfruit varatty by retort processing. 2) Optimization of process parameters for the production of thermally processed jackfruit varatty and 3) Shelf life studies and quality evaluation of retort pouch packed jackfruit varatty.

In the present study, two pasteurization temperatures (100°C and 110°C) and a sterilization temperature (121°C) were selected. Based on the Ball's formula and heat penetration curve, the thermal process time for pasteurization at 100°C to reach F value 1 and F value 2 were 39 min and 58 min, ,respectively. Similarly the thermal process time for pasteurization at 110°C to reach F1 and F2 were 25 min and 36 min, ,respectively. Also, the total process time required for sterilization at 121^{o}C for attaining F_O value was 22 min.Quality evaluation of the stored thermally processed jackfruit varatty were evaluated based on TSS, total sugars, water activity, moisture content, texture and colour. The experimentswere statistically analyzed using Agressoft ware.

Based on the physico-chemical analysis, the samples stored at refrigerated conditions was found to be better than the ambient storage products for all treatments. Apart from quality evaluation, microbiological load of the stored jackfruit varatty was examined at every 30 days interval for a period of 5 months. The number of colony forming units was found to be nil up to first 30 days of storage in all treatments except T1 under refrigerated condition. After 90 days of storage, the observed microbiological counts were within the permissible

limit. For control sample, the microbiological count was within the permissible limit for 30 days of storage. But,after 60 days of storage, the microbiological count was found to be exceed the permissible limit. The results revealed that the thermally processed samples under ambient and refrigerated storage were microbiologically safe.Sensory evaluation was done after 6 months. Various parameters such as colour, texture, taste and overall acceptance were evaluated by a 5 point hedonic scale. Based on sensory evaluation, the samples processed at 100^0C F_1 and stored at refrigerated condition was found to be the best among the treatments.

Microbiological analysis revealed that the thermally processed samples under ambient and refrigerated storage were microbiologically safe for 90 days. Hence, by considering the economy, it is concluded that thermally processed jackfruit at a pasteurization temperature of 100°C, F1 can be stored safe at ambient temperature for a period of 90 days.Cost economics of the thermally processed jackfruit varatty in retort pouch was calculated and the cost of retort pouch contains 100g varatty was found to be Rs.14.