VALUE ADDED PRODUCTS FROM JACKFRUIT RIND

By

THARANI.S

(2016-16-004)

THESIS

Submitted in partial fulfillment of the

Requirements for the degree of

MASTER OF SCIENCE IN COMMUNITY SCIENCE

(Food science and Nutrition)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF COMMUNITY SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2018

DECLARATION

I, hereby declare that this thesis entitled "VALUE ADDED PRODUCTS FROM JACKFRUIT RIND" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or society.

Vellayani

Date: 29.06.2018

Tharani. S

(2016-16-004)

CERTIFICATE

Certified that this thesis entitled **"VALUE ADDED PRODUCTS FROM JACKFRUIT RIND"** is a bonafide record of research work done by Ms. Tharani. S (2016-16-004) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to her.

Vellayani

Date:

Dr.Suma Divakar

Major Advisor, Professor

Department of Community Science

College of Agriculture, Vellayani,

Thiruvananthapuram- 695522

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Tharani. S (2016-16-004), a candidate for the degree of Master of Science in Community Science with major in Food Science and Nutrition, agree that this thesis entitled **"VALUE ADDED PRODUCTS FROM JACKFRUIT RIND"** may be submitted by Ms. Tharani. S, in partial fulfillment of the requirement for the degree.

Dr. Suma Divakar

(Chairman, advisory committee)
Professor
Department of Community Science
College of Agriculture, Vellayani,
Thiruvananthapuram- 695522

Smt. Brigit Joseph

(Member, advisory committee)
Associate Professor
Department of Agricultural Statistics
College of Agriculture, Vellayani,
Thiruvananthapuram- 695522

Dr.Rari John .K

(Member, advisory committee)
Professor and Head
Department of Community Science
College of Agriculture, Vellayani,
Thiruvananthapuram- 695522

Dr.Safia.N.E,

(Member, advisory committee)
Programme coordinator,
KVK Ambalavayal,
Wayanad.

EXTERNAL EXAMINER

Dr. Betty Rani Issac
Associate professor and Head
Department of Home Science
St: Theresas College, Ernakulam

ACKNOWLEDGEMENT

I therefore chose to place on record, my sincere gratitude to all the following individuals without whom this thesis wouldn't have materialized.

I feel immense pleasure and a deep sense of gratitude to ***Dr. Suma Divakar, Professor, Department of community Science and the chairperson of the advisory committee*** *for her guidance suggestions ever glowing smile with patience that gave me constant encouragement, and above all, the kind of understanding throughout the course of this research work and preparation of the thesis.*

I wish to express my sincere gratitude ***to Dr. C. Nirmala Associate Professor,*** *Department of community Science and advisory committee for the help rendered for the smooth conduct of research work, co-operation and critical evaluation of thesis.*

I am grateful to ***Dr. Rari John. K Professor and Head,*** *Department of community Science and advisory committee for her whole hearted co-operation and help during the course of study and period of investigation.*

I express my sincere thanks to ***Dr. Anitha Chandran. C, Dr. Beela. G. K****, teachers of the Department of community Science for their well wishes and support which had rendered heartedly throughout my course of study.*

My deep sense of gratitude to ***Smt. Brigit Joseph, Associate professor*** *of Agricultural Statistics in the statistical analysis of my research work.*

I am obliged to ***Dr. Sajeev Associate professor and Dr. Shanavaz, Assistant professor,*** *CTCRI, Sreekaariyam for rendering the facilities for the development of product.*

I extend my sincere gratitude to ***Dr. Meena Kumari, Professor, and Ms Bindhu*** *Teaching Assistant, Department of Agricultural Microbiology for their help rendered for the Microbial analysis.*

I wish to express my heartfelt thanks to ***Dr. Anil Kumar, Dean, College of Agriculture, Vellayani*** *for providing me all the necessary facilities from the university during the whole course of study.*

Words cannot express enough the gratitude I feel for my dear ***classmate Subha. S. Nair and my roommate Pooja. A.P*** *for being with me from beginning to end lending me a helping hand whenever needed the most. I also most thankful to my friends Abhinav. M.C, Akhil Ajith, Priyanga and many other friends who were supportive to me during my difficult times.*

My loving and whole hearted thanks to ***Shaeba Chechi****, Lab Assistant without whom this research will not be completed.*

I am thankful to ***Mr. Rafeeq*** *for his timely supply of Jackfruit whenever needed. I am thankful to non-teaching staff of department of Community Science especially,* ***Manju Chechi, Binu Chettan*** *for their support during the course of study.*

I am most indebted to my sister ***Barani Subramanian*** *and my parents for their affection, moral support and blessings that have enabled me to finish this work.*

Tharani. S

Dedicated to my Sister Barani

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS USED

JR	Jackfruit rind
JRF	Jackfruit rind flour
VJRF	*Varikka* jackfruit rind flour
KJRF	*Koozha* jackfruit rind flour
BGF	Black gram flour
RF	Rice flour
PPO	Polyphenol Oxidase
$NaHCO_3$	Sodium bicarbonate
$NaHSO_3$	Sodium Bisulfite
PP	Polypropyelene
Viz.,	Namely
et al.	And co-workers
TCP	Total cost of production
TSS	Total soluble solids
HTST	High temperature short time
NS	Not significant
CD	Critical difference
ND	Not detected
WAI	Water absorption Index

OAI	Oil absorption index
FC	Foaming Capacity
SP	Swelling power
Cfu/ml	Colony forming unit per milliliter
Fig	Figure
et al.	And co-workers
Min	Minutes
Hrs	Hours
° C	Degree Celcius
%	Percentage
g	Gram
µg	Microgram
µm	Micrometre
mEq/ Kg	Milli Equalents/ kilogram
N	Newton
Nmm	Neuton millimetre

Introduction

1. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the family Moraceae. The place of origin of jackfruit is believed to be indigenous to the rainforests of the Western Ghats. They grow profusely in Bangladesh, India and in many parts of Southeast Asia. Jackfruit is an awesome example of a food treasure in some areas of the world and let to go waste in others. It is cultivated at low acme throughout India, Ceylon, Burma, southern China, Malaysia and the East Indies. It is usual in the Philippines, both in cultivated and naturalized vegetation.

In South India, jackfruit is a favourite food ranking next to mango and banana in total annual output. The total area planted with jackfruit at all India level was 97,000 ha and it is seen largely grown in the southern states viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh (DAC, 2014). Government horticulturists raise the planting of jackfruit seedlings along highways, watercourse and rail track line to add to the country's food supply chain.

In South India, jackfruits are categorized into two broad types: *Koozha chakka*, the fruits which have little, stringy, cushiony, mushy, but very sweet carpels and the commercially, most valuable cultivar, with distinct carpels of high quality known as *Varikka*. The season of availability of ripe jackfruit in Kerala is from March to May. Post-harvest losses and market gluts are the usual problems encountered during the season.

Jackfruit *(Artocarpus heterophyllus* Lam.*)* is a good source of vitamins, fiber and minerals. It can be unified into food products to increase nutritional value. It possesses a wide variety of nutritional elements such as carotene, Vitamin- B_1, Vitamin B_2 and potassium. Glucose, fructose and sucrose constitute the major sugars, they contain Capric acid, myristic acid, lauric acid, palmitic acid, oleic acid, stearic and linoleic acid are found to be the major fatty acids found in them, with varying ratio in different parts of jackfruit.

Rind of jackfruit is generated as waste of many processing operations. Though value addition of the edible portion of the fruit is well known and is being popularized by technologies across the state, giving best value to the fruit, it is felt that, there is also immense scope through scientific interventions for finding alternate uses for the unutilized rind.

Jackfruit rind is abundant in dietary fiber, which makes it a good bulk evacuant. Fibre content helps to prevent the colon mucous membrane by depreciating exposure time of chyme and also by binding to cancer-causing compounds in the colon.

In India, *Papad* has a vital place in every meal. Manufacturing of *Papad* is one of the traditional activities in the rural areas of the country. It is served as a snack or chaat with main course recipes. *Papad* is an example of the mastermind of Indian cuisine. The basic composition of *papads* varies with ingredients like cereal flours, pulse flours, soya flour, spices and different vegetable juices that improves both the sensory and nutritional quality. *Papad* or *appalam* may not have a privileged position in shop racks, but an Indian meal is incomplete without crushing this thin, crispy disc-shaped item with rice. Among many small-scale industries thriving in India, *papad*-making is significant as it employs more people, who are mostly women.

Similarly Crispies are thin, dry and brittle having a agreeably crisp outer layer, are extruded products of cereal flour which is gaining the attention of modern consumers.

Realizing the importance of the underutilized jackfruit, this study has attempted to standardize these two popular adjuncts of Indian cuisine, namely *papad* and *crispies* based on this fruit.

1.1 SCOPE AND IMPORTANCE

The outcome of the work would benefit small scale processing units and also farm women by bringing about value addition of this under exploited fruit, growing in abundance in the state, enhancing their income and employment.

Jackfruit is perishable and cannot be stored for a long time because of its inherent compositional and textural characteristics. Every year, a considerable amount of jackfruit, specially obtained in glut season (June-July), goes waste due to lack of proper postharvest knowledge, which is needed during the stages of harvesting, improper transporting and storing, that ultimately affects both the quality and quantity of these fruits.

Now a days, consumers are also increasingly conscious about their health, they demand nutritional qualities along with taste and variety. There is an increasing realization that crunchy food items are made of synthetic raw materials and can deteriorate consumer's health. Since, fiber in the diet is gaining importance due to increasing metabolic disorders, jackfruit rind which is a good source of dietary fiber can be used in the development of food products of demand.

There have been innumerable efforts to bring about value addition to raw and ripened jackfruit, but the by-products like rind remains unutilized and are dumped to the environment. Utilization of jackfruit rind for the development of food products would be a green technology, since it could figure out the waste disposal problem of residues along with providing important nutrients for health. If they can be commercially processed, it would diversify daily meals by adding attractive food items. Thus, use of jackfruit rind as a functional food instead of being a mere animal feed, seems to be an engrossing advantageous research, that virtue the study.

1.2 OBJECTIVES

Keeping in view the above facts and also the market prospects of jackfruit based food products, the objective framed for this study is, to develop value added Ready-to- Cook dehydrated products from Jack fruit rind and to assess their qualities.

1.3 LIMITATIONS

The study is conducted with locally available raw materials at retail prices. There are no additives added to the products so as to develop an 'organic' and 'healthy' products. Hence the commercial viability will be less compared to market brands. Moreover separation of rind from the bulb was realized as a laborious process as there is no technology to separate the rind.

1.4 ORGANISATION OF THESIS

The thesis is organized in six chapters. The first chapter is the Introduction, which includes the scope and importance of the study, objectives and limitations. Third chapter on Materials and methods comprises of selection of raw material, identifying variables, measurement of variables and statistical analysis, which is preceded by the chapter on review of related literature. Fourth chapter comprises of results of the study which deals with specific findings of the study. The discussion chapter follows which justifies the findings of the study with related literature. The sixth chapter on Summary portrays the salient findings of the study with future line of work.

Review of Literature

2. REVIEW OF LITERATURE

The literature reviewed which is pertinent to the study entitled "Value added products from jackfruit rind" is presented under the following subheads:

2.1 Importance of value addition of fruits

2.2 Scope of value addition of fruit residues in industries

2.3 Nutritional importance of jackfruit rind

2.4 Health benefits of jackfruit rind

2.5 Scope of utilizing jackfruit rind

2.6 Dehydrated food products from jackfruit

2.7 Extruded food products from jackfruit

2.1 IMPORTANCE OF VALUE ADDITION OF FRUITS

Value addition is the process of altering or transforming a raw material from its primary state to a more worthy state (Sharma *et al.*, 2013).

India relish a salient place on the pomological map of the world. The changing weather conditions of the country render desirable environment for growing different types of fruits. Post-harvest losses of fruits are more severe in developing countries than those in well developed countries. The overall losses from reap to the consumer point are as high as 30-40 per cent, which costs thousands of crores of rupees. Tropical fruits, which are now underexploited, have an most valuable role to play in fulfilling the demand for nutritious, exquisitely flavoured and pleasing natural foods of high therapeutic value (Ravani *et al.*, 2014).

24

Fruit production is progressing dramatically worldwide. According to the FAO (2010), the total fruit production in 2008 was 572.4 million tons globally, which was upgraded to 609.2 million tons in 2010.

Fruits and vegetables play an important part in a healthy diet. In addition to their delicious taste and flavour, they help to reduce the chance of several chronic diseases. They comprise certain quantity of phyto constituents which are proven to be negatively related with morbidity and mortality, especially from cerebrovascular, cardiovascular and different types of cancers (Alesiani *et al.*, 2010).

In this context, it is disheartening to know that, around one- third of the fruits grown in the world are lost or wasted. It is difficult to give exact information on the amount of fruit losses bought forth globally, since fruit losses differs among varieties, places and climatic regions and there is no ubiquitously used method for measuring losses. As a result, the food loss data during post-harvest phase are generally only calculated and the fluctuations are reported as 10 per cent to 40 per cent (Prusky, 2011).

The fruit processing industry is one of the leading industrial enterprise worldwide. While standard principles of fruit processing have witnessed less alteration in the last few years, better improvements are endlessly occurring lately and more effective types of equipment have been developed, that are able to convert vast amount of fruits into pulp, juice, refrigerated products, dehydrated and frozen forms etc., making viable by the preservation of products for year-round consumption. Fruit processing and preservation, even under the mild conditions, involves physical and chemical changes that negatively alter the quality. These unfavourable or destructive changes include, enzymatic and non-enzymatic browning, development of off-flavours, discolouration, shrivelling, case hardening, thermo-physical and rheological changes, that alter the nutrient content and primary taste, colour and visual aspect of fruits. Therefore the ability of the industry to supply a nutritious and healthy fruit product to the consumer is extremely dependent on the cognition of the quality alterations that occur during the processing (El-Ramady *et al.*, 2015).

Jackfruit is one of the most lucrative and essential underexploited native fruits of India. The compound fruit of jackfruit is made of three parts viz., bulb (30-32%), seeds (18%) and the rind (5-55%). The total jackfruit production in India has been recorded to be around 2.04 million tons (NHB, 2015). Out of this a significant part goes waste because of its highly perishable nature and seasonal glut.

Madhavan (1994) was of the opinion that, even though there was a huge production of jack fruit, its processing has not gained much attention when compared to other fruits. According to Nunjundaswamy and Mahadeviah (1993), the difficulty in the gathering of fruit, detachment of bulb from the rind, uncertainty and variability in the characteristics, such as yield and quality, are the major difficulties involved in the utilization of jack fruit.

Shruthy (2005) observed that the processing qualities of jack fruit was excellent with good sensory appeal and hence it is highly suitable for value addition and processing.

Rural small scale enterprises exists for a wide variety of products developing added value and small scale employment and income opportunities for rural populations. Recent work in this area show that product diversification of rural agro-enterprises upgraded incomes by 58 per cent while value addition accounted for a 350 per cent raise in farmer income (Ramirez, 2001).

By doing value addition to the farm products, the food processing economy plays a major part in rural growth, by enhancing farm income and also rendering rural employment. Value addition of farm products is successful in generating employment in the processing industry (Barkama *et al.*, 2001). Hence, efforts to utilize the edible under exploited components has gained focus lately.

2.2 SCOPE OF VALUE ADDITION OF FRUIT RESIDUES IN INDUSTRIES

The word agricultural waste means residues resulted from agriculture produce. They comprise of unutilized wastes or residues from processing of raw agricultural produce such as jackfruit, cocoa, banana, plantain, palm bunches, etc. The residues are those end-products of processing and consumption which have not been utilized or salvaged (Taiwo *et al.*, 2001).

Now-a-days, there is a growing interest in finding phytochemicals as a choice to the synthetic substances, which are generally used in the food, pharmaceutical and cosmetic industry. Several studies have reported that the content of phytochemical components is found higher in peel and seeds with respect to the edible tissue. It is resulted that the total phenolic compounds in the peels of lemons, oranges and grapefruits were 15 per cent higher than that of the pulp of these fruits. Peels from fruits such as apples, peaches and pears were found to contain twice the amount of total phenolic compounds as that contained in fruit pulp. Apple peels were found to contain up to 3300mg/100gm of phenolic compounds (dry weight).

Considerable portion of agricultural residue in the form of skin waste and seeds are produced by the fruit processing industries and these residue if not disposed properly are about to cause serious environmental problems such as water pollution, off-flavour, explosions and combustion, asphyxiation and greenhouse gas emissions. There are several studies highlighting the integral use of bioactive components from these residue and their potential applications as antioxidants, antimicrobials and as flavouring, colourant and texturizing agents (Kumar *et al.*, 2011).

Solid wastes, especially from processing such as peels and cores, generally have high nutritional value and are used as animal feeds. Value addition of products from fruit wastes adds income to the fruit processing units (Vikashkandari *et al.*, 2012).

Ushimaru *et al.* (2007) have suggested that different fruits and vegetable peels have antimicrobial, antioxidant, anti-proliferative and anti-inflammatory activities.

Lemon is a significant medicinal plant of *Rutaceae* family. It is cultivated for its alkaloids that have anticancer activities. The citrus peel oils showed intense antimicrobial activity against the microorganisms like *Pseudomonas aeruginosa* (Dhanavade *et al.*, 2011).

Tsay and Lin (2004) observed that the citrus peel powder extract increased the growth of plants and their yield. In addition, citrus peel powder could be used for the preparation of tissue culture media and they concluded that chemical fertilizers could be replaced by the citrus peel powder and its extracts, to protect the soil from the infertility.

Galbe and Zacchi (2007) conducted a study on bioconversion of vegetable and fruits waste peels into economically viable produce. Four substrates were taken for this *viz.*, turnip, apple, papaya and banana. These peel extracts were prepared and utilized for ethanol and biomass production. Various analytical tests were carried out to estimate total sugar, fermentable sugar, residual sugars, protein, fat, ash, moisture and nucleic acid content before and after fermentation. The kinetics of biomass production on different peel extracts were studied. The effect of time on alcohol production and biomass production were also studied. It was concluded that, papaya contained maximum fermentable sugars and produced maximum amount of alcohol after 48 hours of incubation. The biomass was also maximum in papaya.

Jackfruit (*Artocarpus heterophyllus* Lam.*)*, produces large amount of residue, as its seeds and rinds (Krishna *et al.*, 2006). The post-harvest losses in jackfruit is around 30-35 % during the glut season (Lakshminarayan, 2017).

Jackfruit rinds are usually thrown as residue by food processing industries and vendors. Based on report from the Ministry of Agricultural and Agro-Based Industry (Malaysia), production of 56,631 million tons of jackfruit in the year 2011 had increased production to 33,979 million tons of jackfruit rinds as end-products (Foo and Hameed, 2012).

The removal of jackfruit rinds might cause environment pollution. In spite, efficient utilization of jackfruit rinds can upgrade economic value of the jackfruit rinds and reduce the expenditure of waste disposal. In order to reduce the wastage and negative effect to the environment, beneficial components such as pectin of jackfruit rinds, can be extracted (Koh *et al.*, 2014).

The skin waste of jackfruit has been suggested for anaerobic bio hydrogen production (Krishna *et al.*, 2006).

Food waste are thrown into the environment as agro waste, if used as a source of antimicrobial activity would be more economically feasible, environment- friendly and will cut down pollution to a great extent (Ushimaru *et al.*, 2007).

2.2.1 Pectin from solid waste:

Pedroza *et al.* (1994) had reported the best extraction method for the extraction of pectin from mango solid waste, more pectin yield was obtained at pH-3 by bleaching with alcohol within extraction period of 60 mins.

Peels are seen to be a rich sources of phyto-chemicals like polyphenols, carotenoids, dietary fiber, vitamin E and C and it has also exhibited better antioxidant properties (Ajila *et al.*, 2007).

2.2.2 Production of vinegar from mango waste:

The scope of utilizing mango (*var.* Totapuri) skin waste and stones for the extraction of vinegar has been studied (Ethiraj and Suresh, 1992). Alcoholic fermentation of fruit residue which was done by two methods. Skin waste or stones were treated with cold or hot water (50%w/w) and saccharin. The extracts of rind or stones were soaked in 50 ppm SO_2, inoculated with *Saccharomyces cerevisiae var. ellipsoideus* and fermented (24+4 °C, 72 hrs). The base wine from rind and stone washings contained 2.5 and 3 per cent alcohol, respectively (Ravani and Joshi, 2013).

2.2.3 Jackfruit rind jelly

Jackfruit rind which is a rich source of pectin was used to prepare jelly with different concentrations of pectin and total soluble solids as 65° Brix and filled in clean sterilized and dried glass bottles (Mondal *et al.*, 2013).

2.2.4 Jackfruit rind bread

Fiber rich bread was processed by using jackfruit rind powder in various formulations like 5 per cent, 10 per cent and 15 per cent and its physical properties were ascertained. The incorporation of jackfruit rind flour caused remarkable changes on bread volume and texture attributes (Feili *et al.*, 2013).

2.2.5 Pectin from Jackfruit rind

Pectin can be obtained from different sources using MAE (Microwave-assisted extraction) technique had been analysed for the purpose of bringing down the extraction time and power (Fishman *et al.*, 2006; Kratchanova *et al.*, 2004). Microwave-assisted extraction was found to be more efficient than conventional extraction method in extracting pectin from jackfruit rinds. MAE needed shorter time than conventional extraction in extracting comparable amount and quality of pectin from jackfruit rinds. Increase in microwave power level for MAE did not significantly affect yield and quality of pectin extracted from jackfruit rinds. Economically, MAE at 450 W was the most effective extraction condition among the different power levels for extracting pectin from jackfruit rinds due to its efficiency to extract pectin with similar yield and quality relative to a conventional extraction (Koh *et al.*, 2014).

2.2.6 Jackfruit rind Spread

Spread was prepared using tender coconut pulp as the raw material and also blended with fruit extracts in three proportions viz. Tender coconut pulp (TCP): Jackfruit rind extracts in the ratio of 75:25, 50:50 and 25:75. The mixture of tender coconut pulp and fruit extracts were taken in the required ratio in an open pan and heated continuously with the above ingredients. Heating was stopped when the TSS reached 68-69^0 Brix, and filled in the clean sterilized and dried glass bottles and sealed air tight and stored. (Shahanas *et al.*, 2015).

2.3 NUTRITIONAL IMPORTANCE OF JACKFRUIT RIND

Jackfruit rind is composed of hexagonal, conical carpal apices. It consists of essential nutrients such as carbohydrate, proteins, fiber, fat, vitamins and minerals (Elevitch and Manner, 2006). Fresh fruits contain nutritional and health promoting components, including minerals, antioxidant components, vitamins such as C, E and A, phytochemicals such as folates, glucosinolates, carotenoids, flavonoids and phenolic acids, lycopene, selenium and dietary fibers which are relatively low in calories (Murcia, 2009).

Jackfruit is rich in dietary fiber, which makes it a good bulk laxative. The fiber content helps to protect the mucous membrane of colon by decreasing exposure time and binding with the cancer-causing chemicals in the colon (Mondal *et al.*, 2013). The presence of high fiber content (3.6g/100g) in the jackfruit prevents constipation and produces smooth bowel movements. It also protects mucous membrane of colon by removing carcinogenic chemicals from the large intestine. Rahman *et al.* (1995) stated that jackfruit acts as a laxative and relieves constipation due to high fiber content. It also cleans up the colon thus preventing from colon cancer.

High-Fiber Jackfruit rind powder can be used as food supplement/additive in foods to help preventing constipation. (Feili, 2013).

The proximate composition of raw jackfruit rinds revealed low ash (0.99 %), crude lipid (1.71 %) and crude protein (1.54 %). The crude lipid content of jackfruit rinds was lower than 3 per cent .Ash and crude protein content of jackfruit rinds were low. The crude fiber level was 13.51 per cent and carbohydrate content was only 5.92 per cent (Koh *et al.*, 2014).

Rinds along with other waste parts of the fruits are utilized as a nourishing feed for livestock. To optimize the digestibility, supplemental nitrogen has to be provided. Thus, molasses-urea cake is fed along with the jackfruit waste for cattle for a better digestibility (Haq, 2006).

According to Yapo (2009), good gelling properties of pectin can be obtained when it has low ash and protein content. Therefore, jackfruit rinds are potential source of pectin with good gelling properties. The proximate composition of raw jackfruit rind is given in the table: 1

Table No: 1. Proximate composition of raw jackfruit rind

Sl. No.	Composition	%w/w
1.	Moisture	76.33 ±0.28 [b]
2.	Ash	0.99 ±0.11 [a]
3.	Crude lipid	1.71 ±0.23 [a]
4.	Crude protein	1.54 ±0.15 [a]
5.	Crude fiber	13.51 ±0.24 [a]
6.	Carbohydrate	5.93 [b]

(a- Dry weight basis, b- wet basis) (Koh *et al.*, 2014).

The composition of jackfruit rind flour as assessed by Feili (2014). It is depicted in the table: 2

Table No: 2. Proximate composition of raw jackfruit rind flour

SI. No.	Composition	g/100 g of dry matter
1.	Moisture	9.43±0.13[b]
2.	Ash	0.82±0.04[a]
3.	Crude fat	4.52±0.04[b]
4	Crude protein	5.91±0.22[a]
5.	Crude fiber	11.32±2.14[a]
6.	Carbohydrate	79.32±2.01[b]
7.	Calorie (Kcal/100g of dry matter)	342.74±0.93[a]

(Feili, 2013).

a Proximate composition is given in percentage of wet basis.

b Proximate composition is given in percentage of dry basis.

Very good antimicrobial activity against all tested pathogenic bacteria was shown by the acetone extract of jackfruit peels. Highest antimicrobial activity was observed by the acetone extract of jackfruit peels and the zones of inhibition ranged between 20-30 mm, with largest inhibition diameters was seen against *Klebsiella* *pneumoniae* (30 mm) and *Enterococcus faecalis* (30 mm). The chemical composition of the major retention peaks obtained in GC-MS analysis of acetone extracts of the jackfruit peel depicted furanone (an aroma compound), furfural (heterocyclic aldehyde) and phenolic compounds (mainly benezenetriol) as the prominent retention peaks. It was reported that the furanone peak retention area in jackfruit peel was 59.47 per cent (Roy *et al.*, 2014). Hence jackfruit rinds can certainly be utilized for its health benefits.

2.4 HEALTH BENEFITS OF JACKFRUIT RIND

Epidemiological studies have shown that the risk of several chronic diseases such as Cancer, Cardiovascular diseases, Cataract and macular degeneration can be protected effectively by regular consumption of vegetables (Turkmen *et al., 2005*).

The phytochemical analysis confirmed the presence of alkaloids, flavonoids, carbohydrates, proteins and triterpenoids. Major minerals like calcium, potassium and other minor minerals of peel was identified using Atomic Absorption Spectroscopy. It revealed the availability of various active and phytochemical compounds and also some minerals in the peel. It could be used as a possible source for the development of functional foods (Sundarraj and Ranganathan, 2017).

The phytochemical fabrication and characterization of silver oxide nanoparticles was reported using Jackfruit (*Artocarpus heterophyllus)* rind extract. The UV-vis absorption spectrum of the phytochemical-mediated reduced reaction mixture showed a surface plasmon peak at 428 nm, which confirmed the presence of silver nanoparticles. The silver nanoparticle production was ideal at pH 9 with 2.0 mL jackfruit rind extract, Ag^+ 1.0 mM and 180 min of reaction time. Infrared spectroscopy analysis indicated the presence of acids, esters, alcohols, pyrazine, etc. that acted as capping agents around the nanoparticles (Manikandan *et al.*, 2017).

In the production and processing of jackfruit (*Artocarpus heterophyllus* Lam.) peel is an underutilized by-product. The jackfruit peel and jackfruit pulp was compared for their antioxidant and hypoglycemic potential of, flake and seed. The phytochemical profile like total phenolic and total flavonoid content of peel extract was carried out with HPLC-QTOF-MS/MS. Results revealed that peel extract exhibited the highest, and the level of phenolics were 4.65, 4.12 and 4.95 times higher than that of pulp, flake and seed extract, respectively. The strongest DPPH, $ABTS^+$ scavenging ability and α-glucosidase inhibition were also found in the peel extract, and the α-glucosidase inhibition was about 11.8-fold of that of acarbose. Jackfruit peel is a novel source of natural antioxidants and hypoglycemic constituents (Zhang *et al.*, 2017).

2.5 SCOPE OF UTILIZING JACKFRUIT RIND

Shortage and sharp rise in the prices of conventional food stuffs are forcing nutritionists to explore alternate sources. By products of food processing represents one such class of alternatives. Moreover, these by products are considered as promising sources of functional compounds and bio active constituents. Consumers, the world over, are also increasingly becoming aware of diet related health problems. They are demanding natural ingredients which are safe and health promoting (Schieber *et al.*, 2001).

Wastage and spoilage of food is gaining focus in the recent years since it is creating a huge environmental problem. This has led mainly to three major problems. Foremost is the food insecurity i.e., a number of living population is starving in the developing world which could be due to throwing away food. (Nellemann *et al.*, 2009). Secondly, decreasing availability of fertile land to produce fresh produce and issue of scarcity of natural resources is more (Ridoutt *et al.*, 2010). Lastly, low economic value and unemployment have impact on the food sector and if food goes as waste, instead of utilizing for its desirable purpose, this can lead to instability of this sector (Ventour, 2008; Lee and Willis, 2010; Buzby *et al.*, 2011). Even though reducing food waste alone would not solve the problem, it is estimated that 1.3 billion tons of foods are wasted annually (Gustavsson *et al.*, 2011).

Different food products from jackfruit are developed with the aim of utilizing local resources. The bulbs were extensively used till recent years. Jackfruit rind powder was prepared from jackfruit waste, which is a by-product of the jackfruit processing industry (Asquiri *et al.,* 2008).

The disposal of jackfruit rinds may lead to many environment pollution. However, effective use of jackfruit rinds can decrease the environmental problem, cost of waste disposal and also upgrade the economic value of the jackfruit rinds. In order to reduce the wastage and negative effect to the environment, beneficial compounds such as pectin in jackfruit rinds can be extracted (Foo and Hameed, 2012).

Polygalacturonase enzyme is generally used for extraction and clarification of fruit juices. Solid state fermentation is used to produce polygalacturonase (PGU) by Aspergillus awamori (MTCC 9166) using different pectin-rich fruit wastes like apple peel, banana peel, citrus (orange) peel, jackfruit rind, mango peel, and pine apple peel. These studies revealed that PGU was extracted in better quality from jack fruit rind and mango. Use of such waste raw material is not only cost effective but also catered to the cause of disposing of waste at no cost, which is important for developing Indian economy (Padma *et al.,* 2012).

The production of bio-fuels from wastes have become a solution for the waste management and also energy generation. The powdered rinds of pineapple, jackfruit, watermelon and muskmelon were subjected to saccharification by *Trichoderma viride* followed by fermentation with *Saccharomyces cerevisiae*. Certain amounts of reducing sugars were obtained at the end of the saccharification process, with jackfruit and pineapple rinds being the most effective at 10.28 mg.ml-1 and 10.18 mg.ml-1 respectively (Bhandari *et al.,* 2013).

Feili (2014) reported that in Malaysia, an enormous amount of jackfruit residue is dumped annually into the environment, utilization of this waste product in the production of value-added products would benefit the country economically. Effective use of jackfruit rind as functional food rather than animal feed seems to be an interesting beneficial research.

2.6 DEHYDRATED FOOD PRODUCTS FROM JACKFRUIT

Fruits are undoubtedly very important for nutritional security with a high scope of value addition and commercial value. Fruits are now considered as an essential commodity of exchange as they have gained more potential in the market. India accounts for 12.5 per cent of the total world population of fruit crops and ranks second with the production of 75 million tons in 2013 (FAO, 2014).

Now-a-days, consumers are becoming highly conscious about the health and nutritional aspects of their food basket. The tendency develops to provide nutrition through natural resources rather than from chemicals and synthetic foods. The underutilized fruits are the important sources for poor in order to overcome the problem of malnutrition. They are generally found to be rich in vitamins, minerals and dietary fiber (Gajanana *et al.*, 2010).

Heated air drying which is hygienic and economically suitable newer techniques of drying have been developed. This method has been referred to as dehydration (Das *et al.*, 2004; Motevali *et al.*, 2010).

Removal of water from foods is essential to extend the shelf life of fruits and vegetables. Dehydration is one of the method which combines heat and mass transfer is used to preserve agricultural produce and food products. This is achieved by the principle of reducing the availability of water in food to such an extent, that it is unfavorable for microbial growth and favorable for minimizing rates of chemical reactions. Dehydration is an important method in food processing (Lima *et al.*, 2002). Dehydration helps in reducing the bulk of fresh foods thereby promoting easy transport and also increases the availability of food throughout the year.

Dehydration is an important method adopted in food processing industries. Drying aims at removing the water in the food up to a level where microbial spoilage and deterioration reactions are greatly minimized. There is a wide variety of dehydrated foods available nowadays to the consumer in the form of snacks, soups or dried fruits, dry pickles etc. The shelf life and energy saved compared to other materials makes it inevitable in the food industry (Krokida *et al.*, 2003).

Dehydration of food material has advantages like better control of product quality, achievement of hygienic conditions and reduction of product loss (Corzo *et al.*, 2008). Dried foods could be consumed directly or treated as secondary raw material (Menges and Ertekin, 2006). Food scientists have found that bacteria, yeast, mold and enzymes can be prevented from spoiling the food by decreasing the moisture content of food to between 10 and 20 per cent. Flavour compounds and most of the essential nutrients are preserved and concentrated through dehydration (Dennis, 1999).

Dried foods are great sources of energy, vitamin K and B, minerals, i.e magnesium and phosphorous, fibre and anti-oxidants. This is achieved due to the concentration of nutrients during processing, thereby providing necessary energy to the body (Konopacka *et al.*, 2010).

Pardeshi *et al.* (2009) have reported that the drying methods and conditions like temperature, relative humidity, air velocity and initial physico- chemical characteristics ply an important role in determining the structure of dried foods. It also influences the quality of end product in terms of sensory and other physico- chemical factors (Simal *et al.*, 2005).

The various jackfruit based dehydrated products are discussed herewith

2.6.1 Dehydrated Ripe Jackfruit

Bhatia *et al.* (1956) recommended soaking of ripe jackfruit bulbs for 30 minutes in 0.1 per cent KMS solution helps to increase the quality of the dehydrated products. Good quality dehydrated products were obtained (drying ratio 3: 1), when sulphured at the ratio of 16 lbs sulphur /ton/fruit/1000 cfl space (Shanmugam *et al.*, 1992).

Dehydrated jackfruit developed from jackfruit pulp which is golden – yellow to orange and has a soft texture with a sweet and sour taste is a nutritious snack. It is unique from other dehydrated products, which is free from sulfite preservatives, thus it will not trigger allergic reactions among sensitive consumers (Diamante, 2009).

Microwave vacuum and hot air dehydrated jackfruits were developed by Talib *et al.* (2013). Results revealed that jackfruit bulbs dehydrated by microwave and vacuum obtained higher rehydration ability and scored higher in the sensory evaluation, in terms of colour, appearance and aroma attributes.

Zuniga *et al.* (2004) developed osmotically dehydrated jackfruit slices using sucrose solutions at 30°C, 40° Brix, 50° Brix and 60° Brix, for three hours. Kinetics of drying was conducted using a convective tray drier at 50°C, 60°C and 70°C.

2.6.2. Dehydrated raw Jackfruit Flakes

KAU (1999) have standardized the dehydrated raw jackfruit flakes with a shelf life of one year. The flour prepared from dehydrated jackfruit flakes was found to be suitable for preparing chapathis, *pazhampori* and *baji* by substituting rice flour, maida or Bengal gram flour respectively with jackfruit flours.

2.6.3 Jackfruit Powder

Pua *et al.* (2007) developed drum dried jackfruit powder with different concentrations of soy lecithin and gum arabic. The study revealed that jackfruit puree with incorporations of 2.65 per cent soy lecithin and 10.28 per cent gum arabic were suitable for the production of good quality jackfruit flour.

2.6.4 Jackfruit *Papad*

Jackfruit *papads* could be prepared by using jackfruit bulbs which are either fully matured or completely raw (Bhatia *et al.*, 1956). It was found that jackfruit *papads* that are wrapped in paper had a shelf life of 4-6 months at room temperature (24-30°C).

Ukkuru and Pandey (2005) standardized a very crispy and tasty fried jackfruit *papads* of different taste and flavour from raw jackfruit.

2.6.5 Jackfruit Seed Flour

Jackfruit seed was converted into flour by blanching and drying while the former inactivates the anti-nutritional factors present in it. The flour prepared from jackfruit seeds could be used for making chappathis by mixing with riceflour (25:75) (Gandhi *et al.*, 1974).

2.7 EXTRUDED FOOD PRODUCTS FROM JACKFRUIT

Extrusion originates from the Latin word, 'Extrude' which means 'press' or 'push out'. Extrusion is an emerging technology having the advantages of low production cost and is able to produce end products in various shapes and sizes to form a variety of food materials. These food materials ensure easy digestibility, hygiene and high product quality, leaving behind no effluents or hazardous materials. With increasing consciousness about healthy eating and changing lifestyles, extruded products are becoming a standard feature in many households (Riaz and Aldrich, 2007).

Extrusion is a thermal process which involves preparation and mixing of flours, with optimum moisture content to form dough that could be extruded in well-defined shapes. The principle of this technology is the twin screw system composed inside a barrel that conveys the dough towards small openings at the end of the barrel called dies. With the help of shear force, produced by the rotating screw and additional heating of the barrel, the flour is heated to its melting point or plasticizing point. In this changed rheological status, the food is moved under high pressure through a die or a series of dies and the product expands to its final shape and volume. This results in very different physical and chemical properties of the extrudates when compared to those of the raw materials used (Brncic *et al.*, 2006).

Extrusion helps to reduce the factors that inhibit the absorption of nutrients in the body thereby it helps in higher absorption of minerals. Mineral absorption is generally affected by the phytates that form insoluble complexes with minerals making it unavailable for the body. Extrusion hydrolyses phytates to release phosphate molecules (Alonso *et al.,* 2001).

Extrusion system adds value to the inferior raw materials and waste products in food manufacturing, such as processing dark flours or blending in rice bran for better quality products (Eastman *et al.,* 2001).

Sabbatini *et al.* (2014) studied the pre-mixture prepared for gluten-free noodles for the effect of hydrocolloids using base ingredients like corn starch, cassava starch and rice flour.

Umesh *et al.* (2010) has rightly pointed out that, jackfruit is a rich source of phytochemicals, nutrients, antioxidants, including phenolic compounds and it offered opportunities for the development of value added products such as noodles, which will have commercial value along with health enhancing properties.

Noodles prepared from different proportion of raw jackfruit bulb flour, raw jackfruit seed flour and refined flour (40:30:30, 50:25:25, 50:30:20, 50:40:10, 50:10:40, 50:20:30) were extruded by Veena (2015).The study reported to have more protein, fiber and minerals and less energy and carbohydrate in the samples of jackfruit bulb and seed flour added noodles when compared to control sample.

With this background on jackfruit processing, an extruded and a dehydrated product based on jackfruit rind was attempted. The methodology of this project is discussed in the ensuing chapter.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled, "**Value added products from jackfruit rind**" was aimed at developing value added dehydrated and extruded products from jackfruit rind *(cv. Koozha and cv. Varikka).* The developed products viz. *Papad* and Crispies were studied for their Sensory and shelf-life qualities. In depth analysis of their physico-chemical properties, functional qualities and nutritional profile were also undertaken. The methodology of the present study is presented in the following heads:

3.1 Selection and collection of Jackfruit rind

3.2 Assessment of storage quality of rind

3.3 Processing of jackfruit rind flour

3.4 Functional quality analysis of jackfruit rind flour

3.5 Preparation of composite flour

3.6 Standardization of *papad*

3.7 Standardization of crispies

3.8 Quality evaluation of the products

3.9 Storage stability of the products

3.10 Cost of the products

3.1 SELECTION AND COLLECTION OF JACKFRUIT RIND

Jackfruit (*Artocarpus heterophyllus*) is commonly grown in home gardens of tropical and sub-tropical countries. Jackfruit is considered to be an underutilized fruit, because most of the fruits get wasted due to less awareness of utilization methods, lack of post-harvest technology and gaps in supply chain systems. A wide gap exists in the

Plate: 1 Raw mature jackfruit - The raw materials

Koozha **Jackfruit**

Varikka **Jackfruit**

marketing of jack fruits and its processed value added products which needs to be fully explored for additional income as well as food security.

Jackfruit cultivars *Koozha* and *Varikka* were selected for the conduct of this study. The matured jackfruits were procured from the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram.

Raw mature jackfruits of 90-105 days after fruit set, with optimum visible maturity indices were selected. The fruits were chosen in this state because, raw mature jackfruits are suitable for the better yield of jackfruit rind, as the thickness of the rind diminishes with ripening of the fruit. External visible maturity indices such as distance between spines per unit area, hollow sound on tapping and green coloured spines were ensured before the harvest. The outer thorny portion was cut and separated out and the rind was carefully cut out, after removing the perigones and bulbs. Weight of the each fruit was recorded. The other raw materials viz. raw rice, black gram, sago, refined oil, cinnamon, iodized salt and seasoning masala were procured from the local Super market.

3.2 ASSESSMENT OF STORAGE QUALITY OF RIND

From the quality perspective, it is desirable to preserve the characteristics of fresh-cut fruits and vegetables at their peak. Obviously, any food product should be safe for consumption and fresh-cut products are very sensitive to contamination. Among the limitations to shelf-life of fresh-cut products are: microbial spoilage, desiccation, discolouration or browning, bleaching, textural changes and development of off-flavour or off-odor.

While conventional food processing methods extends the shelf-life of fruits and vegetables, the minimal processing methods to which fresh-cut fruits and vegetables are subjected, renders these products to become easily perishable, thus requiring chilled storage to ensure a reasonable shelf-life (Rosen and Kader, 1989).

Plate No: 2 Visual quality of *Koozha* rind at low temperature

1.Before Refrigeration

2.Before freezing

1a. After 2 days of refrigeration

2a. After 2 days of freezing

Plate No: 3 Visual quality of *Varikka* rinds at low temperature

1. **Before refrigeration**

2. Before freezing

1a. After 1 week refrigeration

2a. After 1 week freezing

1b. After 10 days refrigeration

2b. After 10 days freezing

Shelf-life extension of jackfruit rind by applying low temperature methods would help the processing industries to store the rinds for future use. Hence fresh cut rinds of both cultivars (*Koozha* and *varikka*) were packed in PP covers and stored in two different chilling conditions refrigeration at 4° C and freezer at -18° C for ascertaining their visual quality of rind. The change in visual quality of stored jackfruit rinds were observed at equal intervals of time for 10 days. The changes are shown in the plate 2 and 3 for cultivars *koozha* and *varikka* respectively.

Pre- Treatments to control enzymatic browning

Enzymatic browning is the second largest cause of quality loss in fruits and vegetables. Enzymatic browning is the discolouration which occurs due to the action of a group of enzymes called polyphenol oxidases (PPO), which is reported to be present in all plants. Enzymatic browning has to be distinguished from non-enzymatic browning, which occurs due to heating or storage after processing of foods. Methods to prevent browning is an area where a great deal of research is focused in the food industry (Ioannou *et al.*, 2013).

When assessing plant product quality, consumers take product appearance into consideration as a primary criteria and therefore colour is probably the main factor considered (Kays and Ghoul, 1999).

Among the consequences of mechanical injuries, increase in respiration rate and ethylene production, accelerated senescence and enzymatic browning are the major changes. In conventional types of fruit and vegetable processing, such as canning and freezing, many of these problems are prevented or controlled by the application of heat and consequent inactivation of enzymes, by the use of protective packaging materials or through the application of various additives. Different types of chemicals are used in the control of browning which acts directly as inhibitors of PPO, whereas others act by rendering the medium inadequate for the development of the browning reaction, still others act by reacting with the products of the PPO reaction, before these can lead to the formation of dark pigments (Rosen and Kader, 1989).

The occurrence of enzymatic browning in *Koozha* and *Varikka* jackfruit rinds which were immersed in different pre-treament media were evaluated after 4 hours. The colour change of *Koozha* and *Varikka* jackfruit rind from white to brown was observed after 4 hours. The composition of different pre-treament media used to control the enzymatic browning in jackfruit rinds are listed in the Table: 3

Table: 3 Composition of different pre-treatment media

Sl. No.	Pre-treatment media	Composition (%)
1.	Control	No treatment
2.	Citric acid solution	1
3.	Salt solution	1
4.	Sugar solution	1
5.	Lime juice	1

The comparison of browning in different pretreatment media for the cultivars *koozha* and *varikka* are given in the plate 4 and 5 respectively.

Plate No: 4 Comparison of browning of *Koozha* rinds in different Pre- treatment media

1. Control- Initial observation

1a. After 4 hours

2. 1% citric acid soln- Initial observation -

2a. After 4hours

3. 1% salt soln- Initial observation

3a. After 4hours

4. 1% sugar soln- Initial observation

4a. After 4hours

5. 1% Lime juice- Initial observation

5a. After 4hours

Plate No: 5 Comparison of browning of *Varikka* rinds in different Pre – treatment media

1. Control - Initial observation

1a. After 4 hours

2. 1% citric acid soln- Initial observation

2a. After 4hours

3. 1% salt sol- Initial observation

3a. After 4hours

4. 1% sugar soln- Initial observation

4a. After 4hours

5. 1% Lime juice- Initial observation

5a. After 4hours

3.3 PROCESSING OF JACKFRUIT RIND FLOUR

Jackfruit rind flour was processed according to the method standardized by Feili (2014) as shown in Fig 1. The different stages of processing of rind flour is shown in plate: 6.

Figure: 1 Flow diagram for preparation of jackfruit rind flour (JRF)

Selection of mature raw jackfruit

⇩

Washing and cutting

⇩

Separation of rind from peel and bulbs

⇩

Cutting the rind into equal cubes

⇩

Washing with deionized water

⇩

Pretreatment with chemicals(0.1%$NaHCO_3$, 0.1% $NaHSO_3$)

⇩

Drying (50° C)

⇩

Milling

⇩

Sieving (350 μm)

⇩

Packing (PP)

⇩

Storage at ambient condition

Plate No: 6 Stages of Processing of Jackfruit rind flour

A. *Koozha* jackfruit rind flour

A1. *Koozha* rinds after pre-treatment

A2. *Koozha* dried rinds in PP cover

A3. *Koozha* rind flour in PP cover

B. *Varikka* jackfruit rind flour

B1. *Varikka* rinds after pre-treatment

B2. *Varikka* dried rinds in PP cover

B3. *Varikka* rind flour in PP cover

3.4 FUNCTIONAL QUALITY ANALYSIS OF JACKFRUIT RIND FLOUR

3.4.1 Functional properties

Functional properties are the fundamental physico-chemical properties that reflect the complex interaction between the composition, structure, molecular conformation and physico-chemical properties of food components together with the nature of environment in which these are associated and measured (Kinsella, 1976). Functional qualities such as water absorption index, oil absorption index, foaming capacity, swelling power percentage solubility and gelation concentration were studied.

3.4.1.1 Water Absorption Index (WAI)

A known volume of jackfruit rind flour (1g) and distilled water (10ml) were mixed in a centrifuge tube. The suspension was allowed to stand at room temperature and was centrifuged for 30 minutes. The volume of drained water and sediment was measured. Beuchat (1977) had calculated the water absorption index by the formula

$$\text{Water absorption index} = \frac{\text{Weight of water absorbed (g)} \times 100}{\text{Weight of dry flour (g)}}$$

3.4.1.2 Oil absorption Index (OAI)

A known volume of jackfruit rind flour (1g) and known volume of oil (10ml) were mixed in a centrifuge tube. The suspension was allowed to stand at room temperature and was centrifuged for 30 minutes. The volume of drained oil and sediment was measured. Beuchat (1977) had calculated the oil absorption index by the formula

$$\text{Oil absorption index} = \frac{\text{Weight of oil absorbed (g)} \times 100}{\text{Weight of dry flour (g)}}$$

3.4.1.3 Foaming capacity (FC)

The volume of foam formed after whipping a known quantity of jackfruit rind flour (1 gm) with a known quantity of distilled water (50 ml) at room temperature was noted (Narayana and Narasinga, 1982). The formula used to calculate the foaming capacity was

$$\text{Foaming capacity} = \frac{\text{Volume of AW} - \text{Volume of foam BW} \times 100}{\text{Volume of BW}}$$

Where, AW = Foam volume after whipping,

BW = Foam volume before whipping.

3.4.1.4 Swelling power (SP)

A known volume of jackfruit rind flour (1 gm) and distilled water (10 ml) was heated at 80° C. The resulting product mixture was centrifuged and the weight of paste obtained was recorded after the supernatant was decanted (Leach *et al.*, 1959). Formula used for calculating swelling power was

$$\text{Swelling power} = \frac{\text{Weight of the paste}}{\text{Weight of the dry sample}}$$

3.4.1.5 Percentage solubility

A known volume of jackfruit rind flour (1 gm) and distilled water (10 ml) was heated at 80° C. The resulting product mixture was centrifuged and the supernatant was taken into a pre-weighed petri dish and evaporated for 2 h at 130°C and then weighed. The residue obtained after drying of supernatant represented the amount of flour solubilized in water. (Oladele and Aina, 2011). Formula used for calculating percentage solubility was

$$\text{Solubility \%} = \frac{\text{Weight of the dried sample in supernatant}}{\text{Weight of original sample}} \times 100$$

3.4.1.6 Gelation concentration

The jackfruit rind flour dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 % (w/v) prepared in 5 mL distilled water was heated at 90 °C for 1 h in water bath. The contents were cooled under tap water and kept for 2 hrs at 10 ± 2 °C. The least gelation concentration was determined as that concentration when the sample from inverted tube did not slip (Coffman and Garcia,, 1977).

3.4.1.7 Rehydration ratio

Rehydration ratio of *koozha* and *varikka* jackfruit rind flours were determined by taking about ten grams of the sample, which was mixed with 100 ml of distilled water, stirred and kept for 5 minutes. The contents were filtered using a filter paper. The rehydrated sample was weighed and rehydration ratio was calculated using the formula

$$\text{Rehydration ratio} = \frac{\text{Initial weight of the sample (g)}}{\text{Drained weight of the sample (g)}}$$

3.4.2 Nutrient and chemical composition of jackfruit rind flour

The nutrient and chemical constituents namely carbohydrate, protein, fat dietary fiber, crude fiber, starch, tannins, phenol, iron, polyphenols, flavonoids, pectin and lectin of the raw and ripened jackfruit rind flour were estimated in order to compare its nutritive value as per the following standard procedures. (Table: 4).

Table: 4 Methods of analysis of Nutrient and chemical composition of jackfruit rind flour

Constituents	Method adopted
Moisture %	AOAC (1990)
Carbohydrate (g)	Sadasivam and Manikkam (1992)
Protein(g)	Bradford (1976)
Fat(g)	Sadasivam and Manikkam (1992)
Fiber (g)	Sadasivam and Manikkam (1992)
Starch (g)	Sadasivam and Manikkam (1992)
Total minerals(mg)	Thimmiah (1999)
Tannins	Sun (1988)
Total phenols	Waterhouse (2002)
Polyphenols	Waterhouse (2002)
Flavonoids	Lee (2012)
Lectin	AOAC (1990)
Pectin	AOAC (1990)
Iron	AOAC (1990)
Phosphorous	Hseu (2004)
Peroxide value	AOAC (1990)
Sodium	AOAC (1990)
Potassium	Harway and Heidal (1952)

3.4.3Total antioxidant activity

The total antioxidant activity of raw and ripened jackfruit rind flour was determined by phosphomolybdenum method, the antioxidant capacity was expressed as Ascorbic acid equivalent (AAE) by using the standard Ascorbic acid (Prieto, 1999).

3.5 PREPARATION OF COMPOSITE FLOUR

Composite flour (CF) is a mixture of flours. In this study CF was prepared by substituting rice flour with jackfruit rind flour up to a maximum of 50 per cent in different proportions. The treatments selected for this study are listed in the Table: 5 and 6

Table: 5 Treatments selected for the formulation of *papad* and crispies with *Varikka* jackfruit rind

Treatment	Proportions
T_1	50% *varikka* jackfruit rind flour + 50% rice flour
T_2	40% *varikka* jackfruit rind flour + 50% rice flour + 10% blackgram flour
T_3	30% *varikka* jackfruit rind flour + 60% rice flour + 10% blackgram flour
T_4	20% *varikka* jackfruit rind flour + 70% rice flour + 10% blackgram flour
T_5	10% *varikka* jackfruit rind flour + 80% rice flour + 10% blackgram flour
Control	100% rice flour

Table: 6 Treatments selected for the formulation of *papad* and crispies with *Koozha* jackfruit rind

Treatment	Proportions
T_6	50% *Koozha* jackfruit rind flour + 50% rice flour
T_7	40% *Koozha* jackfruit rind flour + 50% rice flour + 10% blackgram flour
T_8	30% *Koozha* jackfruit rind flour + 60% rice flour + 10% blackgram flour
T_9	20% *Koozha* jackfruit rind flour + 70% rice flour + 10% blackgram flour
T_{10}	10% *Koozha* jackfruit rind flour + 80% rice flour + 10% blackgram flour
Control	100% rice flour

All the ingredients were dried at 50° C and powdered. They were then mixed thoroughly to form the composite flour for the preparation of *papad* and crispies.

3.6 STANDARDIZTION OF *PAPAD*

Rice flour or black gram flour are the commonly used raw materials for the preparation of *papad*. It can be prepared in two ways, either using the flour in dough form or in batter form. The latter method was used in this study to prepare *papad*.

The above prepared composite flour of different proportions with *Koozha* and *Varikka* jackfruit rind flours, raw rice flour and black gram flour were soaked in water for about 4 hours. Sago was also soaked in the ratio of 4: 1 (4 parts flour: 1 part sago) to the composite flour. The quantity and proportion of ingredients are given in the table: 7 and 8. All the ingredients were taken in the specific proportion to prepare the batter.

Table: 7 Composition of the Treatments for jackfruit rind *Papad (Varikka)*

SL.No	Ingredients	Treatments (100g)					
		T_1	T_2	T_3	T_4	T_5	Control
1.	*Varikka* jackfruit rind flour (g)	50	40	30	20	10	0
2.	Rice flour (g)	50	50	60	70	80	100
3.	Black gram flour (g)	0	10	10	10	10	0
4.	Sago (g)	25	25	25	25	25	25
5.	Salt (g)	3	3	3	3	3	3
6.	Cinnamon (g)	2.5	2.5	2.5	2.5	2.5	2.5
7.	Water (ml)	300	300	300	300	300	300

Table: 8 Composition of the treatments for jackfruit rind *Papad (Koozha)*

SL.No	Ingredients	Treatments (100g)					
		T_6	T_7	T_8	T_9	T_{10}	Control
1.	*Koozha* jackfruit rind flour (g)	50	40	30	20	10	0
2.	Rice flour (g)	50	50	60	70	80	100
3.	Black gram flour (g)	0	10	10	10	10	0
4.	Sago (g)	25	25	25	25	25	25
5.	Salt (g)	3	3	3	3	3	3
6.	Cinnamon (g)	2.5	2.5	2.5	2.5	2.5	2.5
7.	Water (ml)	300	300	300	300	300	300

The soaked mixture was then ground to batter form and salt was added which was then allowed to ferment for 24 hours. After fermenting cinnamon was added to the batter and *papad* were developed by taking around 10 – 15 ml of batter in a ladle and spreading on pre-oiled plates in circular motion which were arranged in a vertical stand, this was then placed in hot water for steaming for 2-3 minutes. The cooked *papad* was peeled off from the plate and dried in mechanical drier at 65°C for 5 hours. The number of *papads* obtained and the dried weight of *papad* was noted.

The dried *papad* was fried in refined oil at a temperature of 185°C for about 5 – 20 seconds. The weight of the fried *papads* were recorded. The processing parameters of *papad* is given in the table: 9.

Table No: 9 Processing parameters of *Papad*

Sl. No.	Parameters	
1.	Steaming Time	2-3 minutes
2.	Acceptable shape	Circular
3.	Drying Time	5 hours
4.	Drying Temperature	65° C
5.	Frying Time	5-20 seconds
6.	Frying Temperature	185° C

Figure: 2 Flow diagram for the preparation of *papad*

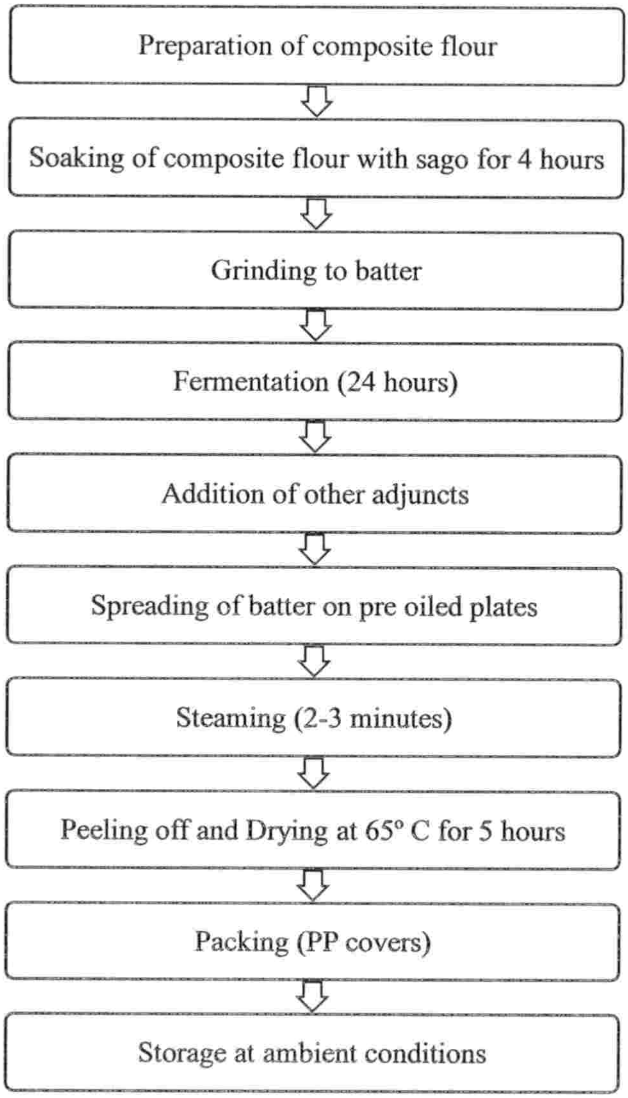


Plate No: 7 Stages of processing of Jackfruit rind *papad*

Preparation of batter

Batter spread on plates

Peeling off *papad* after steaming

3.7 STANDARDIZATION OF CRISPIES

Crispies is a snack that is popular among all classes of people. It is an extruded product from starch rich flour that makes it crispy. Rice flour, corn flour or cassava flour which is rich in starch are generally used to prepare crispies commercially. In this study, starch rich flour was replaced by the fiber rich composite flour made of jackfruit rind flour in different proportions along with the other components. The mix was extruded in the SLG 30 Twin screw extruder at Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram. The quantity and proportion of ingredients in the treatments studied are given in Table: 10 and 11. All the ingredients were taken in the specified proportions to develop the crispies.

Table: 10 Composition of treatments for jackfruit rind Crispies (*Varikka*)

Sl.No	Ingredients	Treatments (100g)					
		T_1	T_2	T_3	T_4	T_5	Control
1.	*Varikka* jackfruit rind flour (g)	50	40	30	20	10	0
2.	Rice flour (g)	50	50	60	70	80	100
3.	Black gram flour (g)	0	10	10	10	10	0
4.	Salt (g)	3	3	3	3	3	3
5.	Water (ml)	12	12	12	12	12	12
6.	Refined oil (ml)	10	10	10	10	10	10
7.	Seasoning Masala (g)	15	15	15	15	15	15

Table: 11 Composition of treatments for jackfruit rind Crispies (*Koozha*)

Sl. No.	Ingredients	Treatments (100g)					
		T_6	T_7	T_8	T_9	T_{10}	Control
1.	*Koozha* jackfruit rind flour (g)	50	40	30	20	10	0
2.	Rice flour (g)	50	50	60	70	80	100
3.	Black gram flour (g)	0	10	10	10	10	0
4.	Salt (g)	3	3	3	3	3	3
5.	Water (ml)	12	12	12	12	12	12
6.	Refined oil (ml)	10	10	10	10	10	10
7.	Seasoning Masala	15	15	15	15	15	15

The composite flour was fed into the input container of the SLG 30 twin screw extruder and the required amount of water was poured into inlet and the temperature was adjusted to 90° C. The first obtained extruded product was discarded in order to get the product with full expansion after the stabilization of temperature. The crispies could be produced in desired shapes like round and lengthy sticks of different sizes by adjusting the dies in the extruder. The extruded crispies were sprayed with refined oil and seasoning masala in the mixer for enhancing the taste. It was then packed in PP covers and stored at ambient conditions. The weight of the product was noted. The processing parameters of jackfruit rind crispies is given in the table: 12.

Table No: 12 Processing parameters of Jackfruit rind crispies

S. No.	Parameters	Temperature required
1.	Phase 1	45° C
2.	Phase 2	50° C
3.	Phase 3	65° C
4.	Phase 4	90° C

Figure: 3 Flow diagram for the extrusion of Crispies

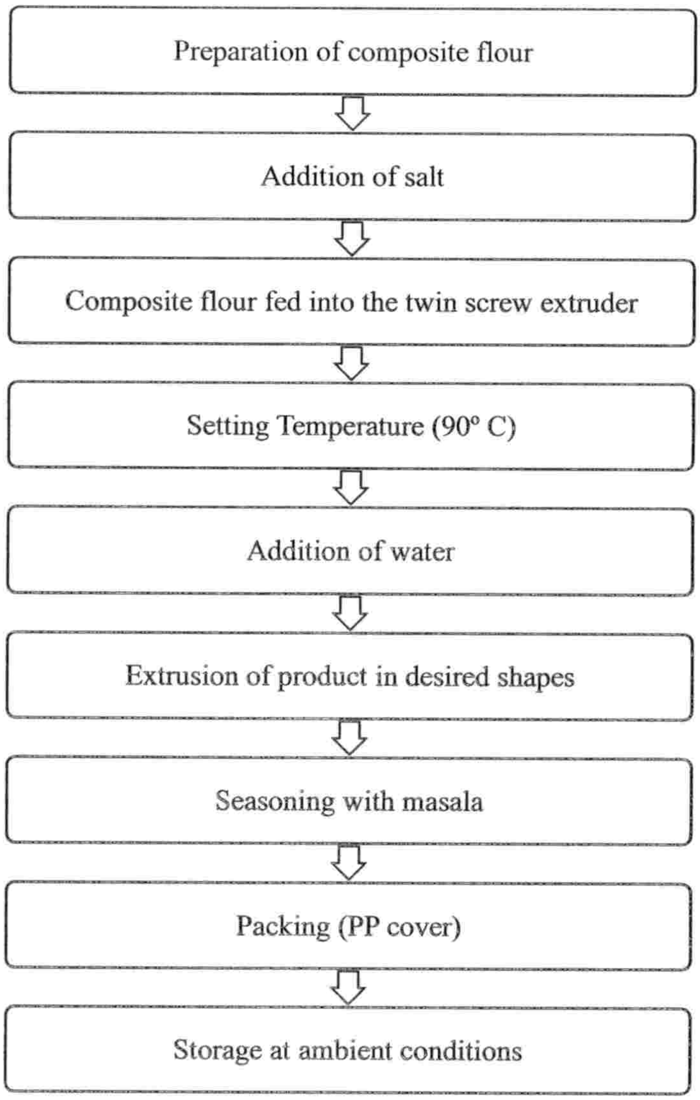
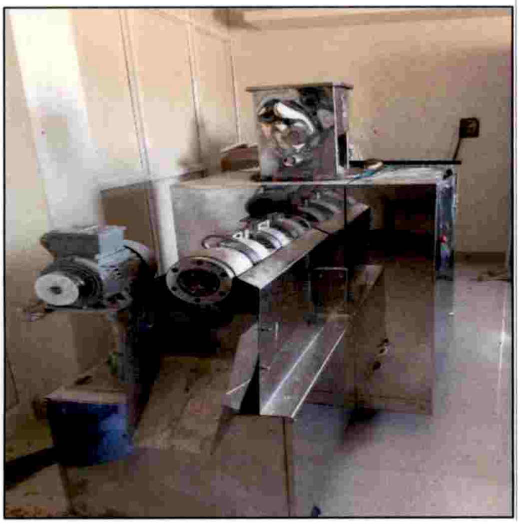
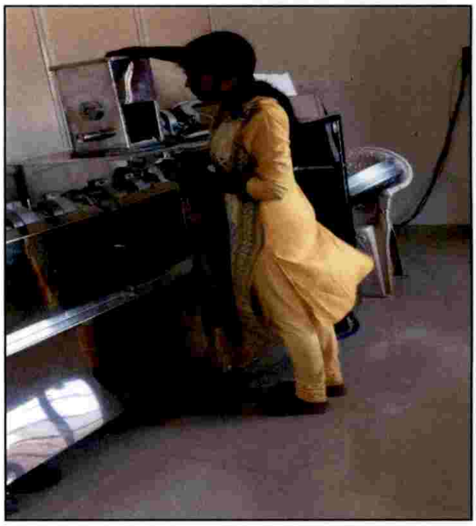


Plate: 8 Processing of Crispies





Twin screw extruder

Extrusion of crispies

3.8 QUALITY EVALUATION OF THE JACKFRUIT RIND BASED PRODUCTS

Quality is a measure of the degree of excellence or degree of acceptability by the consumer. It also covers the safety and value for money. In simple words the product should have attributes to "satisfy the needs of the consumer. Therefore the qualities of standardized products *viz, papad* and crispies were assessed with respect to physical and sensory attributes, chemical constituents, nutrient composition and shelf-life stability.

3.8.1 Sensory Evaluation of the developed Products

Sensory evaluation was performed by semi trained panelists after considering their performance test in recognition of basic tastes and aroma. The panel comprised of 10 members aged between 20-35 years.

Sensory quality is one of the most important criteria that determines the acceptability of any food product by the consumer- The Sensory properties of the developed products included assessment of appearance, colour, aroma, texture, taste and overall acceptability, by a 10-member panel who were familiar with such products. A nine point hedonic rating scale was used to rate each treatment. The differences in scores were analysed using Kruskal- Wallis test.

3.8.1.1 Preparation of score card

Score cards were prepared on a 9 point hedonic rating. The score card for sensory evaluation comprised of the sensory attributes- appearance, colour, aroma, taste, texture and overall acceptability. These were rated as scores ranging from 1-9 as described by Sudha *et al.* (2007).

The 9 point hedonic rating was prepared for evaluating the most acceptable treatment from the two products; 9 representing "like extremely" and 1 representing "dislike extremely" (hedonic rating scale).

3.8.1.2 Selection of the best combination

The best treatment was selected by analysing the scores of hedonic rating scale of various sensory attributes. Appearance, colour, aroma, taste, texture and overall acceptability of the products were assessed.

3.8.2 Physical characteristics of the *papad*

3.8.2.1 Yield (number)

Yield of *papad* in number was calculated by counting the total number of *papads* obtained from a known volume of sample (100 g).

3.8.2.2 Dried weight

Dried weight of the *papad* was calculated by taking the weight of the product after dehydration.

3.8.2.3 Thickness

The thickness of the raw and fried *papad* of *Varikka* and *Koozha* jackfruit rinds were measured using Vernier caliper and were recorded.

3.8.2.4 Diameter of raw and fried papad

The diameter of raw and fried *papad* of *Varikka* and *Koozha* jackfruit rinds were measured using thread and noted.

3.8.2.5 Expansion percentage

The expansion percentage of fried *Varikka* and *Koozha* jackfruit rind *papad* were calculated according to the procedure of Vidyavati *et al.* (2004).

$$\text{Expansion \%} = \frac{DF-DR}{DR} \times 100$$

Where,

DF = Diameter of fried *papad*

DR = Diameter of raw *papad*

3.8.2.6 Colour

The colour of raw and fried *papad* of *Varikka* and *Koozha* jackfruit rinds were recorded by visual observation.

3.8.2.7 Bulk density

Bulk density is the ratio of the weight of the sample to the weight of an equal volume of water. The sample of jackfruit rind *papads* of cultivars *koozha* and *varikka* were taken at a height of 20 cm in 50 ml beaker. It was leveled without compressing. The weight of the sample with the beaker were recorded. The sample was then removed from the beaker and water was filled to the same mark. The weight of water in the beaker was recorded and the bulk density of the sample was calculated using the formula

$$\text{Bulk density} = \frac{\text{Weight of the sample}}{\text{Weight of equal volume of water}}$$

3.8.2.8 Texture

The texture of the products were analyzed for parameters like crispiness, hardness, toughness, firmness, work of penetration, rupture strength, work of cutting, cohesiveness, stringiness, crunchiness using texturometer at NIIST, Thiruvananthapuram.

3.8.2.9 Oil absorption

Oil absorption of fried *papad* of *varikka* and *koozha* jackfruit rinds were calculated by the difference in the volume of oil before and after frying of *papad*.

3.8.3 Physical characteristics of crispies

3.8.3.1 Yield (weight)

Yield of crispies in weight was calculated by weighing the total amount of crispies obtained from a known volume of sample (100 g).

3.8.3.2 Diameter

The diameter of crispies of *Varikka* and *Koozha* jackfruit rinds were measured using a thread and noted.

3.8.3.3 Thickness

Thickness of the jackfruit rind crispies was observed as in 3.8.2.3.

3.8.3.4 colour

Colour of the crispies was observed visually as per 3.8.2.6.

3.8.3.5 Bulk density

Bulk density of the crispies were analysed by the procedure mentioned in 3.8.2.7.

3.8.3.6 Texture

Texture of the crispies were analysed for its parameters as mentioned in 3.8.2.8

3.8.4 Nutrient and chemical composition of the products

The nutrient and chemical constituents of the standardized products namely carbohydrate, protein, fat dietary fiber, crude fiber, starch, tannins, phenol, iron, polyphenols, flavonoids, pectin, lectin, sodium, potassium were estimated in order to compare the nutrient composition of *Koozha* and *varikka* jackfruit rind based products as per the following standard procedures (Table: 4)

3.8.5 Total antioxidant activity

The total antioxidant activity of both the products were determined by phospho-molybdenum method, the antioxidant capacity was expressed as Ascorbic acid equivalent (AAE) by using the standard Ascorbic acid (Prieto, 1999).

3.9 STORAGE STABILITY OF THE PRODUCTS

Storage stability is of utmost importance for a product to become successful commercially. The stability of the product with respect to sensory quality and microbial attack is considered safe for consumption.

To observe the keeping quality, the developed products were stored separately in heat sealed PP pouches in ambient conditions. Samples from the best treatment were stored in PP pouches. One pouch from each product was picked randomly and analysed on a monthly basis for its sensory qualities. The values were analysed in triplicates. Moisture and microbial profile were analysed periodically for 3 months.

3.9.1 Moisture

Moisture content of all the experimental samples was determined by the thermo-statically controlled electric oven dry method. Empty crucibles were taken, washed, dried, cooled and weighed. Then a definite quantity of sample was taken in the crucible and weighed. The crucibles were placed in the oven and dried at temperature of 250^{0}C. After drying the crucibles were removed from the oven and cooled in desiccators. It was weighed again, dried. They were again cooled and weighed repeatedly until a constant weight was obtained. For accuracy, four samples were dried in the oven and percentages of moisture content were then calculated.

3.9.2 Microbial Profile

The developed *papad* and crispies from *koozha* and *varikka* jackfruit rind were stored and were analysed for their microbial load for bacteria, fungus, actinomycetes and *Escherichia coli* and number of colonies of individual microbes were counted and reported as CFU/ g.

3.10 COST ANALYSIS OF THE STANDARDIZED PRODUCTS

Economic analysis of the developed dehydrated *papad* and extruded crispies were assessed by taking into consideration of variable costs and fixed costs. Variable cost included cost of food materials, electricity charge, milling charge, packaging charge, fuel charge and labour cost. The fixed cost included cost of utensils, equipment and other materials. To sell the product in the market the total cost of the product was calculated by assessing fixed cost and variable cost.

TCP (Total cost of product) = FC (Fixed cost) + VC (Variable cost)

The cost of jackfruit rind *papad* and crispies was also compared with the cost of *papad* and crispies available in the market.

Benefit cost ratio (B: C ratio)

Benefit cost ratio of the product was assessed by dividing the gross returns with total expenditure incurred for the development of product.

Analysis of Data

In order to obtain suitable interpretation, the generated data was subjected to statistical analysis like one way analyses of variance (ANOVA) or completely randomized design at 5 per cent significance level and Kruskal- Wallis test. These tests mainly assessed the significant differences in the treatment means. The values of critical difference were used to ascertain the significant differences (Steel and Torrie, 1960).

Results

4. RESULTS

The results of the present study entitled "Value added products from jackfruit rind" are detailed in this chapter under the following headings:

4.1 Selection and collection of Jackfruit rind

4.2 Assessment of storage quality of rind

4.3 Processing of jackfruit rind flour

4.4 Functional quality analysis of jackfruit rind flour

4.5 Preparation of composite flour

4.6 Standardization of *papad*

4.7 Standardization of crispies

4.8 Quality evaluation of the products

4.9 Storage stability of the products

4.10 Cost of the products

4.1 SELECTION AND COLLECTION OF JACKFRUIT RIND

Jackfruit is an aggregate fruit which has numerous fruitlets, each containing one seed, the fruitlets are surrounded with perianth and are covered with a thick layer of rind and protected by thorny skin. The rind, which is rich in fiber and pectin are discarded along with the skin, as the process of separating the fruitlets from the rind is a laborious process and it is wasted to a great extent due to lack of post-harvest technological interventions.

Kerala, which lies in the southern part of Western Ghats, is well known for its diversity in jack fruit types. The availability of the fruit in Kerala is during March to May.

This study aimed to utilize the fiber rich jackfruit rind for the development of value added products *viz, papad* and crispies from two cultivars, *Koozha* and *Varikka*. Raw mature jackfruits of 90-105 days after fruit set of *Koozha* and *varikka* cultivar with optimum visible maturity indices were selected. The fruits with acceptable appearance for raw stage consumption were selected. Raw mature jackfruits are seen to give better quality of rind than ripened fruit. The variation in the physical characteristics of rind of both the cultivars were noted and is listed in the table: 13

Table: 13 Physical characteristics of *Koozha* and *Varikka* Jackfruit

Sl. No	Parameters	*Koozha*	*Varikka*	"t" values (0.05)
1.	Net weight (kg)	12.2	11.8	4.899
2.	Skin weight (g/ kg of fruit) (Thorny layer)	9.2	12.3	-3.455
3.	Rind weight (g/ kg of fruit)	9.8	7.5	2.819
4.	Dried rind weight (g/ kg of rind)	11.3	8.2	37.960
5.	Rind thickness (cm)	1.4	1.2	2.444
6.	Rind texture (Fresh)	Slightly hard	Soft	
7.	Rind texture (after treatment)	Soft	Soft	

(Values indicated are mean values of ten replicates)

Physical characteristics of cv. *Koozha* and *varikka* like net weight, skin weight, fresh rind weight, dried rind weight, rind thickness, fresh rind texture and rind texture after treatment were observed.

Net weight (kg) of cv. *koozha* (12.2) was higher than cv. *Varikka* (11.8) and was significantly different at 5 % level. Skin weight (g/ kg of fruit) of *varikka* (12.3) was higher than *koozha* (9.2). Fresh rind weight (g/ kg of fruit) of cv. *Koozha* (9.8) was higher than cv. *Varikka* (7.5). Dried rind weight (g/ kg of fruit) of cv. *Koozha* (11.3) was higher than cv. *Varikka* (8.2). There was significant difference in the thickness of the rind; rind thickness (cm) of *koozha* rinds (1.4) was greater than *Varikka* (1.2). Texture of the rind was observed by hand feel. Texture of fresh *koozha* rind was slightly hard and became soft after pre-treatment. Texture of fresh *varikka* rinds and rinds after pre-treatment were soft.

4.2 ASSESSMENT OF STORAGE QUALITY OF RIND

In order to observe the shelf-life of fresh cut rinds in storage conditions, about 10 g of rinds of *koozha* and *varikka* were kept in polypropylene (PP) pouches immediately after cutting and were stored in refrigerator and in freezer to study the quality of the rinds after storage.

In the beginning, the rinds of *koozha* was milky white in colour, slightly hard in texture and had no characteristic flavour. *Koozha* rinds which were stored for 2 days were observed visually for their quality such as colour, texture and flavour. The rinds turned slightly brown under refrigerated condition and also in frozen state, but the degree of browning of refrigerated *koozha* rinds were higher than the frozen *koozha* rinds. There was no much change in the flavour of the rinds in both the storage conditions. The texture of the frozen *koozha* rinds was harder than refrigerated rinds. *Koozha* rinds were further stored for one week. It was observed that the rinds completely turned to a chocolate brown colour. The texture of the *koozha* rinds had become juicy and developed an off flavour which was then discarded.

In the beginning, the rinds of *varikka* was white in colour, slightly soft in texture and had no flavour. *Varikka* rinds which were stored for 2 days were observed visually for their quality such as colour, texture and flavour. There was no difference in the quality of the *varikka* rinds under refrigerated condition and also in the frozen state. There was no change in the flavour of the rinds under both the storage conditions. The texture of the frozen *varikka* rinds was harder than refrigerated rinds. *Varikka* rinds were further stored for one week. It was observed that the rinds retained their firmness, colour and flavour. It was further stored for ten days which showed slight hardness and browning in the corners of frozen treatments, whereas refrigerated rinds retained their quality. The stored rinds of both cultivars are shown in the plate: 2 and 3.

Pre-treatments to control enzymatic browning

Fruits and vegetables have health benefits for consumers, due to their content of fiber, vitamins and antioxidant compounds. However, as for as antioxidant compounds are concerned, many changes occur during their harvesting, preparation (fresh-cut fruits) and storage. These changes induce certain losses in their microbiological and antioxidant qualities (Lindley, 1998). Hence, preservation against oxidation during processing and storage has become a priority in the food industry.

Generally when fruits and vegetables are cut, the process of enzymatic browning begins immediately and reaches its maximum in a particular period of time depending on the amount of polyphenol oxidase (PPO) enzyme present in it.

Thus, different pre-treatment media as listed in the table: were used to study the differences in preventing enzymatic browning of the rinds of the cultivars of *koozha* and *varikka*. For this study, cut rinds of about 10 g were taken for each of the treatment. The changes were observed after four hours of the treatment are depicted in the table: 14 and 15 for the cultivars *koozha* and *varikka* respectively.

Table: 14 Browning outcome of *koozha* rinds

SL.No	Treatment	Initial observation	Observation after 4 hours
1.	Control	Milky white	Browning was observed around the rind
2.	1 % Citric acid	Milky white	Remains white
3.	1 % salt solution	Milky white	No colour change until 2 hours. A slight tint of brown was seen at the corners of the rinds
4.	1 % sugar solution	Milky white	No colour change until 2 hours. A slight tint of brown was seen at the corners of the rinds
5.	1 % Lime juice	Milky white	Remains white with bleached effect

Koozha rinds in the pre-treatment media were observed for their colour change due to enzymatic browning after 4 hours. The different pre-treatment media used were 1 % citric acid solution, 1 % salt solution, 1 % sugar solution, 1 % lime juice along with control. The *koozha* rinds were cut and immediately immersed in the pre-treatment media. At the beginning the *koozha* rinds were milky white in colour. After 4 hours, control treatment turned brown, in 1 per cent citric acid solution the *koozha* rinds retained their white colour, whereas in 1 per cent salt solution and 1 per cent sugar solution there was no colour change until 2 hours and thereafter there was a slight tint of brown at the corners of the rinds. In 1 per cent lime juice *koozha* rinds were seen to have a white colour with bleached effect.

Table: 15 Browning outcome of *varikka* rinds

SL.No	Treatment	Initial observation	Observation after 4 hours
1.	Control	White	Remains white
2.	1 % Citric acid	White	Bright white
3.	1 % salt solution	White	No change in colour
4.	1 % sugar solution	White	No change in colour
5.	1 % Lime juice	White	Remains white with bleached effect

Varikka rinds in the pre-treatment media was observed for their colour change due to enzymatic browning after 4 hours. The different pre-treatment media used were 1 % citric acid solution, 1 % salt solution, 1 % sugar solution, 1 % lime juice along with control. The *varikka* rinds which were cut were immediately immersed in the pre-treatment media. At the beginning the *varikka* rinds were white in colour. After 4 hours, the control treatment retained their white colour, in 1 per cent citric acid solution the *varikka* rinds retained their white colour, whereas in 1 per cent salt solution and 1 per cent sugar solution there was no colour change after 4 hours. In 1 per cent lime juice, *varikka* rinds were observed to retain their white colour with bleached effect.

4.3 PROCESSING OF JACKFRUIT RIND FLOUR

Commercially there are various base materials like urad, rice, sago etc., that are used in the preparation of *papad* and other snack poducts. Rice - the most important food crop for human consumption is the staple food for nearly half of the world population. Now-a-days most of the cultivable lands are kept fallow due to scarcity of inputs and scanty rainfall and majority of the population are living under poverty. Hence this study, was aimed to replace the dependence on rice for the production of *papad* and snack products with fiber rich jackfruit rind flour.

4.3.1 Preliminary Processing

After harvesting, fruits were cleaned under running water. The physical characteristics of *koozha* and *varikka* jackfruits were ascertained. The thorns and outer skin of jackfruit were removed. Jackfruit rind was separated from the fruit and perianth. The thickness and weight of the rind was measured and the rind was cut into equal sized cubes of size 2 cm × 1.5 cm (length × breadth).

The cut rinds were washed under running water and again with deionized water. It was soaked in boiling water for 10 mins. It was washed with water and soaked in boiling solution of 0.1 percent of food grade sodium bisulfite ($NaHSO_3$). It was again washed with water followed by soaking in boiling solution of 0.1 per cent of sodium bicarbonate ($NaHCO_3$) for 15 mins.

4.3.2 Flour preparation

The pretreated jackfruit rinds were spread in trays and dried in convection drier at a temperature of 50 °C for 24 hrs. It was then ground using a miller and further sieved through a 355-µm mesh sieve. The obtained jackfruit rind flour was packed in polypropylene (PP) covers and stored in a fridge at 4°C prior to use (Feli, 2013).

4.4 FUNCTIONAL QUALITY ANALYSIS OF FLOUR

4.4.1 Functional properties of jackfruit rind flour

The flour prepared from the dehydrated jackfruit rind of cultivars *Koozha and varikka* were analyzed for various functional properties such as water absorption index, oil absorption index, foaming capacity, swelling power, percentage solubility and least gelation concentration.

Functional properties are reflected from the complex interactions between the physical and chemical components of food along with their association with environment. These properties are essential to ascertain the activities of food components in specific conditions (Siddiq *et al.*, 2009).

In this study, the functional properties of *Koozha and varikka* jackfruit rind flour were analyzed and the results were compared with raw rice flour and is depicted in table: 16 and 17 respectively.

Table: 16 Functional properties of *koozha* jackfruit rind flour

Functional qualities (%)	**Raw rice flour**	***Koozha* jackfruit rind flour**	**"t" values (0.05)**
Water absorption index	5.43	4.98	12.244
Oil absorption index	1.79	1.12	-3.672
Foaming capacity	3.52	0.399	-243.722
Swelling power	7.62	7.7	-
Solubility	1.86	1.8	-
Gelation concentration	6	8	-
Rehydration ratio	0.182	0.179	-

(Values represent mean of three replication)

Table: 17 Functional properties of *varikka* jackfruit rind flour

Functional qualities (%)	Raw rice flour	*Varikka* jackfruit rind flour	"t" values (0.05)
Water absorption index	5.43	4.88	12.244
Oil absorption index	1.79	1.15	-3.677
Foaming capacity	3.52	0.6	-153.722
Swelling power	7.62	7.93	-2.819
Solubility	1.86	1.64	-
Gelation concentration	6	10	-1.227
Rehydration ratio	0.182	0.188	-

(Values represent mean of three replication)

4.4.1.1 Water Absorption Index

The analysis revealed that *koozha* jackfruit rind flour had lower (4.98 %) water absorption capacity than rice flour (5.43 %). It was significantly different at 5 % level.

The analysis revealed that *varikka* jackfruit rind flour had lower (4.88 %) water absorption capacity than rice flour (5.43 %) and this difference was statistically significant.

4.4.1.2. Oil Absorption Index

The oil absorption capacity of *koozha* jackfruit rind flour in this study was lower than that of raw rice flour (1.12 % and 1.79 % respectively). The lower oil absorption capacity of *koozha* jackfruit rind flour could be due to the hydrophobic proteins.

The oil absorption capacity of *varikka* jackfruit rind flour in this study was lower than that of raw rice flour (1.15 % and 1.79 % respectively). The lower oil absorption capacity of *varikka* jackfruit rind flour could also be due to the hydrophobic proteins. The relatively low oil absorption capacity of *koozha* and *varikka* JRF suggests that it will reduce the amount of fat in cooking procedure, which is a healthy attribute.

4.4.1.3 Foaming Capacity

Proteins foam when whipped, since they have higher surface activity. The foaming capacity is used as an index of the whipping feature of protein isolates. This explains why jackfruit rind flour had lower foaming capacity, since it is recorded with lower crude protein content. Here the foaming capacity of raw rice flour was 3.52 per cent, which was higher than the *koozha* jackfruit rind flour (0.399 %). Here the foaming capacity of raw rice flour was higher than the *varikka* jackfruit rind flour (0.598 %).

4.4.1.4 Swelling Power

The swelling power of the flours were 7.63 per cent and 7.7 per cent for *koozha* jackfruit rind flour and raw rice flour respectively. There was no significant difference at 5 % level. Formation of protein amylase complexes in flour could be the cause of the higher swelling power. The extent of swelling depends on the temperature and availability of water. As per literature, increase in water absorption increases the swelling power.

The swelling power of the *varikka* rind flours was 7.92 per cent. The lower swelling power when compared to raw rice flour suggests that jackfruit rind flour could be useful which requires low swelling property in foods.

4.4.1.5 Solubility

Solubility value of *koozha* jackfruit rind flour was 1.8 per cent, while for the raw rice flour it was 1.86 per cent. There is no significant difference seen between the solubility of *koozha* jackfruit rind flour and raw ice flour hence the solubility of *koozha* jackfruit rind flour suggests that, it could be suitable for processing.

Similarly, solubility value of *varikka* jackfruit rind flour was seen to be 1.64 per cent. There is no significant difference between the solubility of *varikka* jackfruit rind flour and raw rice flour.

4.4.1.6 Gelation Concentration

Food gels are viscoelastic in nature and many gelled food products are produced around the world. The least gelation concentration of raw rice flour (6) was lower than the *koozha* jackfruit rind flour (8) and this difference was statistically significant at 5 % level.

The least gelation concentration of *varikka* jackfruit rind flour (10) was also higher than raw rice flour (6) and this difference was statistically significant.

4.4.1.7 Rehydration ratio

Drying brings about a substantial reduction in the volume and weight of a product thereby making it suitable for packaging, storage and transportation and it also helps to increase the storability of the product under ambient temperature (Senadeera, *et al.*, 2005).

Rehydration ratio is the weight of dehydrated sample to drained weight of rehydrated sample. The rehydration ratio of *Koozha* jackfruit rind flour was found to be 0.179 per cent.

Rehydration of dried powder is a complex procedure influenced by several factors such as chemical composition, drying techniques used, temperature and composition of the immersion medium, all of which play a major role on the quality attributes of the product (Kaymak, 2002).

Rehydration ratio is the weight of dehydrated sample to drained weight of rehydrated sample. The rehydration ratio of *varikka* jackfruit rind flour was found to be 0.188 per cent.

4.4.2 Nutrient composition of jackfruit rind flour

A nutrient is a substance that provide nourishment to grow, develop and reproduce. The nutrients like carbohydrates, protein, fat, crude fiber, dietary fiber, starch and ash content was analyzed using standard procedures as given in the table: 18. Nutrients of raw and ripened of cv. *Koozha* and *varikka* were analyzed.

Carbohydrate

Being the major source of calorie, carbohydrate is the nutrient of concern in all food products. The carbohydrate content was higher in ripened *koozha* jackfruit rind flour (RKJRF) (63g/100g) followed by ripened *varikka* jackfruit rind flour (RVJRF) (55 g/100g) then raw *varikka* jackfruit rind flour (VJRF) (45 g/100g) and was lower in raw *koozha* jackfruit rind flour (KJRF) (29 g/100g). This result shows that the KJRF had lower carbohydrate content which would be suitable for low calorie diet.

Protein

Protein is one of the major nutrients required by the body to carry out a wide range of functions essential for the maintenance of life. Proteins are essential components of tissues and cells of the body (Gopalan *et al.*, 2009). Protein content embedded in starch depends on its origin. In general, cereal and pulses have higher protein content than tuber and root starches. The protein content can cause undesirable colour changes in starch due to Mailard reaction. Moreover, proteins could strike the surface charge and the rate of water absorption (Sai *et al.*, 2009).

The protein content was higher in ripened *koozha* jackfruit rind flour (RKJRF) (4.8 g/100g) followed by *koozha* jackfruit rind flour (KJRF) (2.7 g/100g), then ripened *varikka* jackfruit rind flour (RVJRF) (2.2 g/100g) and was lower in *Varikka* jackfruit rind flour (VJRF) (1.2 g/100g) This result shows that the VJRF had lower protein content. The cv. *koozha* was seen to have a high protein content when compared to cv. *varikka*.

Fats

Fat is an essential nutrient as it provides energy, helps to absorb certain nutrients and maintains core body temperature. The fat content was higher in RKJRF (3.8 g/100g) followed by VJRF (2.74 g/100g) then RVJRF (2.7 g/100g) and lowest in KJRF (1.84 g/100g). The result shows that fat content was found to be increasing with ripening. It was also found that KJRF had lower fat content when compared to VJRF which is a healthier attribute for human diets.

Crude fiber

Fibre is the indigestible portion of food derived from plants. Fibre can act by altering the nature of the contents of the gastrointestinal tract and change the rate of absorption of nutrients and chemicals.

The crude fiber was higher in KJRF (18 g/100g) followed by VJRF (15 g/100g). Crude fiber of RKJRF and RVJRF were on par at 5 per cent level with 12 g/100g and 11 g/100g respectively and was found to be decreasing with ripening. Since crude fiber was high in jackfruit rind flour it could be useful in the prevention of constipation.

Table: 18 Nutrient composition of jackfruit rind flour (per 100 g)

SL. No.	Rind flour	Carbohydrates (g)	Proteins (g)	Fats (g)	Crude fiber (g)	Dietary fiber (g)	Iron (µg/g)	Starch (g)	Ash (%)
1.	**KJRF**	29^{d}	2.7^{b}	1.84^{d}	18^{a}	13.56^{a}	84^{a}	20.5^{b}	7.2^{b}
2.	**VJRF**	45^{c}	1.2^{d}	2.74^{b}	15^{b}	12.89^{b}	15^{c}	19^{c}	7.98^{a}
3.	**RKJRF**	63^{a}	4.8^{a}	3.8^{a}	12^{c}	12.11^{c}	25.5^{b}	25.5^{a}	6.98^{c}
4.	**RVJRF**	55^{b}	2.2^{c}	2.7^{c}	11^{c}	11.35^{d}	25^{b}	25^{a}	6.45^{d}
	CD (0.05)	1.888*	0.491*	0.182*	1.888*	0.182*	1.780*	0.944*	0.182*

(Results expressed are mean values of three replicates) *significant @ 5 %

Koozha jackfruit rind flour (KJRF)   Ripened *Koozha* jackfruit rind flour (RKJRF)

Varikka jackfruit rind flour (VJRF)   Ripened *Varikka* jackfruit rind flour (RVJRF)

Values denoted by different letters in the same column are significantly different ($P < 0.05$)

Dietary fiber

Fiber is a carbohydrate polymers with ten or more monomeric units that are not hydrolyzed by the digestive enzymes in the small intestine of human beings. Dietary fiber is a portion of food that is not digested in the human small intestine. It moves into the large intestine where it is partially or fully fermented.

The dietary fiber was higher in KJRF (13.56 g/100g) followed by VJRF (12.89 g/ 100g). Dietary fiber of RKJRF and RVJRF was 12.11 g/100g and 11.35 g/100g. Dietary fiber in raw jackfruit of both cultivars decreased with ripening.

Iron

Iron is an essential micro nutrient found in nearly all living organisms. Iron is important for the normal growth and development of the human body. It helps to digest proteins and in the production of hemoglobin and red blood cells. Iron deficiency in the blood could cause a deficiency condition called iron deficiency anemia.

Iron content was higher in KJRF (84 μg/ 100g) followed by RKJRF (25.5 μg/ 100g) which was on par with RVJRF (25 μg/ 100g) and was lower in VJRF (15 μg/ 100g). Iron rich KJRF could be useful in the prevention of iron deficiency anemia.

Chemical composition of jackfruit rind flour

The chemical constituents like tannins, polyphenols, total phenols, flavonoids, lectin, pectin etc., were analyzed and is given in the table: 19.

Total phenols

Phenolic compounds are grouped into simple phenols or polyphenols depending on the number of phenol units in the molecule. Total phenol content in KJRF (2 g/ 100g) was higher when compared to the total phenol in RVJRF (0.7 g/ 100g), which was on par with VJRF (0.6 g/ 100g) and RKJRF (0.56 g/ 100g).

Polyphenols

Polyphenols also known as polyhydroxy phenols are a structural group of mainly natural, sometimes synthetic or semisynthetic, organic chemicals distinguished by the presence of large multiples of phenolic structural units.

Analysis of polyphenols revealed that KJRF (2 g/ 100g) had higher polyphenols when compared to RKJRF (1 g/ 100g), which was on par with KJRF and RVJRF (0.2 g/ 100g) and VJRF (0.15 g/ 100g).

Tannins

A tannin is an organic matter found in some galls, barks and other plant tissues, consisting of derivatives of gallic acid which is yellowish or brownish that tastes bitter. Tannins are water-soluble polyphenols that are found in different plant foods. It is an astringent, which binds and precipitates proteins and many other organic components like amino acids and alkaloids.

From the analysis of Tannin content, it was found that KJRF (0.088 g/ 100g) had higher tannin content compared to VJRF (0.016 g/ 100g), which was on par with RKJRF (0.018 g/ 100g) and RVJRF (0.019 g/ 100g).

Flavonoids

Flavonoids are water soluble polyphenolic compounds that contains 15 carbon atoms. Flavonoids are a group of plant metabolites providing health benefits through cell signaling pathways and antioxidant properties. These are present in many fruits and vegetables.

Flavonoids were found to be higher in RKJRF (0.65 g/ 100g) and were on par with the flavonoid content of KJRF (0.48 g/100g) the latter was on par with the flavonoid content of VJRF (0.373 g/ 100g) and RVJRF (0.34 g/ 100g).

Table: 19 Chemical composition of jackfruit rind flour (per 100 g)

SL. No.	Rind Flour	Total Phenols (g)	Polyphenols (g)	Tannins (g)	Flavonoid (g)	Moisture (%)	Lectin (g)	Pectin (g)	Peroxide value (mEq/ Kg)	Total Anti-oxidant activity (g)
1.	**KJRF**	2^{a}	2^{a}	0.088^{a}	0.48^{ab}	1	0.32	14^{c}	0.5^{c}	0.3^{bc}
2.	**VJRF**	0.6^{b}	0.15^{b}	0.016^{b}	0.373^{b}	0.5	0.31	16.5^{b}	2^{b}	0.263^{c}
3.	**RKJRF**	0.58^{b}	1^{ab}	0.018^{b}	0.65^{a}	1.5	0.42	26.5^{a}	3.5^{a}	0.346^{ab}
4.	**RVJRF**	0.7^{b}	0.2^{b}	0.019^{b}	0.34^{b}	1	0.43	27.5^{a}	4.0^{a}	0.376^{a}
	CD (0.05)	0.182*	1.190*	0.005*	0.182*	NS	NS	1.888*	0.827*	0.095*

(Results expressed are mean values of three replicates) *significant @ 5 %

Koozha jackfruit rind flour (KJRF) Ripened *Koozha* jackfruit rind flour (RKJRF)

Varikka jackfruit rind flour (VJRF) Ripened *Varikka* jackfruit rind flour (RVJRF)

Values denoted by different letters in the same column are significantly different (P< 0.05)

Moisture

Moisture present in the food is one of the generally calculated properties of foods.

The statistical analysis reveals that there were no significant difference in the moisture content of the processed jackfruit rind flour. The moisture content of KJRF was 1 per cent, VJRF – 0.5 per cent, RKJRF – 1.5 per cent and RVJRF 1 per cent.

Lectin

Lectins are group of proteins which binds to cell membranes. They bind to sugar and form the 'glyco' portion of the glycol-conjugates on membranes. Lectins are sometimes referred as anti-nutrients, since they can reduce the body's ability to absorb nutrients.

Difference in levels of lectin content was found to be statistically non-significant at 5 per cent level among the jackfruit cultivars. Lectin content of KJRF was 0.32 g/ 100g, VJRF- 0.31 g/ 100g, RKJRF - 0.42 g/ 100g and RVJRF - 0.43 g/ 100g.

Pectin

Pectin have a gelatin-like structure that is present in the cell walls of plants. Pectin has the properties of gel and is sometimes cited as a delicate solid in cooking.

Pectin content was higher in RVJRF (27.5 g/ 100g) which was on par with RKJRF (26.5 g/ 100g). It was followed by VJRF (16.5 g/ 100g) and lower in KJRF (14 g/ 100g). This shows that pectin content in the jackfruit increases with ripening.

Peroxide value

Peroxide value is defined as the amount peroxide oxygen per 1 kilogram of fat or oil. Peroxide value is generally used to identify the rancidity of the food containing fat or oil that leads to oxidation.

Peroxide value was found to be higher in RVJRF (4 mEq/ kg) and RKJRF (3.5 mEq/ kg) followed by VJRF (2 mEq/ kg) and lower in KJRF (0.5 mEq/ kg). The result shows that peroxide value was higher in ripened jackfruit rind flour than raw jackfruit rind flour.

4.4.3 Total Anti-oxidant activity

Antioxidants are molecules that help in either delaying or inhibiting the oxidation procedure that takes place due to the presence of atmospheric oxygen or reactive oxygen species. They have the property to stabilize food materials and it is used commercially in many industries. There is a rising scope for antioxidants, especially for its property to protect the harmful effects of free radicals produced in the human body and also the deterioration of fats and other constituents of foodstuffs.

From the analysis of total anti-oxidant activity of jackfruit rind flour of different cultivars, RVJRF had higher total anti-oxidant activity (0.376 g/100g), followed by RKJRF (0.346 g/ 100g), which was on par with RVJRF. KJRF had 0.3 g/ 100g total anti-oxidant activity which was on par with VJRF (0.263 g/100g).

4.5 PREPARATION OF COMPOSITE FLOUR

Composite flour is more beneficial in developing countries since it cut down the importance of rice flour thereby encouraging the utilization of crops that are available in local as flour (Hasmadi *et al.*, 2014). Rice flour replacement by the local raw material is gaining importance due to the developing market for confectioneries (Noor Aziah and Komathi, 2009). Hence many developing countries is encouraging the initiation of programmes to determine the possibility to incorporate alternate flours that are available locally as a replacement for rice flour (Abdelghafor *et al.*, 2011). For this study *koozha and varikka* jackfruit rind flour was taken as the substitute for rice/black gram flour.

In this study, raw rice flour (RF), *koozha* jackfruit rind flour (KJRF), *varikka* jackfruit rind flour (VGRF) and black gram flour (BGF) were the basic materials used for the development of composite flour. The different combinations attempted for the Composite flour formulations are presented in Table: 5 and 6

The table: 7 and 8 presents the treatments selected for the formulation of *papads* and crispies with rice flour, *varikka* jackfruit rind flour and black gram flour respectively in the pre-determined proportions. The proportions of these ingredients in the treatment T_1 to T_5 and control were T_1 (50:50:0), T_2 (50:40:10), T_3 (60:30:10), T_4 (70:20:10), T_5 (80:10:10) and control (100:0:0).

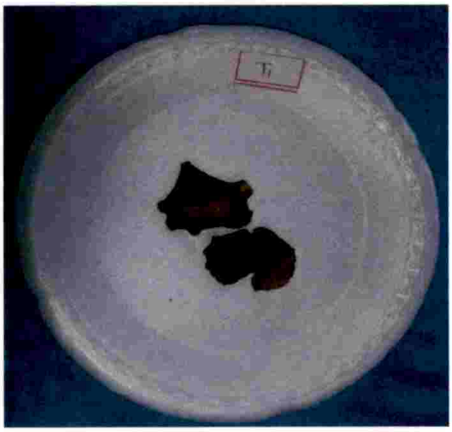
Similarly, the treatments selected for the formulation of *papads* and crispies with, rice flour, *koozha* jackfruit rind flour and black gram flour respectively in the pre-determined proportions is given in the table: 9 and 10. The proportions of these ingredients in the treatment T_6 to T_{10} and control were T_6 (50:50:0), T_7 (50:40:10), T_8 (60:30:10), T_9 (70:20:10), T_{10} (80:10:10) and control (100:0:0).

4.6 STANDARDIZATION OF *PAPAD*

A *papad* is a light, brittle, disc-shaped food from the Indian subcontinent mostly based on a dough o batter generally made from black gram flour (urad flour) or rice flour respectively. Thus in this study, *Papad* was standardized with both the cultivars *koozha and varikka* jackfruit rind flour.

Composition of the treatments for *varikka* jackfruit rind *papad* is given the table: 7 for the net weight of 100g.The composition of rice flour was 50g, 50g, 60g, 70g, 80g and 100g in T_1, T_2, T_3, T_4, T_5 and control respectively. The amount of *varikka* jackfruit rind flour was 50g, 40g, 30g, 20g, 10g and 0 T_1, T_2, T_3, T_4, T_5 and control respectively. The quantity of black gram flour was T1 (0), T2 (10g), T3 (10g), T4 (10g), T5 (10g) and control (0).The composition of sago was 25g/ 100g in all the treatments. The composition of salt used was 3g/ 100g in all the treatments. The composition of

Plate: 9 *Varikka* jackfruit rind *papad* (P)



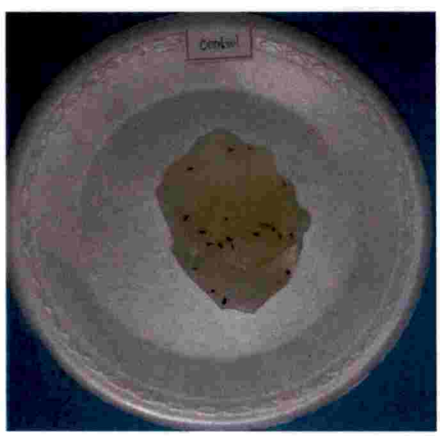
T_1 P

T_2 P

T_3 P

T_4 P

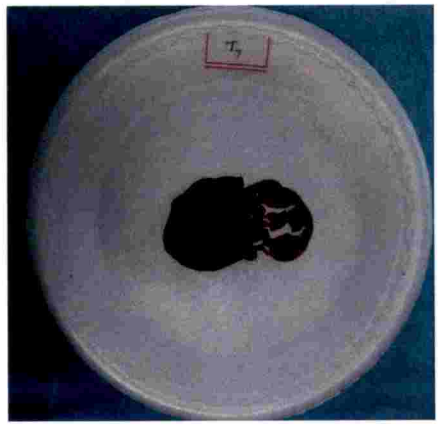
T_5 P



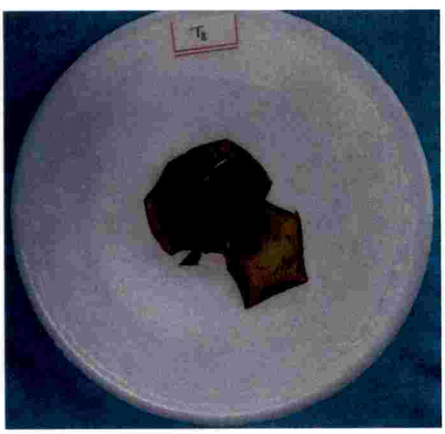
Control

Plate: 10 *Koozha* jackfruit rind *papad* (P)

T_6 P



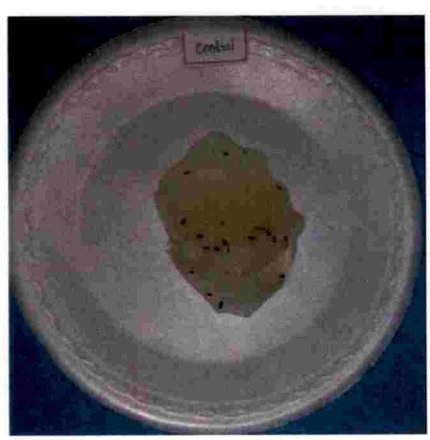
T_7 P



T_8 P

T_9 P

T_{10} P



Control

cinnamon used in the preparation of *papad* was 2.5g/ 100g in the treatments. The composition of water used in all the treatment was 300 ml/ 100g.

Composition of the treatments for *koozha* jackfruit rind *papad* is given the table: 8 for the net weight of 100g. The amount of rice flour was 50g, 50g, 60g, 70g, 80g and 100g in T_6, T_7, T_8, T_9, T_{10} and control respectively. The quantity of *koozha* jackfruit rind flour in T_6, T_7, T_8, T_9, T_{10} and control were 50g, 40g, 30g, 20g, 10g and 0 respectively. The proportion of black gram flour was T6 (0), T7 (10g), T8 (10g), T9 (10g), T10 (10g) and control (0).The amount of sago was 25g/ 100g in all the treatments. The composition of salt used was 3g/ 100g in all the treatments. The quantity of cinnamon used in the preparation of *papad* was 2.5g/ 100g in the treatments. The composition of water used in all the treatment was 300 ml/ 100g of jack fruit rind flour.

Koozha and *varikka* jackfruit rind *papad* was processed by the preparation of composite flour soaked along with sago for 4 hours, which was then ground to batter and fermented for 24 hours. After fermenting, adjuncts like salt and cinnamon were added to the batter. The batter of 10-15g was spread on pre oiled plates and steamed for 2-3 minutes. The steamed *papads* were peeled off and dried at 65° C for 5 hours in a convectional drier. The dried *papads* were packed in polypropylene (PP) covers and stored at ambient conditions. The developed *varikka* and *koozha* jackfruit rind *papad* is shown in the plate: 9 and 10.

4.7 STANDARDIZATION OF CRISPIES

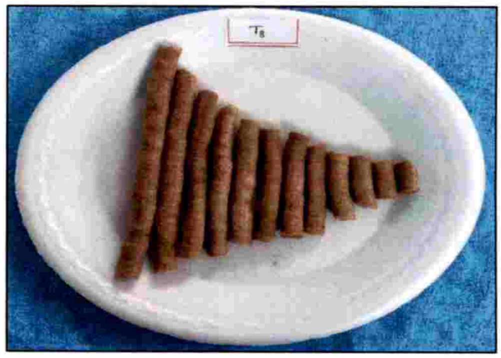
Food extrusion is a process in which a group of different ingredients are thrown into an opening that have a perforated plate or die with a design precise to the food, and is then cut to a desirable size using blades.

The extruder consists of a large, rotating screw tightly fitting within a stationary barrel, at the end of which is the die. Extrusion helps in mass production of food via a ceaseless, competent system that confirms the uniformity of the final product.

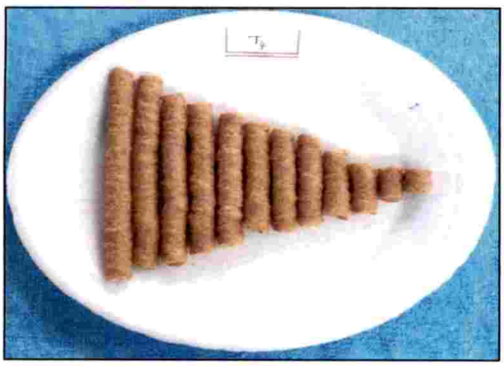
Plate: 11 Extruded crispies (C)

Varrika crispies | *koozha* crispies

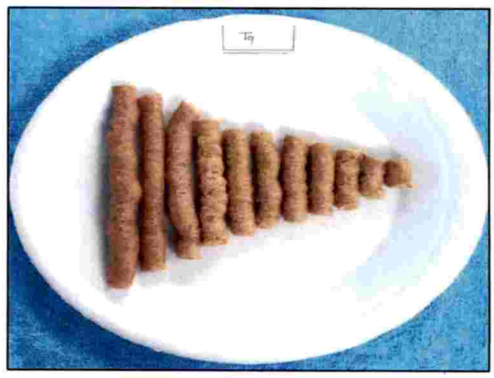
T_3 C



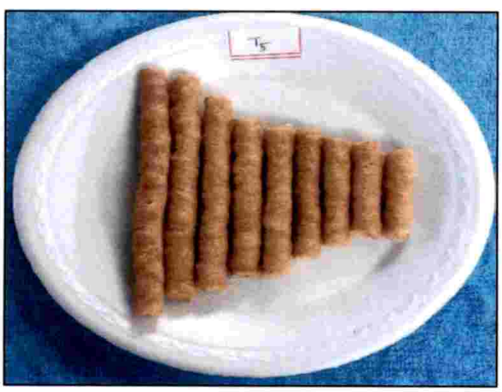
T_8 C



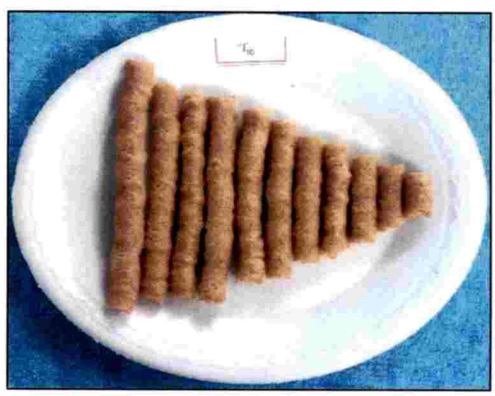
T_4 C



T_9 C



T_5 C



T_{10} C

Crispies are pleasantly thin, dry, and easily broken, having a pleasantly crisp outer layer extruded using extruder. In this study, crispies were standardized with both the cultivars *koozha and varikka* jackfruit rind flour.

Composition of the treatments for *varikka* jackfruit rind crispies is given the table: 10 per 100g. The proportion of rice flour was 50g, 50g, 60g, 70g, 80g and 100g in T_1, T_2, T_3, T_4, T_5 and control respectively. The composition of *varikka* jackfruit rind flour was 50g, 40g, 30g, 20g, 10g and 0 T_1, T_2, T_3, T_4, T_5 and control respectively. The composition of black gram flour was T1 (0), T2 (10g), T3 (10g), T4 (10g), T5 (10g) and control (0).

The composition of salt used was 3g/ 100g in all the treatments. The composition of water used in all the treatment was 12 ml/ 100g. The composition of refined oil used was 10 ml/ 100g in all the treatments. The proportion of seasoning masala (masti masala) (15g/ 100g) which was purchased from spice station, Ernakulam, Kerala, was used in the preparation of crispies was 2.5g/ 100g in the treatments.

Composition of the treatments for *koozha* jackfruit rind crispies is given the table: 11 for the net weight of 100g. The composition of rice flour was 50g, 50g, 60g, 70g, 80g and 100g in T_6, T_7, T_8, T_9, T_{10} and control respectively. The composition of *koozha* jackfruit rind flour in T_6, T_7, T_8, T_9, T_{10} and control were 50g, 40g, 30g, 20g, 10g and 0 respectively. The composition of black gram flour was T_6 (0), T_7 (10g), T_8 (10g), T_9 (10g), T_{10} (10g) and control (0).

The quantity of salt used was 3g/ 100g in all the treatments. The amount of water used in all the treatment was 12 ml/ 100g. The proportion of refined oil used was 10 ml/ 100g in all the treatments. The composition of seasoning masala (masti masala) (15g/ 100g) which was purchased from spice station, Ernakulam, Kerala, was used in the preparation of crispies was 2.5g/ 100g in the treatments.

The composite flour was fed into the input container of the SLG 30 twin screw extruder and the required amount of water was poured into inlet and the temperature was adjusted to 90° C.

The first obtained extruded product was discarded in order to get the product with full expansion after the stabilization of temperature. The crispies could be produced in desired shapes like round and lengthy sticks of different sizes by adjusting the dies in the extruder.

The extruded crispies were sprayed with refined oil and seasoning masala in the mixer for enhancing the taste. It was then packed in PP covers and stored at ambient conditions. The developed *varikka* and *koozha* jackfruit rind *papad* is shown in the plate: 11. The processing parameters of crispies using SLG 30 twin screw extruder was given in the table: 12.

4.8 QUALITY EVALUATION OF THE JACKFRUIT RIND BASED PRODUCTS

Quality is the level of excellence of a food with the inclusion of all the characteristics of a food that are important and it makes the food satisfactory. Food quality is an essential part of the food production because, the people choice depends highly on quality. Consumer acceptance is important to the food industries, who wants to benefit as wide a profit in the market for the produce.

4.8.1 Sensory Evaluation of the developed Products

Sensory analysis is a field of study that uses the principles of experimental design and statistical analysis to utilize human senses like sight, smell, taste, touch and hearing in the aim of assessing consumer products.

4.8.1.1 Sensory evaluation of varikka jackfruit rind papad

Sensory evaluation scores are the mean rank scores of 10 judges who were selected to evaluate the product. They rated the appearance, texture, taste, aroma and overall acceptability for *varikka* jackfruit rind *papad* and is give in the table: 20.

Appearance

Piles of factors impart to the total perception of the appearance of a food. This perception is developed from all the visual sensations felt when a product is seen on the shelf, because when it is prepared and presented on the plate, all three zones are essential to the consumer.

The sensory evaluation revealed that the mean rank value for appearance of *varikka* jackfruit rind *papad* ranged between 11.4– 41.65. From Kruskal- Wallis test it was analyzed that T_5 obtained the first rank with the mean rank value of 41.65 after control (45.56). While T_1 got the last rank with mean rank value 11.4. T_5 was on par with T_4 whereas other treatments were significantly different from T_5 at 5 % level.

Colour

The colour seen by human eyes is the perception of the wavelengths released from the surface of the food on the retina of the eyes. Food appearance can change according to the intensity of light, source of the light, the observer's angle of view, size and background differences.

The sensory evaluation revealed that the mean rank value for colour of *varikka* jackfruit rind *papad* ranged between 11.65– 41.55. From Kruskal- Wallis test it was analyzed that T_5 obtained the first rank with the mean rank value of 41.55 after control (44.32). While T_1 got the last rank with mean rank value 11.65. T_5 was on par with T_4 whereas other treatments were significantly different from T_5 at 5 % level.

Aroma

Because of aroma, a mass of people who experience different flavour while eating actually occurs through their sense of smell, not taste. Olfactory scientists realize that the cells present in the lining of the nose that have different components accountable for aroma. Food flavour seems to be the most important acceptability criterion before texture and appearance.

Table: 20 Sensory evaluation of jackfruit rind *Papad (varikka)*

Treatment	Appearance		Color		Aroma		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
T_1	11.40	2.9	11.65	3.0	14.60	3.5	14.40	3.2	12.35	3.0	11.25	2.9
T_2	17.75	3.7	18.30	3.9	15.80	3.9	19.20	4.2	20.10	4.4	17.60	4.1
T_3	22.00	4.2	23.05	4.5	22.35	4.6	20.70	4.4	21.25	4.6	22.55	4.8
T_4	34.70	5.9	32.95	5.7	34.25	6.1	33.25	6.2	33.15	6.3	34.70	6.4
T_5	**41.65**	**7.1**	**41.55**	**7.1**	**40.50**	**7.1**	**39.95**	**7.0**	**40.65**	**7.4**	**41.40**	**7.4**
Control	45.56	7.7	44.32	7.6	45.20	7.7	45.70	7.8	46.63	7.9	45.90	7.8
K	29.70		27.17		25.33		21.95		24.37		29.40	
χ^2	9.49											
CD (0.05)	18.299											

(MRV- Mean rank value, MS- Mean score)

The sensory evaluation revealed that the mean rank value for aroma of *varikka* jackfruit rind *papad* ranged between 14.6– 40.5. From Kruskal- Wallis Test, it was analyzed that T_5 obtained the first rank with the mean rank value of 40.50 after control (45.2). While T_1 got the last rank with mean rank value 14.6. T_5 was on par with T_4 and T_3 with respect to aroma whereas T_1 and T_2 were significantly different from T_4 and T_5 at 5 % level.

Texture

Texture can be defined as the sensation experienced by the tongue or skin and is characterized by coarseness or fineness. From the evaluation of texture it was found that T_5 got the highest mean rank value of 39.95 for this attribute after the control (45.70) and T_1 got the lowest mean rank value of 14.4.The difference among these scores were found to be significant at 5 % level.

Taste

One of the main reason that taste sensations are essential is that they boost our bodies to digest food. For example, tasting and smelling food, triggers our salivary glands and digestive enzymes. Thus, we learn to rely on our senses of taste and smell to be aware of foods that are harmful.

The sensory evaluation revealed that the mean rank value for taste of *varikka* jackfruit rind *papad* ranged between 12.35– 40.65. From Kruskal- Wallis test, it was analyzed that T_5 obtained the first rank with the mean rank value of 40.65 after control (46.63). While T_1 got the last rank with mean rank value 12.35. T_5 was on par with T_4 whereas other treatments were significantly different from T_4 and T_5 at 5 % level.

Overall acceptability

Over all acceptability of a food products can be judged through their appearance colour, texture and taste of the product. It was noted that T_5 obtained the highest mean rank value of 41.4 after control (45.90). While T_1 got the last rank with mean rank value of 11.25. T_5 was on par with T_4 in overall acceptability, whereas T_1 was significantly different from T_4 and T_5 at 5 % level from other treatments.

4.8.1.2 Sensory evaluation of koozha jackfruit rind papad

Sensory evaluation scores of *koozha* jackfruit rind *papad* is given in the table: 21.

Appearance

The appearance of a food influences its craving and acceptance, before the product ever touches the lips.

The sensory evaluation revealed that the mean rank value for taste of *koozha* jackfruit rind *papad* ranged between 11.75– 40.90. From Kruskal- Wallis test it was analyzed that T_{10} obtained the first rank with the mean rank value (40.90) after control (45.56). While T_6 got the last rank with mean rank value 11.75. T_{10} was on par with T_9 whereas other treatments were significantly different from each other at 5 % level.

Colour

While taste and smell of food plays an important role, most of us also prefer food of certain colours. Doctors recommend that we eat different coloured foods, especially fruits and vegetables, so as to get different nutrients. The sensory evaluation revealed that the mean rank value for colour of *koozha* jackfruit rind *papad* ranged between 13.40– 42.50. From Kruskal- Wallis test, it was analyzed that T_{10} obtained the first rank with the mean rank value of 42.50 after control (44.32), while T_6 got the last rank with mean rank value 13.4. T_{10} was on par with T_9 whereas other treatments were significantly different from each other at 5 % level.

Aroma

The intricate association between aroma and flavour demands rigorous sensory analysis in order to determine what products will be acceptable to the consumer. The sensory evaluation revealed that the mean rank values for aroma of *koozha* jackfruit

Table: 21 Sensory evaluation of jackfruit rind *Papad (Koozha)*

Treatment	Appearance		Color		Aroma		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
T_6	11.75	3.9	13.40	3.7	13.85	3.5	13.95	3.7	14.90	3.9	14.25	3.9
T_7	17.90	4.7	15.75	4.0	17.05	4.1	19.40	4.5	16.60	4.4	17.80	4.7
T_8	22.60	5.6	25.00	5.4	25.35	5.4	22.85	5.1	25.65	6.0	23.15	5.7
T_9	34.35	6.9	30.85	6.2	30.75	6.2	32.10	6.4	30.10	6.5	30.50	6.6
T_{10}	**40.90**	**7.6**	**42.50**	**7.9**	**40.50**	**7.6**	**39.20**	**7.3**	**40.25**	**7.7**	**41.80**	**7.9**
Control	45.56	7.7	44.32	7.6	45.20	7.7	45.70	7.8	46.63	7.9	45.90	7.8
K	27.69		26.84		22.21		19.72		20.96		23.39	
χ^2	9.49											
CD (0.05)	18.299											

(MRV- Mean rank value, MS- Mean score)

rind *papad* ranged between 13.85– 40.50. It was analyzed statistically that, T_{10} obtained the first rank with the mean rank value of 40.5 after control (45.2), while T_6 got the last rank with mean rank value 13.85. T_{10} was on par with T_9 and T_8 in aroma whereas T_6 and T_7 were significantly different from other treatments at 5 % level.

Texture

Texture can be defined as the sensation experienced by the tongue or skin and it is characterized by coarseness or fineness. From the evaluation of texture it was found that T_{10} got the highest mean rank value of 39.20 for this attribute after the control (45.7) and T_6 got the lowest mean rank value of 13.95.The difference in these scores were found to be significant at 5 % level.

Taste

The sensory evaluation revealed that the mean rank value for taste of *koozha* jackfruit rind *papad* ranged between 14.90– 40.25. It was analyzed that T_{10} obtained the first rank with the mean rank value of 40.25 after control (46.63), while T_6 got the last rank with mean rank value 14.90. T_{10} was on par with T_9 and T_8 whereas other treatments were significantly different from T_{10} at 5 % level.

Overall acceptability

Over all acceptability of a food product can be judged through its appearance colour, texture and taste of the product. It was noted that T_{10} obtained the highest mean rank value of 41.80 after control (45.90), while T_6 got the last rank with mean rank value 14.25. T_{10} was on par with T_9 in overall acceptability, whereas other treatments were significantly different at 5 % level.

4.8.1.3 Sensory evaluation of varikka jackfruit rind crispies

Sensory evaluation scores of *varikka* jackfruit rind crispies is given in the table: 22.

Appearance

The sensory evaluation revealed that the mean rank value for appearance of *varikka* jackfruit rind crispies ranged between 10.15– 20.55. From Kruskal- Wallis test it was analyzed that T_4 obtained the first rank with the mean rank value of 20.55 after control (25.33), while T_3 got the last rank with mean rank value 10.15. T was on par with T_4 at 5 % level.

Colour

Colour is one of the most important cues used by consumers to assess the quality of a food product. The sensory evaluation revealed that the mean rank value for colour of *varikka* jackfruit rind crispies ranged between 9.80– 21.20. The results after analysis showed that, T_4 obtained the first rank with the mean rank value of 21.2 after control (24.52). While T_1 got the last rank with mean rank value 9.8, T_4 was on par with T_5 at 5 % level.

Aroma

Flavour or aroma plays an important role in the consumption and acceptance of food and in the quality of life in general.

The sensory evaluation revealed that the mean rank value for aroma of *varikka* jackfruit rind crispies ranged between 14.15– 18.20. From Kruskal- Wallis test, it was analyzed that T_4 obtained the first rank with the mean rank value of 18.20 after control (22.20), while T_3 got the last rank with mean rank value 14.15. T_4 was on par with T_5 and T_3 with respect to aroma at 5 % level.

Texture

Texture is essential in evaluating the eating quality of foods and can have a important role in the food intake and nutrition. From the evaluation of texture, it was found that T_4 got the highest mean rank value 20.90 for this attribute after the control

Table: 22 Sensory evaluation of jackfruit rind *Crispies (Varikka)*

Treatment	Appearance		Color		Aroma		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
T_1	-	-	-	-	-	-	-	-	-	-	-	-
T_2	-	-	-	-	-	-	-	-	-	-	-	-
T_3	10.15	6.5	9.80	6.5	14.15	7.2	11.25	6.9	13.15	6.9	9.65	6.5
T_4	**20.55**	**8.1**	**21.20**	**8.1**	**18.20**	**7.8**	**20.90**	**8.0**	**20.70**	**8.0**	**22.95**	**8.3**
T_5	15.80	7.5	15.50	7.5	14.15	7.3	14.35	7.3	12.65	7.1	13.90	7.2
Control	25.33	8.7	24.52	8.6	22.20	8.3	25.70	8.8	26.20	8.9	25.90	8.8
K	7.727		9.417		1.59		7.035		5.923		13.086	
χ^2	5.99											
CD (0.05)	9.425											

(MRV- Mean rank value, MS- Mean score)

(25.70) and was on par with T_5, whereas T_3 which got the lowest mean rank value of 11.25 at 5 % level.

Taste

Food tasting helps to understand its acceptance among the target consumer groups. The sensory evaluation revealed that the mean rank value for taste of *varikka* jackfruit rind crispies ranged between 13.15– 20.70. From Kruskal- Wallis test it was analyzed that, T_4 obtained the first rank with the mean rank value (20.70) after control (26.20). While T_3 got the last rank with mean rank value 13.15 which was on par with T_5 and T_4.

Overall acceptability

The process by which man accepts or rejects food is of a multi-dimensional nature. It was noted that T_4 obtained the highest mean rank value of 22.95 after control (25.90), while T_3 got the last rank with mean rank value 9.65. T_4 was on par with T_5 in overall acceptability, at 5 % level.

4.8.1.4 Sensory evaluation of koozha jackfruit rind crispies

Sensory evaluation scores of *koozha* jackfruit rind crispies is given in the table: 23.

Appearance

The sensory evaluation revealed that the mean rank value for appearance of *koozha* jackfruit rind crispies ranged between 10.15– 20.55. From Kruskal- Wallis test it was analyzed that T_9 obtained the first rank with the mean rank value of 19.68 after control (25.33), while T_8 got the last rank with mean rank value of 11.70. T_9 was on par with T_{10} at 5 % level.

Colour

Colour is one of the most important cues used by consumers to assess the quality of a food product. The sensory evaluation revealed that the mean rank value for

Table: 23 Sensory evaluation of jackfruit rind *Crispies (Koozha)*

Treatment	Appearance		Color		Aroma		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
T_6	-	-	-	-	-	-	-	-	-	-	-	-
T_7	-	-	-	-	-	-	-	-	-	-	-	-
T_8	11.70	6.5	10.20	6.3	12.60	6.4	11.55	6.1	11.70	5.8	9.60	6.4
T_9	**19.68**	**7.8**	**21.05**	**7.9**	**19.60**	**7.7**	**20.15**	**7.9**	**20.20**	**7.8**	**22.40**	**8.2**
T_{10}	16.25	7.5	15.25	7.1	14.30	6.9	14.80	7.2	14.60	7.0	14.50	7.2
Control	25.33	8.7	24.52	8.6	22.20	8.3	25.70	8.8	26.20	8.9	25.90	8.8
K	4.381		8.019		3.814		5.197		5.037		11.558	
χ^2	5.99											
CD (0.05)	9.425											

(MRV- Mean rank value, MS- Mean score)

colour of *koozha* jackfruit rind crispies ranged between 10.20– 21.05. The results after analysis showed that T_9 obtained the first rank with the mean rank value (21.05) after control (24.52). While T_3 got the last rank with mean rank value of 10.20. T_9 was on par with T_{10} at 5 % level.

Aroma

The sensory evaluation revealed that the mean rank value for aroma of *koozha* jackfruit rind crispies ranged between 12.60– 19.60. It was analyzed statistically that T_9 obtained the first rank with the mean rank value of 19.60 after control (22.20). While T_3 got the last rank with mean rank value 12.60, T_4 was on par with T_5 and T_3 in aroma at 5 % level.

Texture

The food texture is a sense that plays an important role in influencing consumer preference of a food material based on its texture. Consumer importance and focus of food texture varies from one type of food to another. From the evaluation of texture it was found that T_9 got the highest mean rank value 20.15 for this attribute, after control (25.70) and was on par with T_5 and T_3 which got the lowest mean rank value of 11.55 at 5 % level.

The sensory evaluation revealed that the mean rank value for taste of *koozha* jackfruit rind crispies ranged between 11.70– 20.20. From Kruskal- Wallis test it was analyzed that T_9 obtained the first rank with the mean rank value of 20.20 after control (26.20), while T_3 got the last rank with mean rank value 11.70 which was on par with T_5 and T_4.

Overall acceptability

From the statistical analysis for overall acceptability, it was noted that T_9 obtained the highest mean rank value of 22.40 after control (25.90), while T_3 got the lowest rank with mean rank value 9.6. T_4 was on par with T_5 in overall acceptability at 5 % level.

4.8.1.2 Selection of best combination

From the sensory evaluation of the developed products based on jackfruit rind flour with respect to the different parameters like appearance, colour, aroma, texture, taste and overall acceptability, it can be concluded that T_5 and T_{10} got the maximum mean rank values in all aspects in *varikka* and *koozha papad* respectively, whereas in crispies T_4 and T_9 had scored maximum mean rank values of the product based on *varikka* and *koozha* respectively.

To assess the acceptability of the four products the selected treatments of each product were then rated with a 9 point scale (hedonic rating) where the score 9 represented 'like extremely' and 1 represented 'dislike extremely', the middle values representing intermediated ratings

A ten member panel which comprised of students from the Department of Community science evaluated the selected treatments of all the four products, using the 9 point hedonic scale.

Among all the four products, 'T_5P' scored a total of 75, 'T_{10}P' scored 76, T_4C scored 72 and T_9C scored 79 indicating that T_9C was the most acceptable product. These four best treatments were kept for storage studies. T_{10}P and T_9C were adjudged as the best among *papad* and crispies which were made of *koozha* jackfruit rind flour.

So T_5 and T_{10} with the combination of rice flour, *varikka* jackfruit rind flour and black gram flour in the ratio 80:10:10 and the combination of rice flour, *koozha* jackfruit rind flour and black gram flour in the ratio 80:10:10 respectively were the most acceptable treatments in *papad*.

T_4 and T_9 with the combination of rice flour, *varikka* jackfruit rind flour and black gram flour in the ratio 70:20:10 and the combination of rice flour, *koozha* jackfruit rind

Table: 24 Hedonic rating value of the developed products

Rating scale	Scores	T_5P	$T_{10}P$	T_4C	T_9C
Like extremely	9	18(2)	27(3)	18(2)	27(3)
Like very much	8	24(3)	24(3)	16(2)	32(4)
Like moderately	7	28(4)	14(2)	21(3)	14(2)
Like slightly	6	-	6(1)	12(2)	6(1)
Neither like or dislike	5	5(1)	5(1)	5 (1)	-
Dislike slightly	4	-	-	-	-
Dislike moderately	3	-	-	-	-
Dislike very much	2	-	-	-	-
Dislike extremely	1	-	-	-	-
Max score	90	75	76	72	79

(Scores indicated are total scores and figures in parentheses are the no of members)

T_5P- T_5 *papad*, $T_{10}P$- T_{10} *papad*, T_4C- T_4 crispies, T_9C- T_9 crispies flour and black gram flour in the ratio 70:20:10 respectively were the most acceptable treatments in crispies. Hedonic rating scores of the developed products is given in the table: 24.

4.8.2 Physical characteristics of the *papad*

Physical characteristics of *papad* evaluated included yield (number), unit dried weight, diameter, diameter expansion, expansion percentage, thickness, thickness after frying, oil uptake (%), bulk density and colour of the *papad* has been studied and noted in the table: 25.

4.8.2.1 Yield (number)

The total number of *papad* obtained out of 100g of the composite flour was 16 in T_5P and 15 from $T_{10}P$. When the yield was analyzed statistically, there was no significant difference in the yield between T_5P and $T_{10}P$ which was made of *varikka* and *koozha* jackfruit rind flour at 5 % level.

4.8.2.2 Dried weight

Table: 25 shows the result of unit dried weight of jackfruit rind *papad* obtained from 100 g of composite flour made up of *Koozha* and *varikka* jackfruit rind flour. The unit weight of a dried *papad* $T_{10}P$ (4.6g) was higher than T_5P (4.5g) and it was significantly different at 5 % level. $T_{10}P$ was the *papad* made from *koozha* jackfruit rind flour.

4.8.2.3 Thickness

The data pertaining to the thickness of raw jackfruit rind *papad* and the thickness of the *papad* after frying is given in the table: 25. There was no significant difference between T_5P and $T_{10}P$ with regard to the thickness of the raw jackfruit rind *papad*. Irrespective of the cultivars, there was significant difference in the thickness of the fried jackfruit rind *papad*.

Table: 25 Physical characteristics of *papad*

Product	Yield (nos/ 100g)	Unit Dried weight (g)	Diameter (cm)	Diameter expansion (cm)	Expansion (%)	Thickness (mm)	Thickness after Frying (cm)	Oil uptake (%)	Bulk density (g/cm3)	Colour (Visually)
T_5P	16	4.5	9.9	13.2	33.3	1.15	1.67	5.3	0.37	Yellowish orange
$T_{10}P$	15	4.6	9.7	13.5	39.1	1.18	1.84	4.65	0.36	Brownish orange
"t" (0.05)	NS	2.776*	NS	NS	2.776*	NS	2.776*	2.776*	NS	

(Results expressed are mean values of three replicates) *significant @ 5 %

T_5P - *Varikka* jackfruit rind *papad* $T_{10}P$- *Koozha* jackfruit rind *papad*

4.8.2.4 Diameter of raw and fried papad

The data pertaining to the diameter of raw jackfruit rind *papad* and the diameter of the *papad* after frying is given in the table: 25. There was no significant difference between T_5P and $T_{10}P$ in the diameter of raw and fried jackfruit rind *papad*. The diameter of raw jackfruit rind *papad* for T_5P was 9.9cm and $T_{10}P$ was 9.7cm, whereas the diameter expansion after frying jackfruit rind *papad* was 13.2 cm 13.5 cm for T_5P and $T_{10}P$ respectively.

4.8.2.5 Expansion percentage

The expansion per cent of the fried jackfruit rind *papad* prepared from *koozha* and *varikka* jackfruit rind flour is presented in the table: 25. The highest expansion was observed in $T_{10}P$ (39.1 %) and lower expansion in T_5P (33.3 %). There was significant difference between T_5P and $T_{10}P$ with regard to expansion percentage of the jackfruit rind *papad* at 5 % level.

4.8.2.6 Colour

The change in the colour of the jackfruit rind *papad* is noted in Table: 25. The change in the colour was observed visually by a group of panel members towards lightness to darkness of the *papad*. The colour observed for T_5P was yellowish orange and $T_{10}P$ was brownish orange in colour.

4.8.2.7 Bulk density

Bulk density varies according to the particle size. It is the determination of heaviness of sample. It is important for determining packing needs, handling of materials and application in wet processing in food industry. There was no significant difference in the bulk density of T_5P and $T_{10}P$. The bulk density of T_5P was 0.37 g/cm^3 and $T_{10}P$ 0.36 g/cm^3.

Table: 26 Texture Analysis of *papad*

Products	Crispiness (N)	Hardness (N)	Toughness (N)	Firmness (N)	Work of Penetration (Nmm)	Rupture strength (N)	Work of Cutting (Nmm)	Cohesive-ness (N)	Stringiness (mm)	Crunchi-ness (Nmm)
T_5P	14.72	6.643	6.643	6.643	2.923	6.643	2.923	-0.0478	-33.660	0.953
$T_{10}P$	12.93	4.92	4.92	4.92	1.968	4.92	1.968	-0.0251	-30.589	0.680
"t" (0.05)	–	–	–	–	2.776*	–	2.776*	2.776*	2.776*	2.776*

(Results expressed are mean values of three replicates) *significant @ 5 %

T_5P - *Varikka* jackfruit rind *papad* $T_{10}P$- *Koozha* jackfruit rind *papad*

4.8.2.8 Texture

Table: 26 gives the comparison of textural parameters namely crispiness, hardness, brittleness, toughness, firmness, work of penetration, rupture strength, work of cutting, cohesiveness, stringiness and crunchiness. The result shows that there was significant difference between T_5P and $T_{10}P$. The work of penetration (2.923 Nmm), work of cutting (2.923 Nmm), cohesiveness (-0.0478 N), and crunchiness (0.953 Nmm) was higher in T_5P whereas stringiness was higher in $T_{10}P$ (-30.589 Nmm).

4.8.2.9 Oil absorption

The amount of oil absorbed by the jackfruit rind *papad* during frying is given in the table: 25. Oil uptake by the jackfruit rind *papad* was significantly different between T_5P and $T_{10}P$ at 5 % level. The oil uptake of T_5P was 5.3 % and $T_{10}P$ was 4.65 %.

4.8.3 Physical characteristics of the crispies

Physical characteristics of crispies included yield (weight), diameter, thickness, oil uptake (%), bulk density and colour of the crispies were observed and is presented in the table: 27.

4.8.3.1 Yield (weight)

The total amount of crispies obtained out of 1Kg of the composite flour was 880g for T_4C and 890 from T_9C. When the yield was analyzed statistically, there was no significant difference in the yield between T_4C and T_9C, which was made of *varikka* and *koozha* jackfruit rind flours respectively at 5 % level.

4.8.3.2 Thickness

The data pertaining to the thickness of jackfruit rind crispies is given in the table: 27. There was significant difference between T_4C and T_9C at 5 % level with

Table: 27 Physical characteristics of Crispies

Product	Yield (g/kg)	Thickness (mm)	Bulk density (g/ cm3)	Colour (Visually)
T_4C	880	12.52	0.14	Brown
T_9C	890	13.3	0.137	Dark brown
"t" (0.05)	–	2.776*	–	

Table: 28 Texture Analysis of crispies

Product	Crispiness (N)	Hardness (N)	Toughness (N)	Firmness (N)	Work of Penetration (Nmm)	Rupture strength (N)	Work of Cutting (Nmm)	Cohesive-ness (N)	Stringiness (mm)	Crunchi-ness (Nmm)
T_4C	35.818	14.318	14.318	14.318	3.243	14.318	3.243	-0.0257	-11.999	24.774
T_9C	24.233	13.923	13.923	13.923	7.558	13.923	7.558	-0.016	-9.008	20.387
"t" (0.05)	2.776*	–	–	–	2.776*	–	2.776*	2.776*	2.776*	2.776*

(Results expressed are mean values of three replicates) *significant @ 5 %

T_4C- *Varikka* jackfruit rind Crispies T_9C- *Koozha* jackfruit rind Crispies regard to the thickness of the jackfruit rind crispies. There was significant difference in the thickness of the jackfruit rind crispies with the thickness of T_4C (12.52 mm) and (T_9C 13.3 mm). The thickness of T_9C was higher than T_4C.

4.8.3.3 Bulk density

Bulk density is an indicator of compaction. There was no significant difference in the bulk density of T_4C and T_9C. The bulk density of T_4C was 0.14 g/cm^3 and T_9C 0.137 g/cm^3.

4.8.3.4 Colour

The change in the colour of the jackfruit rind crispies was observed in Table: 27. The change in the colour was observed visually by the sensory panel members with respect to lightness to darkness of the crispies. The colour observed for T_4C was brown and T_9C was dark brown in colour.

4.8.3.5 Texture

Table: 28 gives the comparison of textural parameters namely crispiness, hardness, brittleness, toughness, firmness, work of penetration, rupture strength, work of cutting, cohesiveness, stringiness and crunchiness of jackfruit rind crispies. The result shows that there was significant difference between T_4C and T_9C. The crispiness (35.818 Nmm), cohesiveness (-0.0257 N) and crunchiness (24.774 Nmm) was higher in T_4C than T_9C, whereas work of penetration (7.558 Nmm), work of cutting (7.558 Nmm) and stringiness (-9.008 Nmm) was higher in T_9C than T_4C.

4.8.4 Nutrient composition of developed products

Nutrient labels are detailed information about the nutritionally important components of foods and provide values for energy and nutrients including protein, carbohydrates, fat, vitamins and minerals and for other important food components such as fibre. The nutrients like carbohydrates, protein, fat, crude fiber, dietary fiber, starch and ash content of the developed products viz., jackfruit rind *papad* (T_5P and $T_{10}P$) and jackfruit rind crispies (T_4C and T_9C) were analyzed using standard procedures as given in the table: 29.

Carbohydrate

Carbohydrates perform numerous roles in living organisms. Polysaccharides serve as a source of energy (e.g. starch and glycogen) and as structural components. The carbohydrate content was higher in T_4 *varikka* jackfruit rind crispies T_4C-78g/100g followed by T_5, *varikka* jackfruit rind *papad* T_5P was 74.6 g/100g followed T_9 C *koozha* jackfruit rind crispies (75.6 g/100g) and was lower in *koozha* jackfruit *papad* $T_{10}P$- 69 g/100g. This result shows that $T_{10}P$ had lower carbohydrate content which could be an acceptable attribute for healthy eating.

Protein

Protein is a body building nutrient. Protein maintains the body and skin quality by inducing the growth of the hair follicle and keratinization and thereby reducing the likelihood of skin diseases producing off-odours. The utilization of protein as a fuel is especially necessary under starvation situation, because it allows the proteins present in the body to be used in order to help life, particularly those present in muscle. The protein content was higher in T_4C (0.41 g/100g) and T_5P (0.4 g/100g) followed by T_9C (0.25 g/100g) and was lowest in $T_{10}P$ (0.21 g/100g). This result shows that the $T_{10}P$ had lower protein content.

Fats

From the analysis the fat content was seen to be higher in T_4C (4.35 g/100g) followed by T_5P (2.26 g/100g) which was on par with T_9C (2.26 g/100g) and lower in

Table: 29 Nutrient composition of standardized products (per 100 g)

SL. No.	Standardized products	Carbohydrates (g)	Proteins (g)	Fats (g)	Crude fiber (g)	Dietary fiber (g)	Iron (µg/g)	Starch (g)	Ash (%)
1.	**T_5P**	74.6^{b}	0.4^{a}	2.26^{b}	0.4^{b}	0.29^{b}	9.6^{b}	4.73^{b}	5.3^{a}
2.	**$T_{10}P$**	69^{c}	0.21^{c}	1.02^{c}	0.9^{a}	0.78^{a}	11.17^{a}	5.96^{a}	5.1^{b}
3.	**T_4C**	78^{a}	0.41^{a}	4.35^{a}	0.3^{b}	0.21^{b}	4.72^{d}	3.98^{c}	3.8^{d}
4.	**T_9C**	75.6^{b}	0.25^{b}	2.26^{b}	0.8^{a}	0.69^{a}	5.75^{c}	4.57^{b}	4.1^{c}
	CD (0.05)	1.717*	0.018*	0.182*	0.176*	0.177 *	0.269*	0.185*	0.192*

(Results expressed are mean values of three replicates) *significant @ 5 %

T_5P - *Varikka* jackfruit rind *papad* T_4C- *Varikka* jackfruit rind Crispies

$T_{10}P$- *Koozha* jackfruit rind *papad* T_9C- *Koozha* jackfruit rind Crispies

Values denoted by different letters in the same column are significantly different ($P< 0.05$)

$T_{10}P$ (1.02 g/100g). The result shows that fat content was found to be higher in *varikka* based products when compared to *koozha* based products.

Crude fiber

Crude fiber is one of the major components of dietary fiber which is insoluble with acid or alkali and remains as residue after digestion. The crude fiber was higher in $T_{10}P$ (0.9 g/100g) which was on par with T_9C (0.8 g/100g). Crude fiber of T_5P and T_4C was on par at 5 % level being 0.4 g/100g and 0.3 g/100g respectively and was found to be lower in *koozha* based products than *varikka*.

Dietary fiber

Dietary fibers has the capacity to change the nature of the compounds present in the gastrointestinal tract and also changes the absorption of other nutrients and chemicals. The dietary fiber was higher in $T_{10}P$ (0.78 g/100g) which was on par with T_9C (0.69 g/100g). Dietary fiber of T_5P and T_4C was on par at 5 % level with 0.29 g/100g and 0.21 g/100g respectively.

Iron

Iron is essential for life. The iron–sulfur clusters are pervasive and include nitrogenase, the enzymes responsible for biological nitrogen fixation. Iron-containing proteins participate in transport, storage and use of oxygen. Iron proteins are involved in electron transfer.

Iron content was found to be higher in $T_{10}P$ (11.17 μg/ 100g) followed by T_5P (9.6 μg/ 100g), then T_9C (5.75 μg/ 100g) and was lowest in T_4C (4.72 μg/ 100g). The result reveals that the iron content of jackfruit rind crispies was lower than jackfruit rind *papad*.

Chemical composition of the developed products

Table: 30 depicts the composition of the chemical constituents like tannins, total phenols, polyphenols, flavonoids, lectin, pectin, sodium and potassium etc., of the standardized products.

Total phenols

Total phenol content in T_9C (0.28 g/ 100g) was higher when compared to the total phenol in T_4C (0.22 g/ 100g), followed by T_5P (0.042 g/ 100g) which was on par with $T_{10}P$ (0.037 g/ 100g). The result shows that jackfruit rind *papad* had lower amount of total phenols than jackfruit rind crispies.

Polyphenols

Polyphenols are simpler natural phenols that incorporate smaller parts and building blocks. Polyphenols has the property to bind with proteins due to its affinity towards it, which can lead to the formation of soluble and insoluble protein-polyphenol complexes. Analysis of polyphenols showed that $T_{10}P$ (1.31 g/ 100g) had higher polyphenols then T_9C (1.13 g/ 100g), followed by T_4C (0.022 g/ 100g) and was lowest in T_5P (0.24 g/ 100g). Results of polyphenol analysis showed that the products developed from *koozha* jackfruit rind flour had comparatively higher amount of polyphenols than products of *varikka* jackfruit rind flour.

Tannins

Tannins have traditionally been considered anti-nutritional, but now they are known for their beneficial or anti-nutritional properties. From the analysis of Tannin content, it was found that $T_{10}P$ and T_9C respectively (0.049 g/ 100g and 0.047 g/ 100g) had higher tannin than T_5P and T_4C (0.024 g/ 100g and 0.022 g/ 100g) respectively.

Table: 30 Chemical composition of developed products (per 100 g)

Sl. No	Prod-ucts	Total Phenols (g)	Poly Phenols (g)	Tannin (g)	Flavon-oid (g)	Moistu-re (%)	Lectin (g)	Pectin (g)	Peroxide value (mEq/ Kg)	Total Anti-oxidant activity (g)	Sodium (g)	Potassi-um (g)
1.	T_5P	0.042[c]	0.24[d]	0.024[b]	4.73[b]	6.8[c]	0.023	3.36[a]	6.0[a]	0.014[c]	2.844[c]	0.037
2.	$T_{10}P$	0.037[c]	1.31[a]	0.049[a]	5.96[a]	6.9[c]	0.031	3.15[b]	6.05[a]	0.015[c]	2.55[d]	0.038
3.	T_4C	0.22[b]	0.58[c]	0.022[b]	3.98[c]	8.1[b]	0.032	3.4[a]	3.2[b]	0.049[b]	5.062[b]	0.044
4.	T_9C	0.28[a]	1.13[b]	0.047[a]	4.57[b]	8.9[a]	0.036	2.53[c]	3.0[c]	0.053[a]	6.28[a]	0.041
	CD (0.05)	0.016*	0.043*	0.004*	0.551*	0.260*	-	0.176*	0.177*	0.196*	0.160*	-

(Results expressed are mean values of three replicates) *significant @ 5 %

T_5P - *Varikka* jackfruit rind *papad*　　T_4C- *Varikka* jackfruit rind Crispies

$T_{10}P$- *Koozha* jackfruit rind *papad*　　T_9C- *Koozha* jackfruit rind Crispies

Values denoted by different letters in the same column are significantly different ($P< 0.05$)

Flavonoids

Flavonoids are catechins that has a common group of polyphenolic compounds in the human diet and are also present in plants. Flavonoids were found to be higher in $T_{10}P$ (5.96 g/ 100g) followed by T_9C (4.57 g/ 100g) which was on par with the flavonoid content of T_5P (4.73 g/100g) and recorded the lowest in T_4C (3.98 g/ 100g).

Moisture

Moisture content influences the sensory quality and also shelf life of the product. A slight change in the moisture content could affect its physical properties and sensory qualities.

The statistical analysis revealed that, there was significant difference in the moisture content of the products developed from jackfruit rind flour. The moisture content was higher in T_9C- 8.9 per cent, followed by T_4C – 8.1 per cent, lower in $T_{10}P$– 6.9 per cent and T_5P- 6.8 per cent which were both on par at 5%.

Lectin

Lectins performs recognition at the cellular and molecular level and play numerous roles in biological recognition phenomena involving cells, carbohydrates and proteins.

Lectin content of T_5P was 0.023 g/ 100g, $T_{10}P$ was 0.031 g/ 100g, T_4C was 0.032 g/ 100g and T_9C was 0.036 g/ 100g. These values were significantly different.

Pectin

Pectin is white coloured, amorphous, colloidal carbohydrate of high molecular weight occurring in ripe fruits. Pectin content was higher in T_4C (3.4 g/ 100g) it was on par with T_5P (3.36 g/ 100g) .It was followed by $T_{10}P$ (3.15 g/ 100g) and found to be lowest in T_9C (2.53 g/ 100g). The result shows that products from *varikka* jackfruit rind flour had higher pectin content than products from *koozha* jackfruit rind flour.

Peroxide value

Peroxide value was found to be higher in $T_{10}P$ (6.05 mEq/ kg) and T_5P (6.0 mEq/ kg) followed by T_4C (3.2 mEq/ kg) and lower in T_9C (3.0 mEq/ kg). The result indicated that peroxide value was higher in jackfruit rind *papad* than jackfruit rind crispies.

Sodium

The sodium content of the developed products from jackfruit rind are depicted in Table: 30. The higher sodium content was found in T_9C (6.28 g/ 100g) followed by T_4C (5.062 g/ 100g), then T_5P (2.844 g/100g) and lowest in $T_{10}P$ (2.55 g/ 100g). The sodium content of the developed products were significantly different at 5 % level.

Potassium

Potassium ions are important for the effective functioning of all living cells. In order to maintain the proper nerve transmission, transfer of potassium ions through nerve cell membranes is important. Potassium is rich in fresh fruits and vegetables. The dietary potassium helps to raise serum potassium levels, with a balance of potassium from outside to inside the cells and excess potassium is excreted by the kidneys

The potassium content of the developed products are depicted in Table: 31. There was no significant difference in the potassium content of the developed *papad* and crispies. The values were seen to be on par.

4.4.3 Total Anti-oxidant activity

An antioxidant is a molecule which helps in the inhibition of oxidation of other molecules which releases free radicals through chemical reaction that have the capacity to damage the cells.

From the analysis of total anti-oxidant activity of the developed products, T_9C had higher total anti-oxidant activity (0.053 g/100g), followed by T_4C (0.049 g/ 100g).

$T_{10}P$ had 0.015 g/ 100g total anti-oxidant activity which was on par with T_5P (0.0.14 g/100g).

4.9 STORAGE STABILITY OF THE PRODUCTS

Storage stability of food is one of the foremost problems faced by food processors to give maximum shelf-life to a product

4.9.1 Microbial Profile

Microbial profile of the jackfruit rind flour and the products developed from jackfruit rind flour in the study was conducted to determine the keeping quality. The rate of contamination with bacterial colonies, fungal colonies, actinomycetes and coli forms were analyzed to ascertain the microbial profile.

Microbial analysis of jackfruit rind flour

It is evident from the Table: 31 that in $1x10^{-6}$ dilution and $1x\ 10^{-7}$ dilution up to 3 months of storage, no bacterial colonies were found to appear in *koozha* and *varikka* jackfruit rind flour. But, in the third month of storage of *varikka* jackfruit rind flour, 2 colonies of fungi were observed in $1x\ 10^{-4}$ dilution. The analysis was conducted at monthly intervals and no actinomycetes and coli form colonies were found during the three months of storage.

Microbial analysis of jackfruit rind papad

The analysis for the microbial profile of jackfruit rind *papad* is shown in the table: 32. During the analysis conducted at monthly intervals there was no detection of bacterial, fungal, actinomycetes and coliform colonies, upto two months of storage.

After the third month of storage, 3 and 1 bacterial colonies were observed in 10^{-6} and 10^{-7} dilution respectively. 5 and 3 fungal colonies were observed in the dilution of 10^{-4} and 10^{-5} respectively for T_5P which was made of *varikka* jackfruit rind flour.

Table: 31 Microbial analysis of jackfruit rind flour

Rind Flour	Time Interval	Bacteria (CFU/ml)		Fungi (CFU/ml)		Actinomycetes (CFU/ml)		*Escherichia coli* (CFU/ml)	
	Dilution	10^{-6}	10^{-7}	10^{-4}	10^{-5}	10^{-3}	10^{-4}	10^{-6}	10^{-7}
***Koozha* rind flour**	Fresh	-	-	-	-	-	-	-	-
	After 1 month	-	-	-	-	-	-	-	-
	After 2 month	-	-	-	-	-	-	-	-
	After 3 month	-	-	-	-	-	-	-	-
***Varikka* rind flour**	Fresh	-	-	-	-	-	-	-	-
	After 1 month	-	-	-	-	-	-	-	-
	After 2 month	-	-	-	-	-	-	-	-
	After 3 month	-	-	**2x 10^{-4}**	-	-	-	-	-

(Results are expressed as mean values of four replicates), (CFU/ml – Colonies forming unit/ml), (- No colonies detected)

Table: 32 Microbial analysis of jackfruit rind *papad*

Product	**Time Interval**	**Bacteria (CFU/ml)**		**Fungi (CFU/ml)**		**Actinomycetes (CFU/ml)**		***Escherichia coli* (CFU/ml)**	
	Dilution	10^{-6}	10^{-7}	10^{-4}	10^{-5}	10^{-3}	10^{-4}	10^{-6}	10^{-7}
T5P	Fresh	-	-	-	-	-	-	-	-
	After 1 month	-	-	-	-	-	-	-	-
	After 2 month	-	-	-	-	-	-	-	-
	After 3 month	**3 x 10^{-6}**	**1 x 10^{-7}**	**5 x 10^{-4}**	**3 x 10^{-5}**	-	-	-	-
T10P	Fresh	-	-	-	-	-	-	-	-
	After 1 month	-	-	-	-	-	-	-	-
	After 2 month	-	-	-	-	-	-	-	-
	After 3 month	**2 x 10^{-6}**	**1 x 10^{-7}**	**3 x 10^{-4}**	**2 x 10^{-5}**	-	-	-	-

(Results are expressed as mean values of four replicates), (CFU/ml – Colonies forming unit/ml), (- No colonies detected)

Table: 33 Microbial analysis of jackfruit rind crispies

Product	Time Interval	Bacteria (CFU/ml)		Fungi (CFU/ml)		Actinomycetes (CFU/ml)		*Escherichia coli* (CFU/ml)	
	Dilution	10^{-6}	10^{-7}	10^{-4}	10^{-5}	10^{-3}	10^{-4}	10^{-6}	10^{-7}
T4C	Fresh	-	-	-	-	-	-	-	-
	After 1 month	-	-	-	-	-	-	-	-
	After 2 month	-	-	-	-	-	-	-	-
	After 3 month	-	-	-	-	-	-	-	-
T9C	Fresh	-	-	-	-	-	-	-	-
	After 1 month	-	-	-	-	-	-	-	-
	After 2 month	-	-	-	-	-	-	-	-
	After 3 month	-	-	-	-	-	-	-	-

(Results are expressed as mean values of four replicates) (CFU/ml – Colonies forming unit/ml), (- No colonies detected)

Whereas in the case of $T_{10}P$ i.e., *papad* made of *koozha* jackfruit rind flour, 2 and 1 bacterial colonies were observed in the dilution of 10^{-6} and 10^{-7} respectively. 3 and 2 fungal colonies were observed in the dilution of 10^{-4} and 10^{-5} respectively.

Microbial analysis of jackfruit rind crispies

The analysis for the microbial profile of jackfruit rind crispies is shown in the table: 33. During the analysis conducted at monthly intervals there was no detection of bacterial, fungal, actinomycetes and coliform colonies, upto three months of storage.

The four standardized products were thus evaluated for their physical, chemical and nutrient qualities along with shelf life stability and cost. The discussion pertaining to the results obtained is discussed in the ensuing chapter.

Discussion

5. DISCUSSION

The results of the present investigation entitled "Value added products from jackfruit rind" is discussed below, under the following heads:

5.1 Selection and collection of Jackfruit rind

5.2 Assessment of storage quality of rind

5.3 Processing of jackfruit rind flour

5.4 Functional quality analysis of jackfruit rind flour

5.5 Preparation of composite flour

5.6 Standardization of *papad*

5.7 Standardization of crispies

5.8 Quality evaluation of the products

5.9 Storage stability of the products

5.10 Cost of the products

5.1 SELECTION AND COLLECTION OF JACKFRUIT RIND

Jackfruit originated in the Western Ghats of India and is extensively grown in this region for its ripe and unripe fruits. Ripe jackfruit, owing to its strong aroma and intense sweetness, is widely relished for dessert purpose, whereas unripe fruits are mostly utilized in culinary preparations and also in pickle making. Two cultivars of jackfruit, namely, *varikka* and *koozha* are recognized in Kerala based on the texture of bulbs. Trees bearing fruits having firm textured, crunchy flakes are referred to as *varikka* types and those with soft, fibrous and melting bulbs are referred to as *koozha*. *Varikka* types are preferred to *koozha* for dessert purpose and hence the ripe bulbs of *koozha* types are usually wasted (Gomez *et al.,* 2015). Whatever the type, a considerable amount of the fruit is unutilized which comprises of rind, perianth and thorns.

Fruit quality and shelf life is influenced by the maturity of the fruit during harvest. Fruit is sometimes let down to fall and has to be collected immediately, because it has a shelf life of only 2–3 days. The whole fruit is mostly moved immediately to market. Half-ripe fruit cut in sections has a longer shelf life and is often sold in Indian grocery stores, where a wide variety of whole fruit sizes are also available. Mature, undamaged fruit can be stored at 50°F for 2–3 weeks. Fruit ripens in 3–7 days at 71–80°F, depending upon the stage of maturity at harvest (Love and Paul, 2011).

In the present study, to obtain rind of good quality, jackfruit cv. *koozha* and *varikka* in the raw mature state was selected. The fruits were harvested from the trees grown in the Instructional Farm, College of Agriculture, Vellyani.

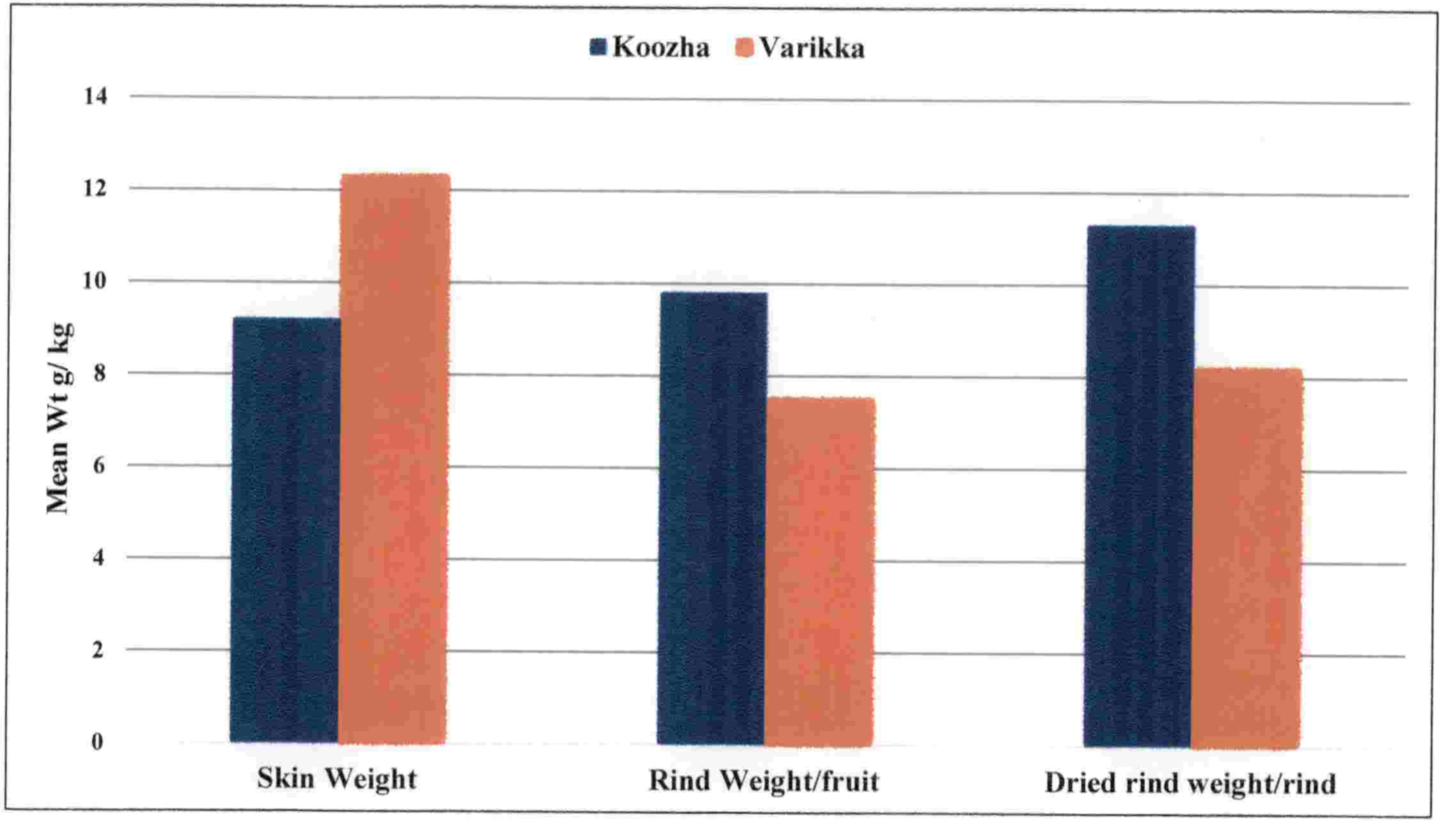
Raw mature jackfruits of 90-105 days of cultivar *Koozha* and *varikka* after fruit set with optimum visible maturity indices were selected. Raw matured jackfruits are suitable for the better yield of jackfruit rind, because the thickness of the rind diminishes with ripening of the fruit. The fruits were cut into eight parts. The thorny portion was shred off and the rind was carefully separated out with sharp knife after removing the perigones.

Physical characteristics of *Koozha* and *Varikka* Jackfruit

The total fruit weight ranged between 1.69 to 17.50 kg. The total bulb weight and seed weight varied between 0.80 to 10.25 kg and 0.16 to 3.63 kg, respectively (Krishnan *et al.,* 2015).

Jackfruits have a big yellowish syncarp (30-100 cm long and 25-50 cm in diameter), which is round and cylindrical that hangs on a stout stalk. The outer cover

Graph: 1 Physical Characteristics of Koozha and varikka jackfruit



of the fruit is protected with a large number of protruding pyramidal thorns (Corner, 1938).

The fruit axis is rigid and slightly fleshy. The perianth's lower part (bulbs) is edible and spongy; while the middle and the upper parts form the rind of the fruit. The perianth forms the bulk of the fruit (Prakash *et al.*, 2009)

Similarly the pithy core or receptacle ranges from about 1.9 cm to 7.5 cm in width. Nevertheless, it only comprises about 16% of the total fruit width. As the fruit matures, the latex amount in the core increases, however, it is reduced as the fruit ripens (Moncur, 1985).

In this study, the physical characteristics of *koozha* and *varikka* jackfruit had shown that rind thickness was higher in *koozha* jackfruit (1.4 cm) than *varikka* (1.2 cm), It was found that fresh and dried rind weight was also higher in *koozha* jackfruit (9.8 and 7.5 g/ kg of fruit) than *varikka* (11.3 and 8.2 g/ kg of rind) respectively.

5.2 ASSESSMENT OF STORAGE QUALITY OF RIND

The minimal processing of vegetables and fruits have acquired a swift vogue among consumers, because of its nutritional benefits, fresh nature and convenience to use. The processes like washing, cleaning, sorting, grading, peeling, cutting and slicing are some examples of minimal processing.

According to Sexena *et al.* (2012) minimal processing of precut fruit and vegetables affects their quality by increase in oxidative stress. The cause of degradation in quality are microbial contaminations, exhaustion of phytochemicals, tissue softening and browning.

Storage of minimally processed fruits and vegetables at low temperature (4 to 6^{o} C) was reported to extend their shelf life (Piga *et al.*, 2000).

Freezing is a method generally used to reduce the browning reactions that takes place in the fruit. Obviously, freezing leads to decrease in available water for enzymatic reactions. It was confirmed by Lavelli and Caronni. (2010) that, in apple at water activity (a_w) below 0.3, the PPO were no longer active. In order to reach an a_w of 0.3, the storage temperature would be -24°C, because water activity decreases with temperature, (Heldman & Taylor, 1997).

In the present study, for the assessment of storage stability of jackfruit rind, the rinds of *varikka* were seen to retain their white colour, soft texture and flavorlessness. There was no difference in the quality of the *varikka* rinds under refrigerated condition and in frozen condition. *Koozha* rinds which were stored for 2 days turned light brown on refrigeration and also on freezing but the degree of browning of refrigerated *koozha* rinds were higher than the frozen *koozha* rinds.

Pre-treatments to prevent browning

The anti-browning agents are generally used to increase the shelf-life of fruits during their storage. It acts as a layer of any edible material on the surface of fruit. Actions of these anti-browning agents focus to decrease the moisture and aroma loss, delay of colour changes, gas transfer and the improvement of the overall quality (Olivas & Barbosa-Canovas, 2005). The anti-browning agents leads to delay of enzymatic browning, because they develop a modified atmosphere on coated fruits by placing the coated product from the environment.

Browning, tissue softening and weight loss are the major problems in storage of minimally processed products (Koukounaras *et al.*, 2008). The treatment of the coating with sucrose, trehalose and NaCl reportedly solved these problems in minimally processed apples (Albanese *et al.*, 2007). Use of antibrowning chemicals such as ascorbic acid and citric acid prevented enzymatic browning in vegetables and fruits (Limbo and Piergiovanni, 2006).

Rana *et al.* (2018) reported that, there was increase in shelf life of fresh cut tender jackfruit by 10 to 15 days in refrigerated conditions. With increase in shelf life, the quality of tender jackfruit was also retained in terms of colour and firmness. There was no or minimum browning recorded in samples and the overall acceptance of fresh cut tender jackfruit was higher in terms of overall acceptability. The treatment adopted for minimal processing was dipping of fresh cut tender jackfruit slices in solutions of different concentration of $CaCl_2$ and citric acid for various time interval.

In this study, when both *koozha* and *varikka* rinds were immersed in different pre-treatment media, browning of rind was very much lower in the 1 % citric acid media and the rinds seemed to be bleached in the 1 % lime juice which could be due to the bleaching effect of ascorbic acid, which affects the fruit tissues, making it easier for water to diffuse. This is consistent with the observations of Blanco *et al.* (2006) that the pretreatment with lemon juice which is acidic in nature with a major component being ascorbic acid might have caused a similar effect on the tissue of the mangoes.

5.3 PROCESSING OF JACKFRUIT RIND FLOUR

Jackfruit rind powder (JRP) could be produced from jackfruit residue, a byproduct of the jackfruit processing industry. Increasing the utilization of jackfruit waste from animal feed to functional food will be of great benefit to the economy of the country.

5.3.1 Preliminary Processing

Preliminary processing is the primary step carried out in the processing of flour. In this step, the unwanted parts of the fruits were removed and made ready for further processing. This is one of the essential steps to ensure quality of the product. In this study the preliminary processes like cleaning, cutting, blanching, immersing, drying and milling, constituted the various steps in the processing of jackfruit rind flour.

After harvesting, when the fruit crops come from the field it contains different types of undesirable particles like dust, insects etc., which may affect the quality and shelf life of product. So the jackfruits were washed in running water before processing.

After selection of raw materials, cleaning and cutting is an important preliminary step in the value addition from jackfruit. As jackfruit is a big fruit, it was first cut into big pieces, then into smaller pieces for easy handling. After this, the whole rind were removed from the fruit and the weights of the rind were taken.

5.3.2 Preparation of jackfruit rind flour

Drying is an ancient method to preserve food. It is simple, safe, and an easy method. Dried foods are found to be a rich source of immediate energy. The principle involves removing water from the food, which inhibits the growth of bacteria, yeasts, and mould and slows down enzymatic action without deactivating them.

The cut rinds were washed in running water and again with deionized water. It was soaked in boiling water for 10 mins to make the rind soft. It was soaked in boiling solution of 0.1 percent of food grade sodium bisulfite ($NaHSO_3$) which is a decolouration agent in purification procedures and can reduce strongly coloured oxidizing agents, conjugated alkenes and carbonyl compounds, thus preventing browning, inhibiting bacterial growth and this helps to retain nutrients in jackfruit rind. It was washed with water, then soaked in boiling solution of 0.1 % of sodium bicarbonate ($NaHCO_3$) for 15 mins in order to remove the milky latex around the rind making it soft.

In this study, the pre-treated rinds were dried in convection drier at 50° C for 24 hours, thus removing the water content present in it. It was then packed in polypropyelene (PP) covers.

Milling is an act or instance of subjecting something to the operation of a mill. This is defined as a process of grinding, especially grinding grains, or any dried products into flour or meal.

Dried jackfruit rinds were milled to convert it into flour and was then sieved by 350μm sieve to get fine powder. In the present study, a significant portion of rice flour was substituted for the development of the dehydrated and extruded product by replacing with jackfruit rind (JR) flour in different proportions, with the aim of improving the nutritional quality and diversification into new products.

5.4 FUNCTIONAL QUALITY ANALYSIS OF FLOUR

Functional characteristics of jackfruit rind flour need to be ascertained to evaluate how proteins, fat, fibre and carbohydrates may behave in specific systems, as well as demonstrate whether or not such proteins can be used to stimulate or replace conventional protein (Siddiq *et al.*, 2009).

In the present study, the jackfruit rind flour was analyzed for its functional properties viz. water absorption index, oil absorption index, foaming capacity, swelling power, percentage solubility, gelation concentration and rehydration ratio.

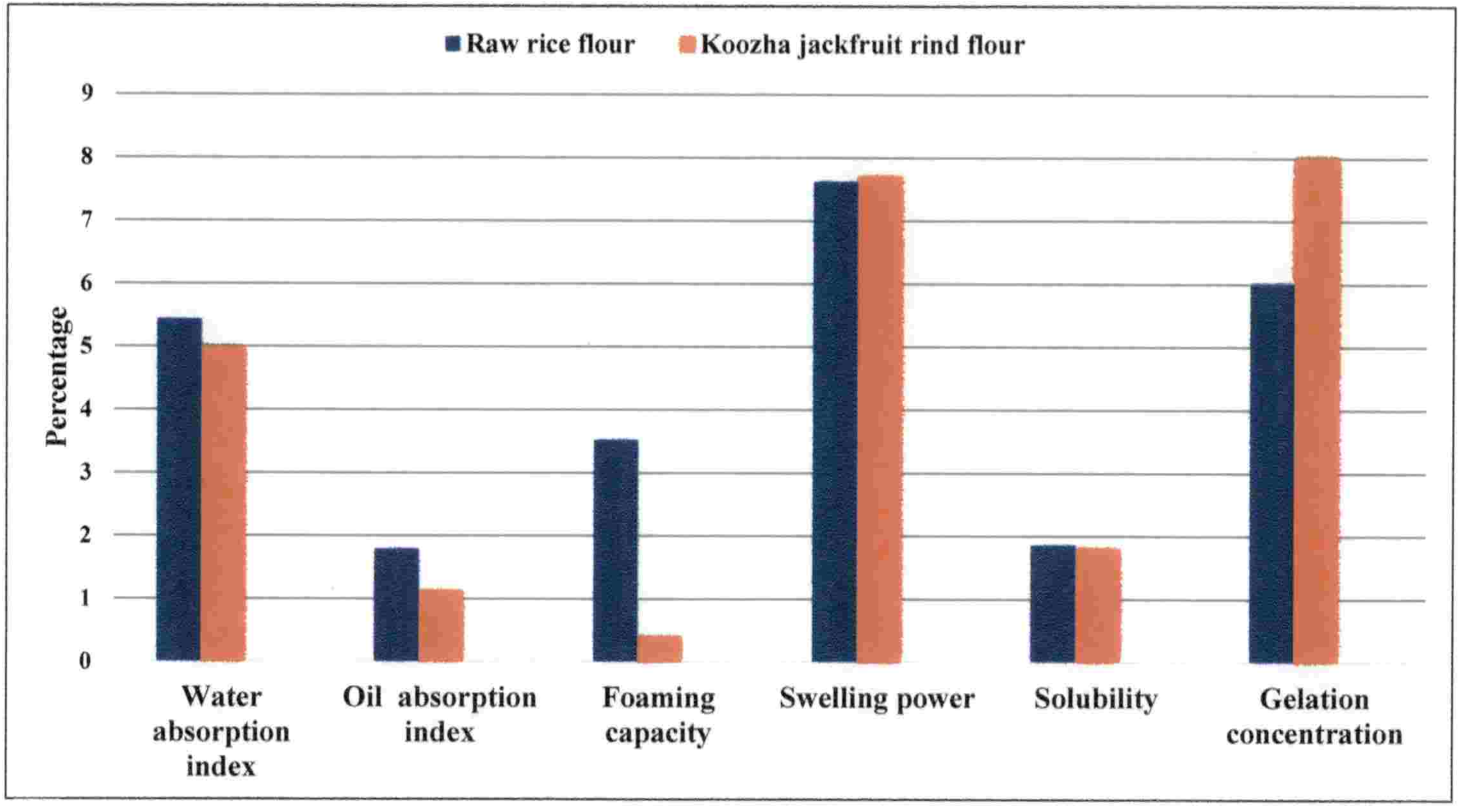
5.4.1.1 Water Absorption Index

Water absorption index of flour is defined as the difference in weight of the flour before and after water absorption, (Abbey and Ibeh, 1988). It describes the ability of the flour for association with water under limited supply. Imbibing of water is an important functional properties in foods such as sausages, custards and dough. (Adebowale and Lawal 2003).

Water absorption capacity is specific for each type of starch that depends on factors such as amylase: amylopectin ratio, intra and inter molecular forces and size of granules, (Rahman *et al.,* 1999).The smaller the size of the granules, the higher the absorption index (Singh *et al.*, 1991).

The presence of some hydrophilic constituents like polysaccharides causes high water absorption capacity of flours. The water adsorption takes place through existing polar binding sites which is distributed over the surface of the protein and the rearrangement of molecules leads to increase in water absorption capacity. High water

Graph: 2 Functional properties of *koozha* jackfruit rind flour



absorption could be due to the nature of the starch and contribution to water absorption by the cell wall membranes (Sathe *et al.*, 1982).

A study conducted by Oppong *et al.*, (2015) reported a water absorption capacity of 2.27 per cent in cowpea flour. In the present study, water absorption index of jackfruit rind flour was compared with the raw rice flour and from the analysis it was found water absorption index of *koozha* and *varikka* jackfruit rind flour was significantly lower from rice flour. It could be due to increased insoluble fiber content of the fruit compared to rice.

5.4.1.2 Oil Absorption Index

Oil absorption capacity of a food material is defined as the difference in weight of flour before and after oil absorption (Giami *et al.*, 2004). Oil absorption index is an important criteria in food formulations. It aids in food formulations and gives an indication of the flavour-retention capacity of flours (Odoemelam, 2000). Moreover, it is useful in the physical structural interactions of food, including shelf life extension of the products (Adebowale and Lawal, 2003). Hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind to the paraffin chains of fats (Adejuyitan *et al.*, 2009).

Oil absorption index of bread fruit flour was found to be ranging between 0.50 ml per gram to 1.25 ml per gram. Udensi and Okoronkwo (2006) reported that all the flours of the *Artocarpus spp.* had higher oil absorption capacities than mucuna bean.

Aremu *et al.* (2006) reported relatively high oil absorption capacity of *T. africana* flour suggesting that it could be useful in food formulations where oil holding capacity is needed such as in sausage making, soups and cakes. According to Sreerama *et al.* (2012), it was observed that decrease in solid content (carbohydrate) resulted in increased oil absorption in chickpea flour. Osundahunsi (2009) observed decreased oil absorption in ripe plantain flour with decreased carbohydrate content.

In this study, the oil absorption capacity of *koozha* jackfruit rind flour (1.12%) and *varikka* jackfruit rind flour (1.15%) was lower than raw rice flour (1.79 %).The lower oil absorption capacity of jackfruit rind flour could be due to lower concentration of hydrophobic proteins. The relatively low oil absorption capacity of JR (Jackfruit rind) flour suggested that it could absorb only little fat, which is a healthy characteristic for daily diet.

5.4.1.3 Foaming Capacity

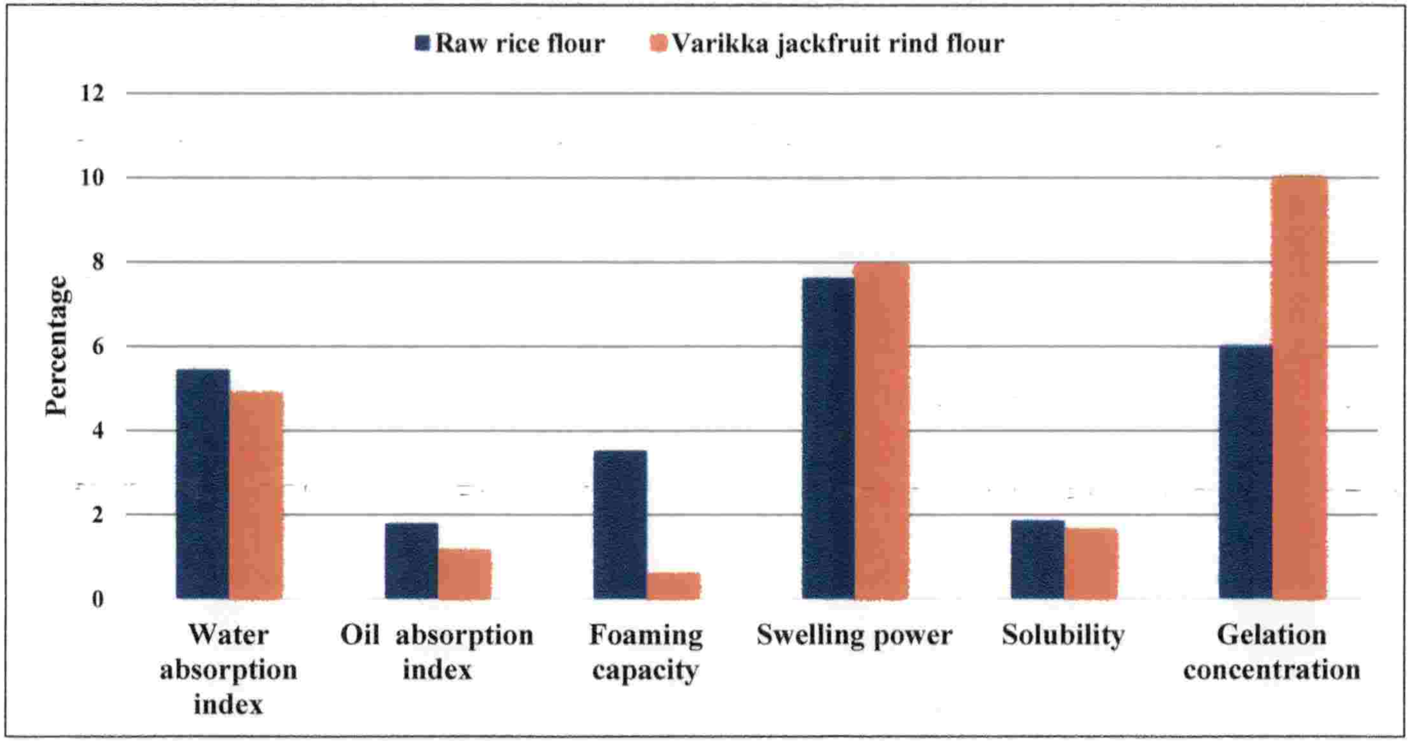
Adebowale and Lawal (2003) had reported that, protein–protein interaction was enhanced by increasing the concentration of proteins, which increases viscosity and helps in the formation of a multilayer cohesive protein film at the interface. So, thicker films can be obtained by increasing the concentration that limits the drainage of protein from films. Foam stability is essential, because the need of whipping agents depends on their ability to maintain the whip foam as long as possible (Lin *et al.,* 1974).

From the study, it was noted that the foaming capacity of rice flour was 3.52 per cent which was higher than the *koozha* jackfruit rind flour (0.399 %) and *varikka* jackfruit rind flour (0.398 %) which suggests that the lower content of protein in jackfruit rind flour.

According to Jones *et al.* (2000), increased unfolding and fragmentation of protein may enable the formation of more continuous phases of thin liquid layers which traps air bubbles, resulting in increased foaming capacity The foaming capacity of the flours of breadfruit cultivars was found to be between 5.83 per cent and 25.00 per cent.

According to Narayana and Narayasinga (1982), foam capacity is attributable to protein content and solubility, since foaming is a property of solubilised proteins. Nwokolo (1985) reported that, the amount of polar and non-polar lipids in a sample affects foaming capacity of a sample.

Graph: 3 Functional properties of *varikka* jackfruit rind flour



5.3.1.4 Swelling Power

According to Loos *et al.* (1981), swelling power is an indication of the water absorption index of the granules, during heating. Dengate (1984) stated that, swelling power is seen as the result of swelling of granules permitting the exudation of amylose. King (2005) reported that, higher the swelling power, the more soluble the flour is in solution.

Iwe (2003) stated that, swelling is often affected by the processing time. In the present study the swelling power of the jackfruit rind flour was 7.7 and 7.93 per cent for *koozha* and *varikka* jackfruit rind flour respectively and for rice flour it was 7.62 percent.

5.4.1.5 Percentage Solubility

According to Singh and Kumbhar (2001), solubility is indication of water penetration capacity of flours into the starch granules. Changing the property of starches of flour is important for absorption and retention of water, which leads to increase in swelling powers of starches, which is essential for the production of confectionery goods. More leaching of solubilized amylose molecules from swelled starch granules depicts increased solubility (Tumaalii and Wooton, 1988).

According to Johnson (2001), higher solubility would provide better digestibility. Solubility of bread fruit flours in distilled water ranged between 8.01 percent and 11.9 percent.

From the study it was seen that, solubility of jackfruit rind flour was 1.8 and 1.64 percent for *koozha* jackfruit rind flour and *varikka* jackfruit rind flour respectively and for rice flour it was 1.86 percent. It may be observed that the jackfruit rind flour is having similar solubility inspite of the difference in cultivars.

5.4.1.6 Gelation concentration

Sathe *et al.* (1982) suggested that, this change is based on the relative ratio of many components such as proteins, carbohydrates and lipids and the interactions between those compounds.

According to Wu *et al.* (2009), protein gels comprises of three dimensional matrices or intertwined networks, which is partially linked with polypeptides, in which de-ionized water is entrapped. Protein gelation is important for the production and overall acceptability of many foods, including vegetable and other food products.

Gelation concentration of *koozha* rind flour was 8 whereas for *varikka* it was 10 and for rice flour it was 6. It shows that *varikka* rind flour has higher gelation property than koozha jackfruit rind flour. It proves that *koozha* rind flour is more suitable for the development of extruded and dehydrated products.

5.4.1.7 Rehydration Ratio

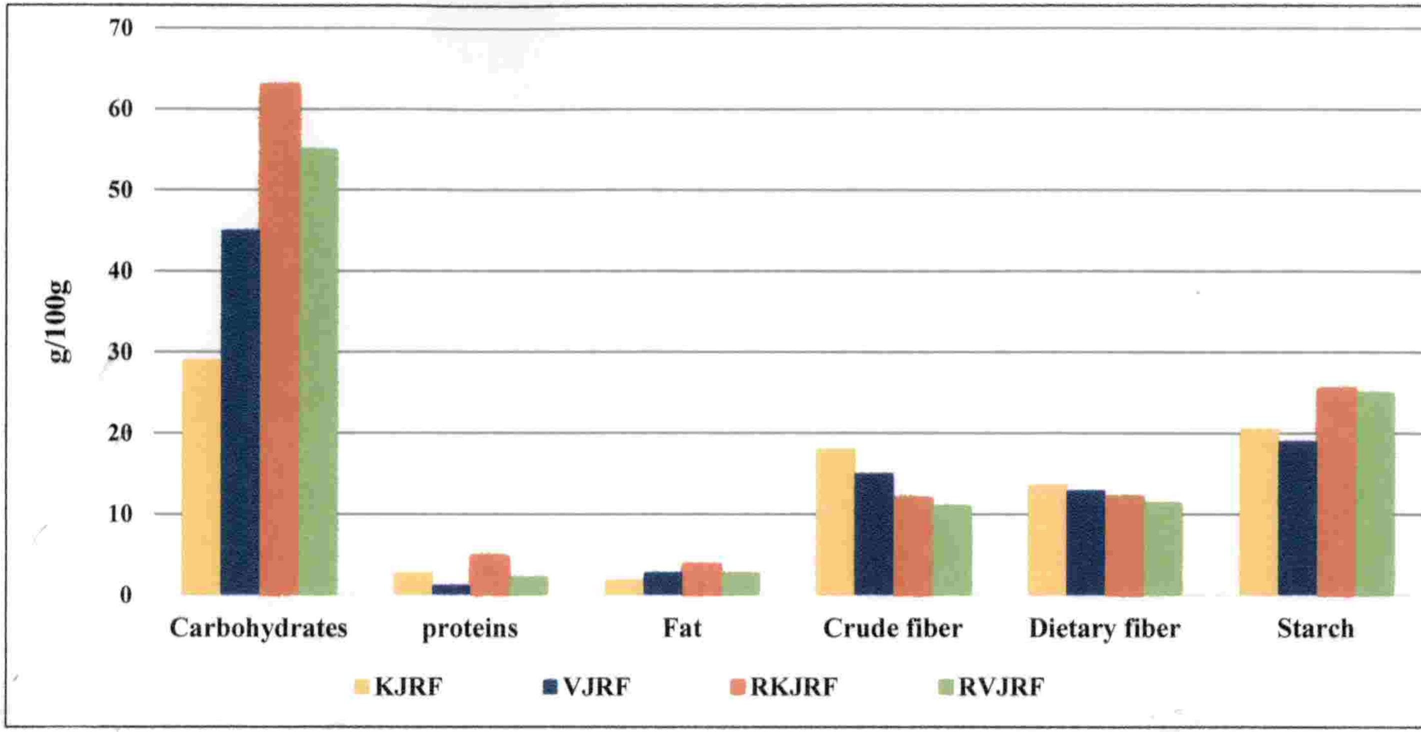
Rehydration characteristics are used as a quality parameters of dried products (Vrac and Gurna, 1994). Rehydration is used to express the ability of dried material to absorb water. In the investigation on jackfruit based curry mixes, the rehydration ratio of developed RTC mixes ranged from 0.34-042. The rehydration ratio of dried banana slices treated with ascorbic acid was 1.21 (Abano and Samamoah, 2011).

Singh *et al.* (2009) reported that rehydration ratio of bitter gourd slices dried at 70°C was 0.78.In this study, much difference was not noted in the rehydration ratio of *koozha* (0.179 %) and *varikka* (0.188 %) jackfruit rind flour and raw rice flour (0.182 %).

5.4.2 and 5.8.4 Nutrient and chemical composition of jackfruit rind flour and the developed products

Studies have proved that the nutritional and phytochemical composition among jackfruit varies depending on the cultivar as well as region.

Graph: 4 Nutrient composition of jackfruit rind flour



Koozha jackfruit rind flour (KJRF)	Ripened *Koozha* jackfruit rind flour (RKJRF)
Varikka jackfruit rind flour (VJRF)	Ripened *Varikka* jackfruit rind flour (RVJRF)

According to a report by Azad (2000), potassium (191-407 mg/100 g fresh weight), phosphorus (38-41 mg /100 g fresh weight) and magnesium (27mg /100 g fresh weight) are the most abundant elements in the ripe fruit.

Jackfruit rind powder (JRP) has the capacity to be identified as an effective ingredient in the formulation of functional food products since it is found to be rich in dietary fiber. It consists of 60 per cent dietary (Feili, 2013).

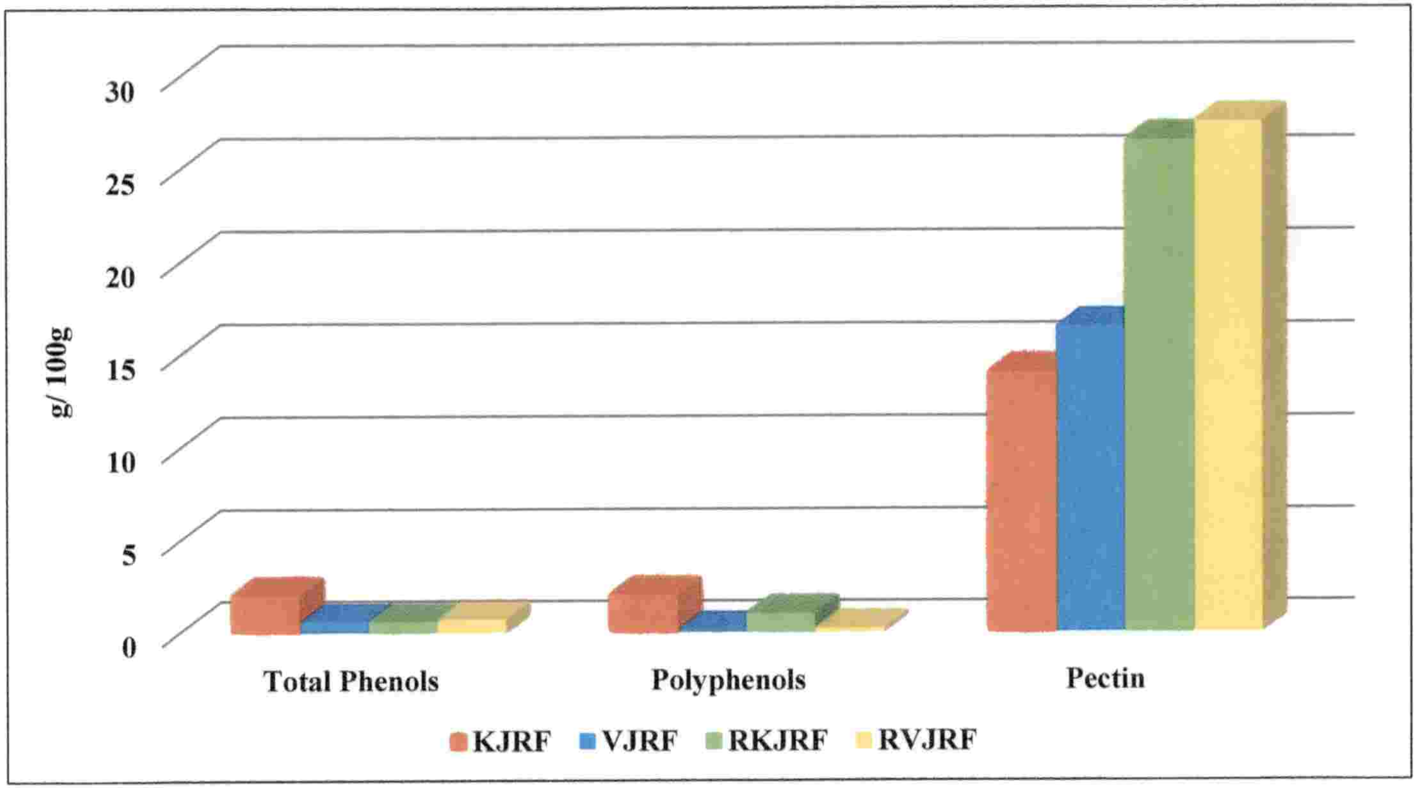
The JRF had a higher amount of crude fat (0.82 g/100 g of dry matter), ash (5.91g/100 g of dry matter) and crude fiber (11.32 g/100 g of dry matter) than Wheat flour. But, it had a low moisture content (9.43g/100 g of dry matter), and crude protein (4.52 g/100 g of dry matter). Processing the jackfruit rind pieces in water could be the reason for loosing of water-soluble proteins of the final sample (Rodriguez-Ambriz *et al.,* 2008). Since JRF have higher amount of crude fiber it could be applied as a high fiber source in the development of food products (Feili, 2013).

In this study, *koozha* jackfruit rind flour had lower carbohydrate and fat content of 29 and 1.84 g/ 100g respectively. It indicates that *koozha* rind flour can be utilized in daily diets for health since it has low carbohydrate and fat. Protein was found to be high in ripened *koozha* jackfruit rind flour. The slight difference in the fat, protein and crude fiber content can be due to the cultivar of jackfruit used, place of origin, assessment methods etc.,

In the standardized products, carbohydrate, protein and fat were found to be higher in T_4C and T_9C i.e in crispies than in *papad*, this may be due to the retention of nutrients in extrusion technique than the process of dehydration.

Dietary fibers (DF) promote beneficial physiological effects including laxation which results from increasing the dietary fiber component of diets instead of other food components. This physiological effect is mostly taken for granted though it is reported to impart positive feelings to the individuals consuming these dietary fibers along with other benefits of improved laxation. Not all dietary fibers impart all of the positive physiological effects, but they are expected to impart at least one of the positive effects.

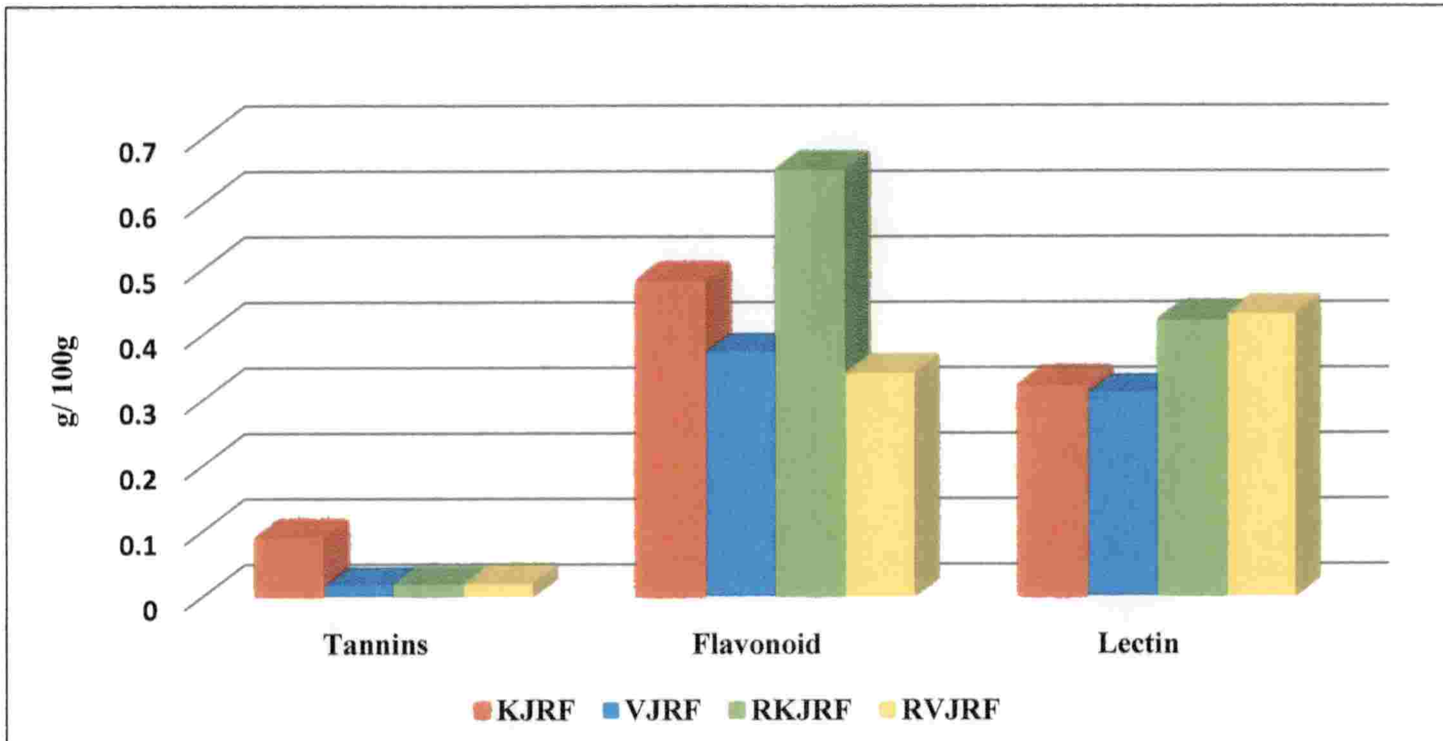
Graph: 5 Chemical Composition of Jackfruit rind flour



Koozha jackfruit rind flour (KJRF) Ripened *Koozha* jackfruit rind flour (RKJRF)

Varikka jackfruit rind flour (VJRF) Ripened *Varikka* jackfruit rind flour (RVJRF)

Graph: 6 Chemical Composition of Jackfruit rind flour



Koozha jackfruit rind flour (KJRF)	Ripened *Koozha* jackfruit rind flour (RKJRF)
Varikka jackfruit rind flour (VJRF)	Ripened *Varikka* jackfruit rind flour (RVJRF)

The quantity of different dietary fibers present depends on the growing stages of the plant. Ripening stage and part of the plant consumed and the storage of the fruit have the considerable impact on the composition of dietary fiber (Elleuch *et al.,* 2011).

This present study shows that crude fiber and dietary fiber were higher in raw *koozha* jackfruit rind flour and it also revealed that fiber content decreased with maturity of the fruit. Fiber content of the standardized products revealed that $T_{10}P$ and T_9C i.e products of *koozha* jackfruit rind flour had higher crude fiber and dietary fiber than products of *varikka* jackfruit rind flour.

Jackfruit seeds contains about 73 per cent starch on dry basis) (Dutta *et al.,* 2011). The starch has been analyzed in recent times for their native and modified properties (Kittipongpatana and Kittipongpatana, 2011; Rengsutthi and Charoenrein, 2011). With 27.1 per cent of amylose, it may have both food and non-food applications.

Jackfruit is a great source of vitamins (A, C, thiamine, riboflavin, niacin) and minerals (calcium, potassium, iron, sodium, zinc) (Azad, 2000; Haq, 2006). Sodium, potassium and chlorine have an important role in the maintenance of osmotic balance between cells and the interstitial fluid.

Starch content was found to be higher in *koozha* jackfruit rind flour and also in *koozha* rind flour based products. This content helps in the good expansion capacity of the products while extruding crispies and frying the *papad*.

Arina *et al.* (2016) reported that, the TPC did not vary much ranging from 54.042 ± 0.596 mg GAE/100g fresh weight (FW) to 76.836 ± 0.619 mg GAE/100g FW. Fried jackfruit had the highest TPC, followed by fresh jackfruit, fried cempedak, fresh cempedak, and fried breadfruit. The lowest TPC was seen in fresh breadfruit

Polyphenols have a capacity to act as antioxidants through a number of mechanisms such as radical scavenging by H-donation, inhibition of chain initiation by donating electrons or by binding of transition metal ion catalysts. Polyphenols present in *koozha* jackfruit rind flour was higher (2 g/ 100g) than *varikka* rind flour. It shows that depending on the cultivar of fruits, content of the polyphenols changes accordingly.

Flavonoids prevent platelet stickiness and hence platelet aggregation (Gupta *et al.*, 2011). In this study, flavonoid content was higher in ripened *koozha* jackfruit rind flour (0.65 g/ 100g). This indicates that the flavonoid content of the fruit increases during ripening.

Tannins limit the intake of nutrients through astringency, inhibits enzyme activity, and reduce forage digestibility (Onwuka, 1986). Tannins form complexes primarily with proteins, carbohydrates, amino acids and several minerals, thereby reducing intake, digestion and animal growth (Makkar *et al.*, 2006).

The formation of complexes of tannins with nutrients, especially proteins, has positive effects on feed utilization such that condensed tannins protect proteins from rumen degradation, thus, increasing the bioavailability of amino acids for direct absorption in the intestine (Reed, 1986).

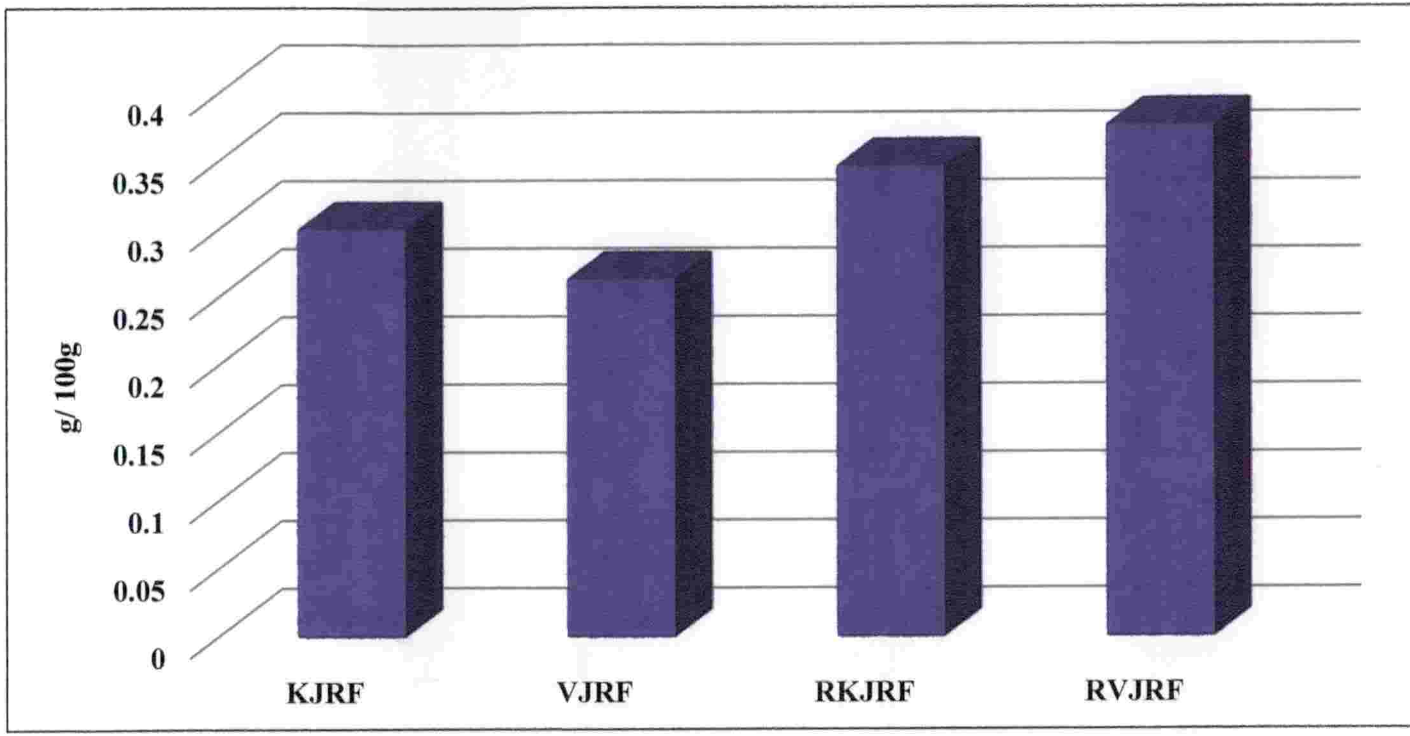
Tannin content was found to be higher in *koozha* rind flour and *koozha* based *papad* and crispies. Even though there are disadvantages of high tannin consumption, it has its positive effects that make amino acids available for absorption.

Pectin content in this study was lower in raw *koozha* jackfruit rind flour and was found to be increasing on ripening of the fruit. Standardized products from jackfruit rind flour also revealed that *koozha* jackfruit rind flour products had lower pectin content than *varikka* rind flour products.

Lectin content of raw and ripened jackfruits of both cultivars *koozha* and *varikka* have similar lectin content irrespective of its cultivar difference and maturity. The products developed out of rind flour of different cultivars have not shown any difference in their lectin content.

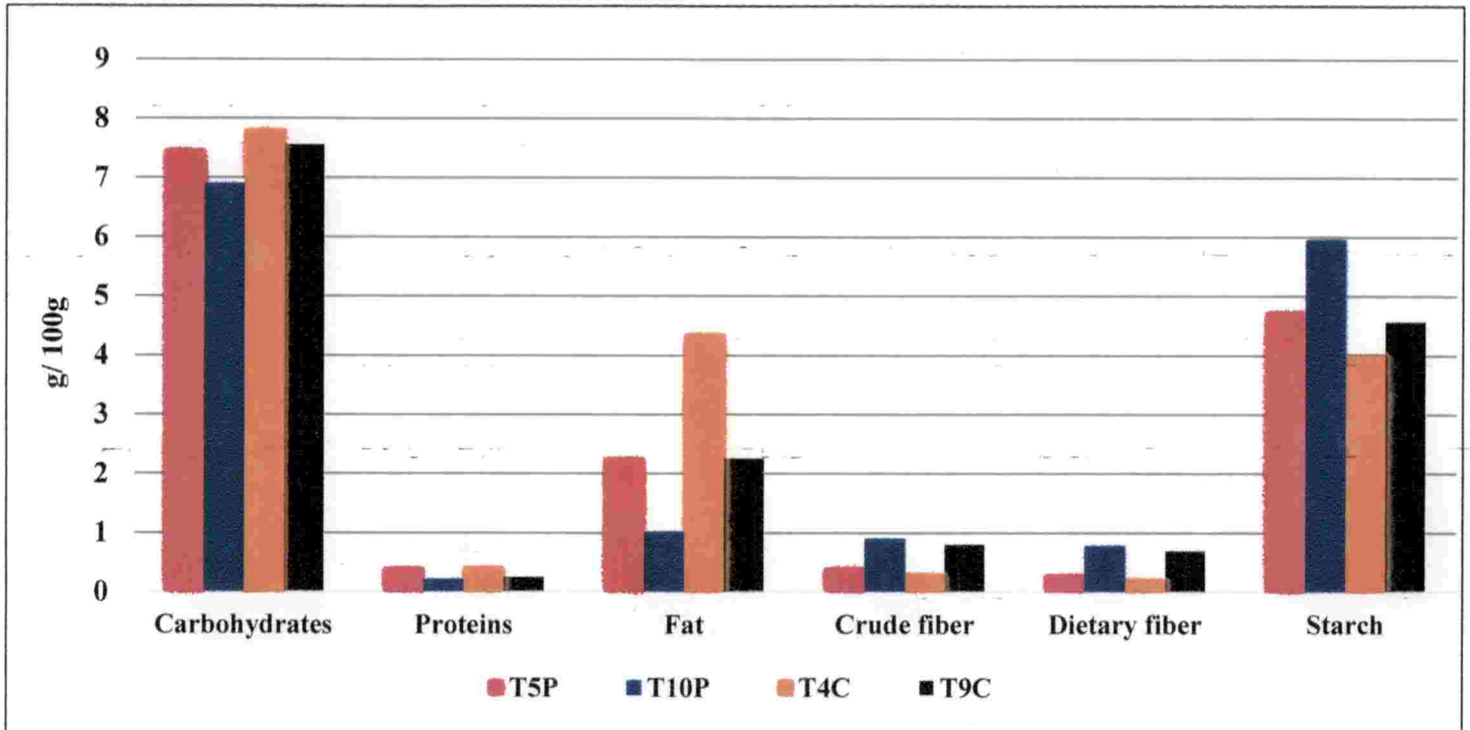
Peroxide value determines the quality of the flour and the product. Higher the peroxide value, higher is the spoilage. *Koozha* jackfruit rind flour had lower peroxide value (0.5 mEq/ kg) proving its higher shelf-life of the flour. Peroxide value of the

Graph: 7 Total Anti-oxidant activity of jackfruit rind flour



Koozha jackfruit rind flour (KJRF)   Ripened *Koozha* jackfruit rind flour (RKJRF)
Varikka jackfruit rind flour (VJRF)   Ripened *Varikka* jackfruit rind flour (RVJRF)

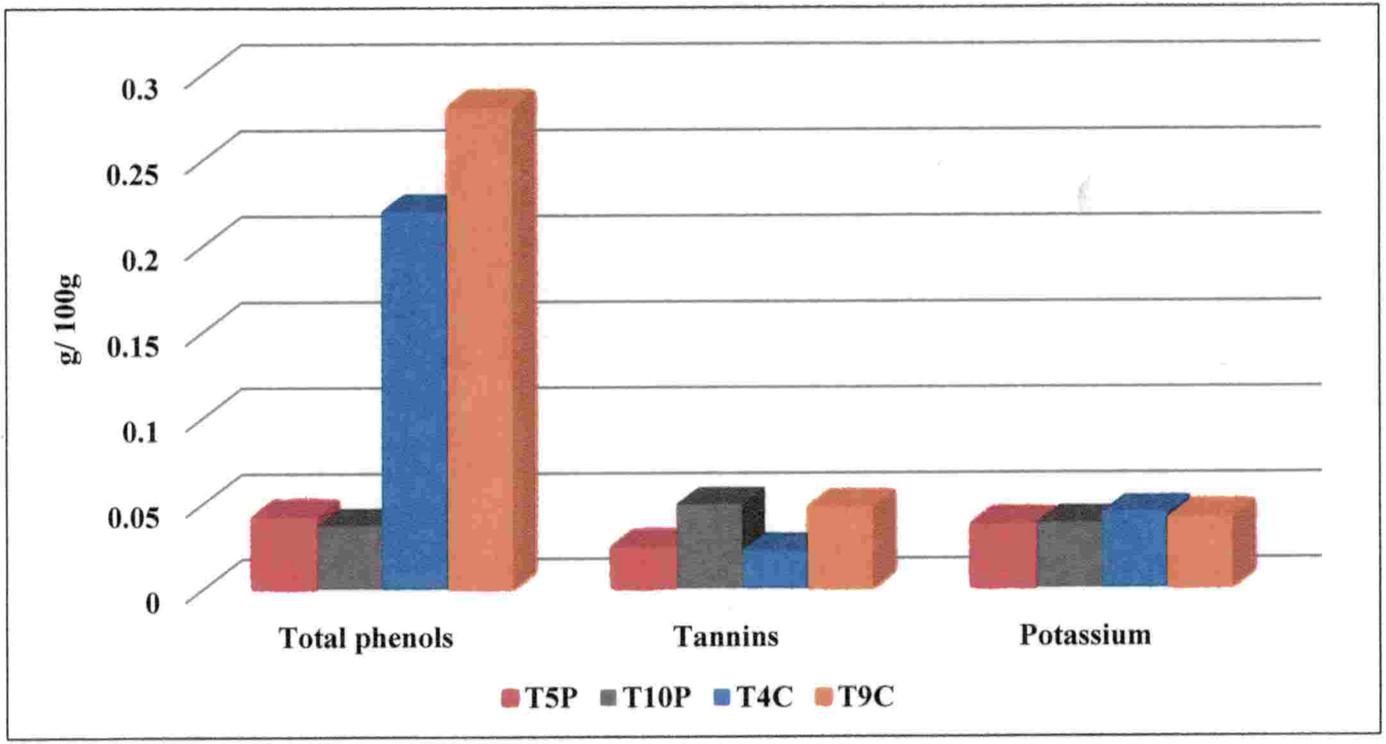
Graph: 8 Nutrient composition of the standardized products



T_5P - *Varikka* jackfruit rind *papad* T_4C- *Varikka* jackfruit rind Crispies

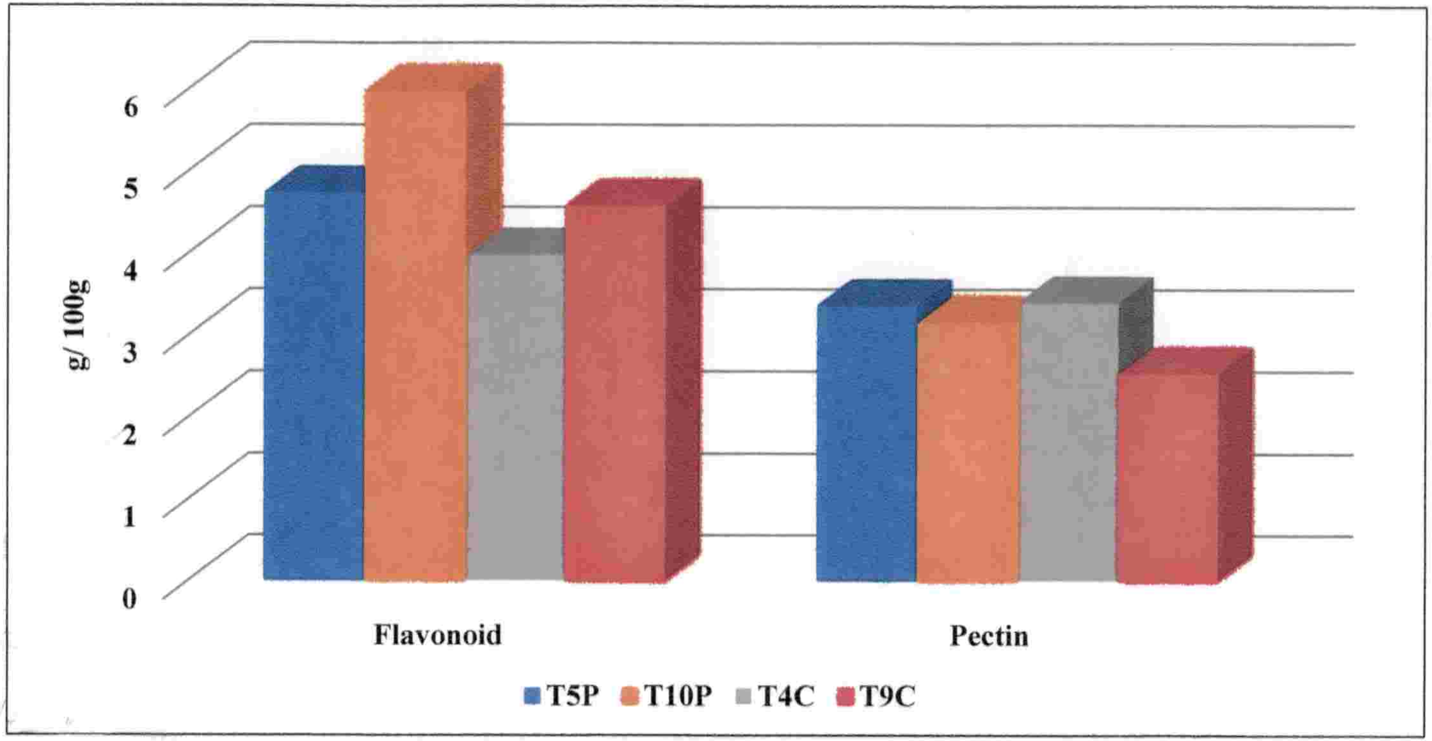
$T_{10}P$- *Koozha* jackfruit rind *papad* T_9C- *Koozha* jackfruit rind Crispies

Graph: 9 Chemical composition of the developed products



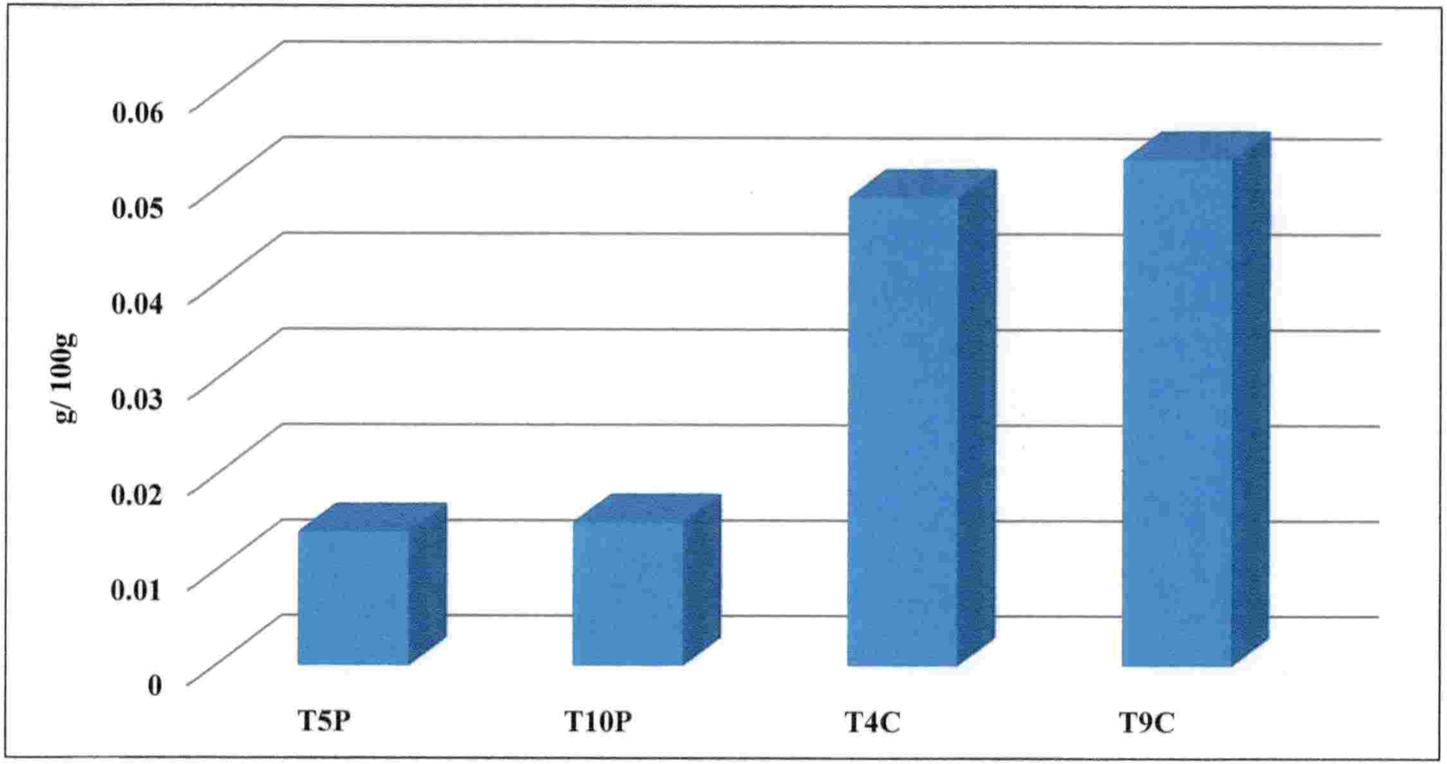
T_5P - *Varikka* jackfruit rind *papad*
$T_{10}P$- *Koozha* jackfruit rind *papad*
T_4C- *Varikka* jackfruit rind Crispies
T_9C- *Koozha* jackfruit rind Crispies

Graph: 10 Chemical composition of the developed products



T_5P - *Varikka* jackfruit rind *papad* T_4C- *Varikka* jackfruit rind Crispies
$T_{10}P$- *Koozha* jackfruit rind *papad* T_9C- *Koozha* jackfruit rind Crispies

Graph: 11 Total-Antioxidant Activity of standardized products



T_5P - *Varikka* jackfruit rind *papad* T_4C- *Varikka* jackfruit rind Crispies

$T_{10}P$- *Koozha* jackfruit rind *papad* T_9C- *Koozha* jackfruit rind Crispies

papad was higher (6 mEq/kg) than crispies (3.2 mEq/kg) which can be due to the usage of oil during processing.

Jackfruit rind flour based products in this study was found to have higher sodium content in T_9C and T_4C than T_5P and $T_{10}P$. Even though the *papad* is generally salty, sodium content of *papad* was less than crispies which can be due to the addition of seasoning masala to the crispies.

5.4.3 and 5.8.3 Total Anti-oxidant activity of jackfruit rind flour and the developed products

Arina *et al.* (2016) reported that fresh fruits had higher antioxidant activity than fried fruits which was analyzed by FRAP assay. But, the result of antioxidant activity using beta-carotene bleaching assay did not show similar pattern. Jackfruit and breadfruit had only showed high antioxidant activity in fresh fruits compared to fried fruits, but not for cempedak.

Burci (2015) identified high antioxidant activity and high radical scavenging activity in the extract of *A. heterophyllus* seeds. The phytochemicals found in the extract prepared from different solvents showed higher antioxidant activity indicated that these phytochemicals contributing to the antioxidant activity of the seeds tested does not belonged to same groups of plant metabolites and depends on their chemical properties.

In this study, total anti-oxidant activity shows that, it was higher in ripened jackfruit rind flour than raw jackfruit rind flour. Anti-oxidant activity remained higher in extruded crispies than dehydrated *papads*, proving that extrusion does not affect the anti-oxidant activity much when compared to dehydration.

5.5 PREPARATION OF COMPOSITE FLOUR

Composite flour is a mixed flour, starches and other ingredients are added to replace wheat flour totally or partially in bakery and convenience products. Composite flours are the mixture of many vegetable flours that are rich in starch or protein, with or without wheat flour or rice flour for certain group of products.

Noorfarahzilah *et al.* (2014) reported that the development of food products using composite flour has increased and is attracting much attention from researchers, especially in the production of bakery products and pastries and has found to give positive effects with respect to functional and physicochemical properties. There was also improvement in health benefits of raw blended flours with increased percentage of blending.

In a study by Giwa and Abiodun (2010), composite flour from quality protein maize (QPM) flour and wheat flour was utilized for the preparation of cookies, with the bid to improve the quality of protein in the biscuit and increase the use of QPM. The QPM and wheat flours were blended at various ratios to give five blends. The ratios were (wheat: QPM) 100:0; 70:30; 50:50; 30:70 and 0:100.The mixture were very well mixed by mixer. The biscuits produced from the composite flour were acceptable and compared favorably with the control.

In the present study, composite flour was prepared with the combination of rice flour, *varikka* (T1 to T5) and *koozha* (T6 to T10) jackfruit rind flours and black gram flour in the increasing order from 50 per cent to 80 per cent of rice flour, decreasing order of jackfruit rind flour from 40 per cent to 10 per cent and constant composition of black gram flour of 10 per cent in order to maintain the protein content of the product.

5.6 STANDARDIZATION OF *PAPAD*

Papad is one of the favourite snack which is widely consumed in many parts of the world. It is generally prepared from a blends of cereal flour, edible starch and pulse flour along with common salt, spices, edible oil, alkaline and mucilaginous additives (Miaruddin, *et al.,* 2006).

Some varieties of *papads* are prepared from vegetables, egg, jackfruit, banana or sweet potato. The important varieties of *papads* are those made from i) blackgram ii) mungbean iii) lentils iv) rice flour and v) Potato (Chowdhury *et al.*, 2009).

In this study, *Koozha* and *varikka* jackfruit rind based *papad* were developed from the composite flour. Rice flour gives crispy texture due to its starch content, jackfruit rind flour has high nutritional and phytochemical components in it and black gram provides protein to the diet. Thus a more nutritious *papad* was envisaged.

5.7 STANDARDIZATION OF CRISPIES

Extrusion is a upcoming thermal processing method in the food industries that makes use high heat, high pressure, and shear forces to a mixture of uncooked flours like cereal foods in order to develop different range of products including snacks, ready to eat (RTE) cereals, confectioneries and crisp breads (Kim *et al.*, 2006). The necessary environment for rapid processing and transforming the food into visco-elastic melt was provided by the shear forces created by the rotating action of the screws, together with frictional, compressive and pressure forces (Firibu, 2011).

Extrusion process has the capacity to modify the functional properties of food ingredients. It has both beneficial and undesirable effects on nutritional value. Beneficial effects include starch gelatinization, removal of anti-nutritional factors, increased soluble dietary fibers, reducing lipid oxidation and harmful microorganisms and retention of natural hue and aroma of foods. In addition to this, the extrusion process denatures undesirable enzymes and sterilizes the finished product (Bjorck and Asp, 1983; Singh *et al.*, 2007).

O the other hand, the disadvantages of this process is the mailard reaction that reduces the nutritional value of the protein and loss of heat-labile vitamins (Singh *et al.*, 2007).

In this study of extruded crispies from jackfruit rind flour, crispies turned brown which could be due to the polyphenol content in the rind flour and high temperature in the extruder that burns the fiber in the composite thus making it brown. The crispies were unable to be extruded in higher proportion of jackfruit rind flour (T1, T2, T6 and T7) which could be due to the high pectin and fiber content in it.

5.8 QUALITY EVALUATION OF THE JACKFRUIT RIND BASED PRODUCTS

5.8.1 Sensory Evaluation of the developed Products

The standardized products were evaluated for various sensory attributes like color, taste, flavor, crispness, texture and overall acceptability. The results regarding each product is discussed here.

5.8.1.1 and 5.8.1.2 Sensory evaluation of varikka and koozha based jackfruit rind papad

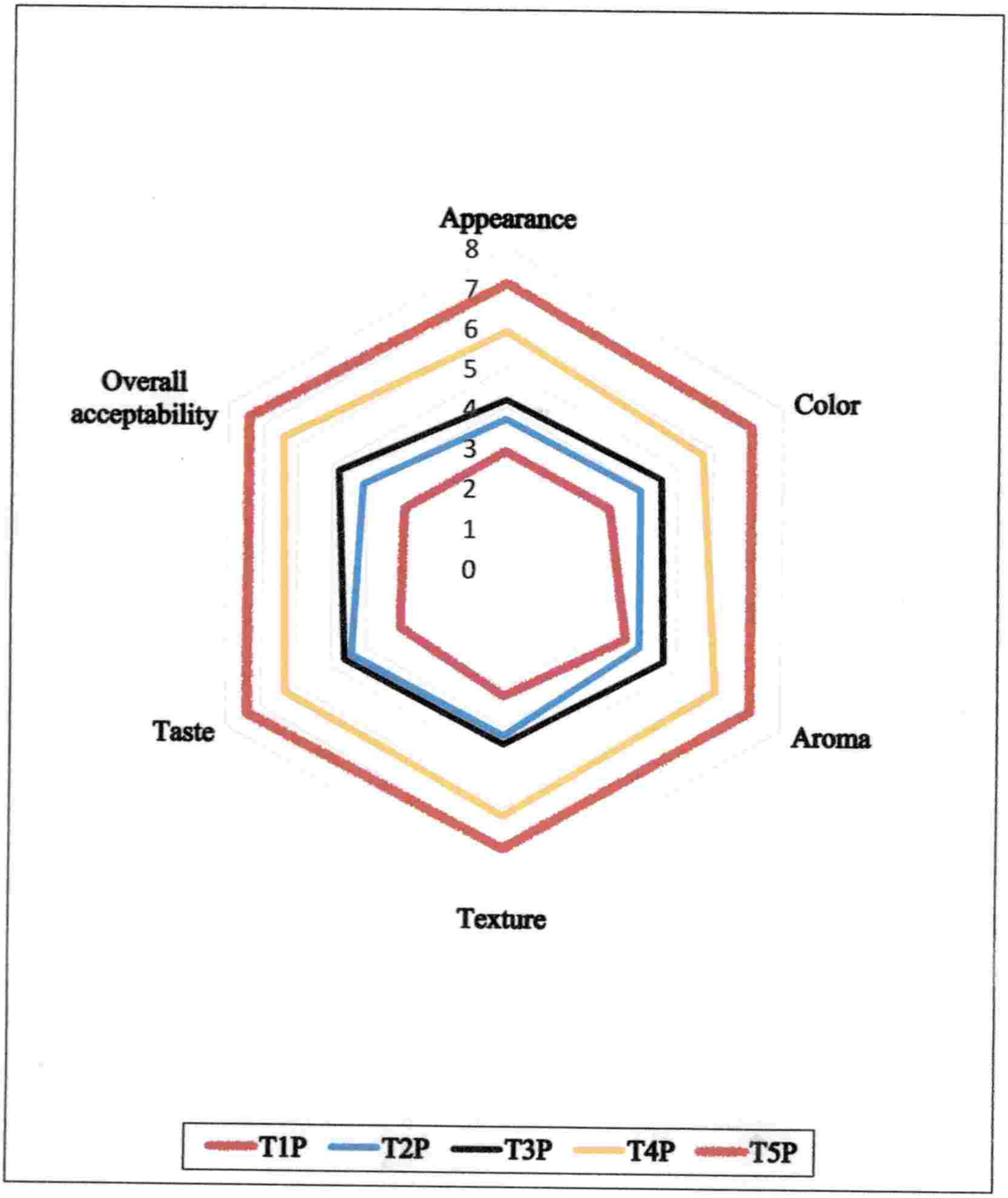
Appearance of a product refers to the size, shape, color, and condition of the outside and interior surface. The sensory evaluation revealed that the mean rank value for appearance of *varikka* jackfruit rind *papad* ranged between 11.40– 41.65. T_5 obtained the first rank with the mean rank value of 41.65 after control (45.56), while, T_1 got the last rank with mean rank value of 11.40.

The sensory evaluation revealed that the mean rank value for taste of *koozha* jackfruit rind *papad* ranged between 11.75– 40.90. T_{10} obtained the first rank with the mean rank value of 40.90 after control (45.56) while, T_6 got the last rank with a mean rank value 11.75.

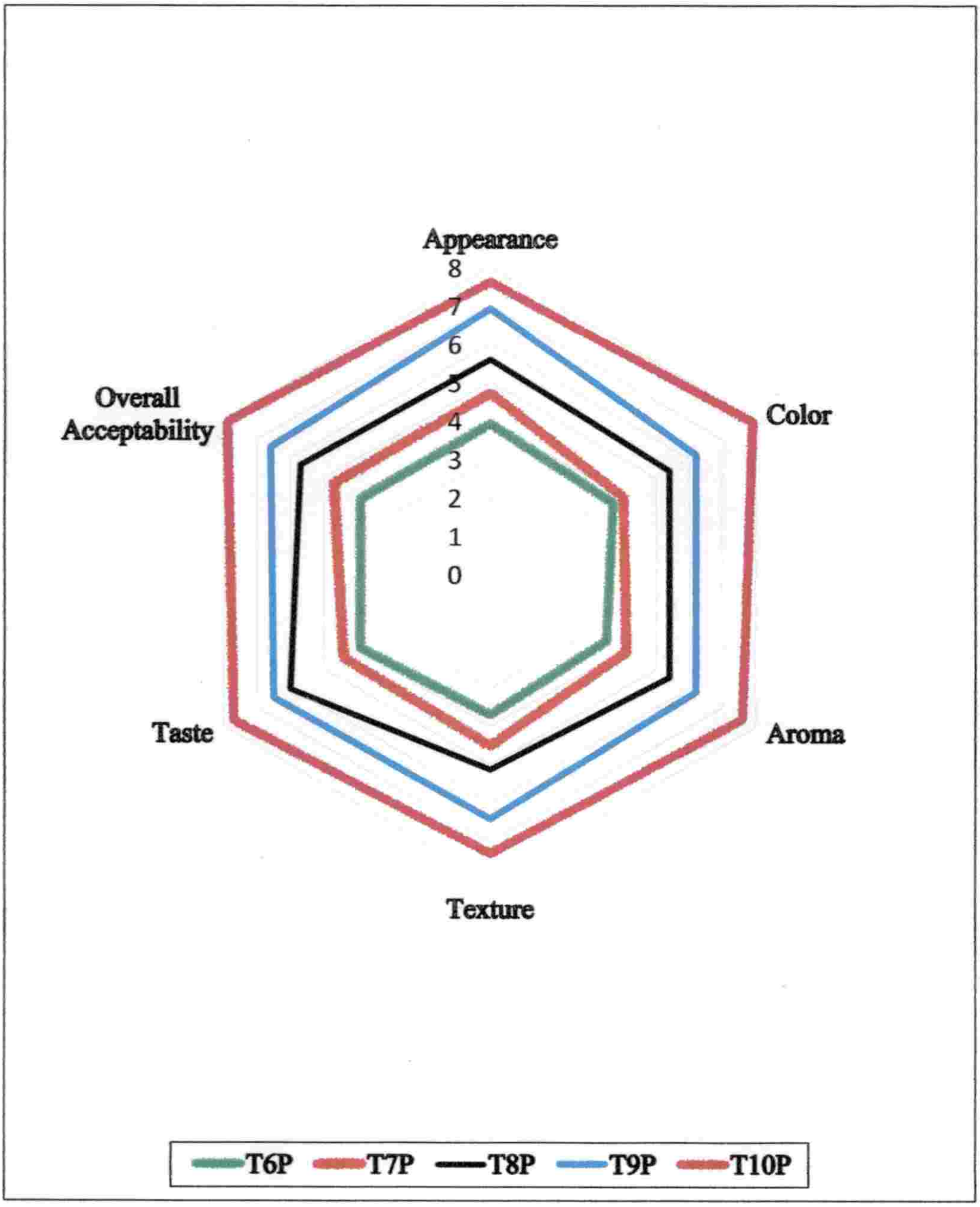
Colour is one of the important parameter that decides the acceptance of the product by the consumer. The sensory evaluation revealed that the mean rank value for color of *varikka* jackfruit rind *papad* ranged between 11.65– 41.55. T_5 obtained the first rank with the mean rank value of 41.55 after control (44.32), while T_1 got the last rank with mean rank value of 11.65.

The scores for colour of *Koozha* jackfruit rind *papad* ranged between 13.04– 42.50. T_{10} obtained the first rank with the mean rank value of 42.50, after control

Graph: 12 Sensory evaluation of *varikka* jackfruit rind *papad*



Graph: 13 Sensory evaluation of *koozha* jackfruit rind *papad*



(44.32), while T_6 got the last rank with mean rank value of 13.40. Colour of the *papad* was slightly yellowish orange and brownish orange in *varikka* and *koozha papad* respectively which could be due to the polyphenol content present in the rind flour.

Papad prepared from five day soaked grains of sorghum finger millet developed very mild off flavor (Prabhakar *et al.*, 2016). The sensory evaluation revealed that the mean rank value for aroma of *varikka* jackfruit rind *papad* ranged between 14.60– 40.50. T_5 obtained the first rank with the mean rank value of 40.50 after control (45.2), while T_1 got the last rank with mean rank value 14.60.

The sensory evaluation revealed that the mean rank value for aroma of *koozha* jackfruit rind *papad* ranged between 13.85– 40.50. It was analyzed statistically that T_{10} obtained the first rank with the mean rank value of 40.50 after control (45.20), while T_6 got the last rank with mean rank value 13.85.

The textural changes in *papad* were attributed to the increased surface area by carbon dioxide liberated from *Papad* khar during frying (Chowdhury et al., 2009). From the evaluation of texture of *varikka papad*, it was found that T_4 got the highest mean rank value of 20.90 for this attribute after the control (25.70).

From the evaluation of texture of *koozha papad*, it was found that T_{10} got the highest mean rank value of 39.20 for this attribute after the control (45.70) and T_6 got the lowest mean rank value of 13.95.

Even though all the sensory parameters are necessary, taste is the factor that decides the acceptance and promotion of the product in the market. Hence, the sensory evaluation revealed that the mean rank value for taste of *varikka* jackfruit rind *papad* ranged between 12.35– 40.65; T_5 obtained the first rank with the mean rank value of 40.65 after control (46.63) while T_1 got the last rank with mean rank value 12.35.

The sensory evaluation revealed that the mean rank value for taste of *koozha* jackfruit rind *papad* ranged between 14.90– 40.25. T_{10} obtained the first rank with the mean rank value of 40.25 after control (46.63), while T_6 got the last rank with mean rank value 14.9.

Papad prepared with addition of 10 per cent garden cress seed was highly acceptable followed by 20 per cent garden cress seed with better sensory qualities but beyond 20 per cent level, there was negative impact on qualities of *papad* specially in case of colour and after taste, due the alkaloid content, which were shown to have bitter properties (Talpade, 2018).

Overall acceptability of *varikka* rind *papad* showed that, T_4 obtained the highest mean rank value of 22.95 after control (25.90). While T_3 got the last rank with mean rank value 9.65. *koozha* rind *papads* revealed that T_{10} obtained the highest mean rank value of 41.80 after control (45.90),while T_6 got the last rank with mean rank value of 14.25.

In this study, *varikka* rind *papad* T_5 (80:10:10) comprised of rice flour, *varikka* jackfruit rind flour and black gram flour and *koozha* rind *papad* T_{10} (80:10:10) made of rice flour, *koozha* rind flour and black gram flour were selected as the best treatments, since they obtained the highest scores in all the parameters like appearance, color, aroma, texture taste and overall acceptability.

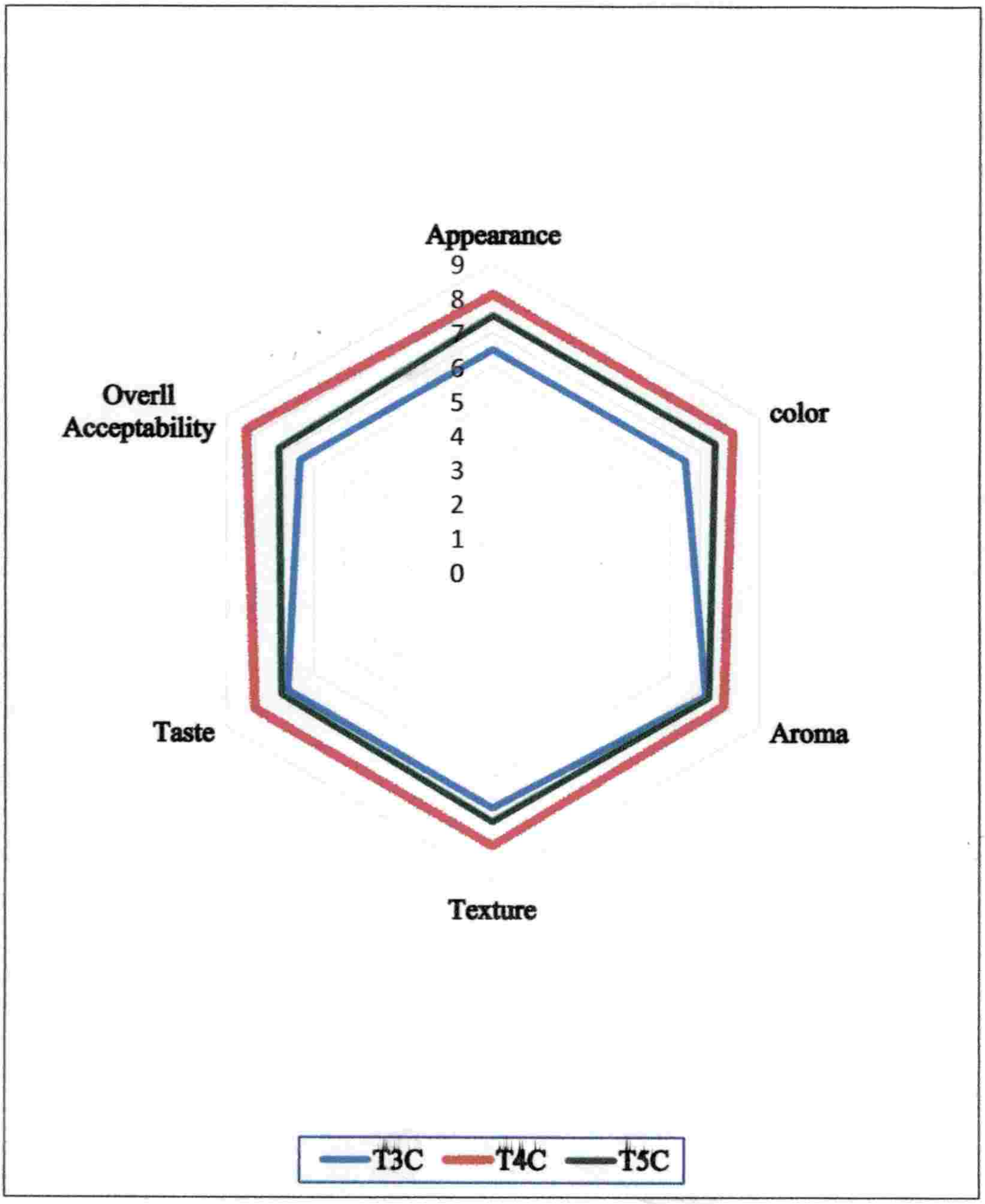
5.8.1.3 and 5.8.1.4 Sensory evaluation of varikka and koozha crispies

Sensory evaluation revealed that the mean rank value for appearance of *varikka* jackfruit rind crispies ranged between 10.15– 20.55. From Kruskal- Wallis test it was analyzed that T_5 obtained the first rank with the mean rank value of 20.55 after control (25.33), while T_3 got the last rank with mean rank value of 10.15.

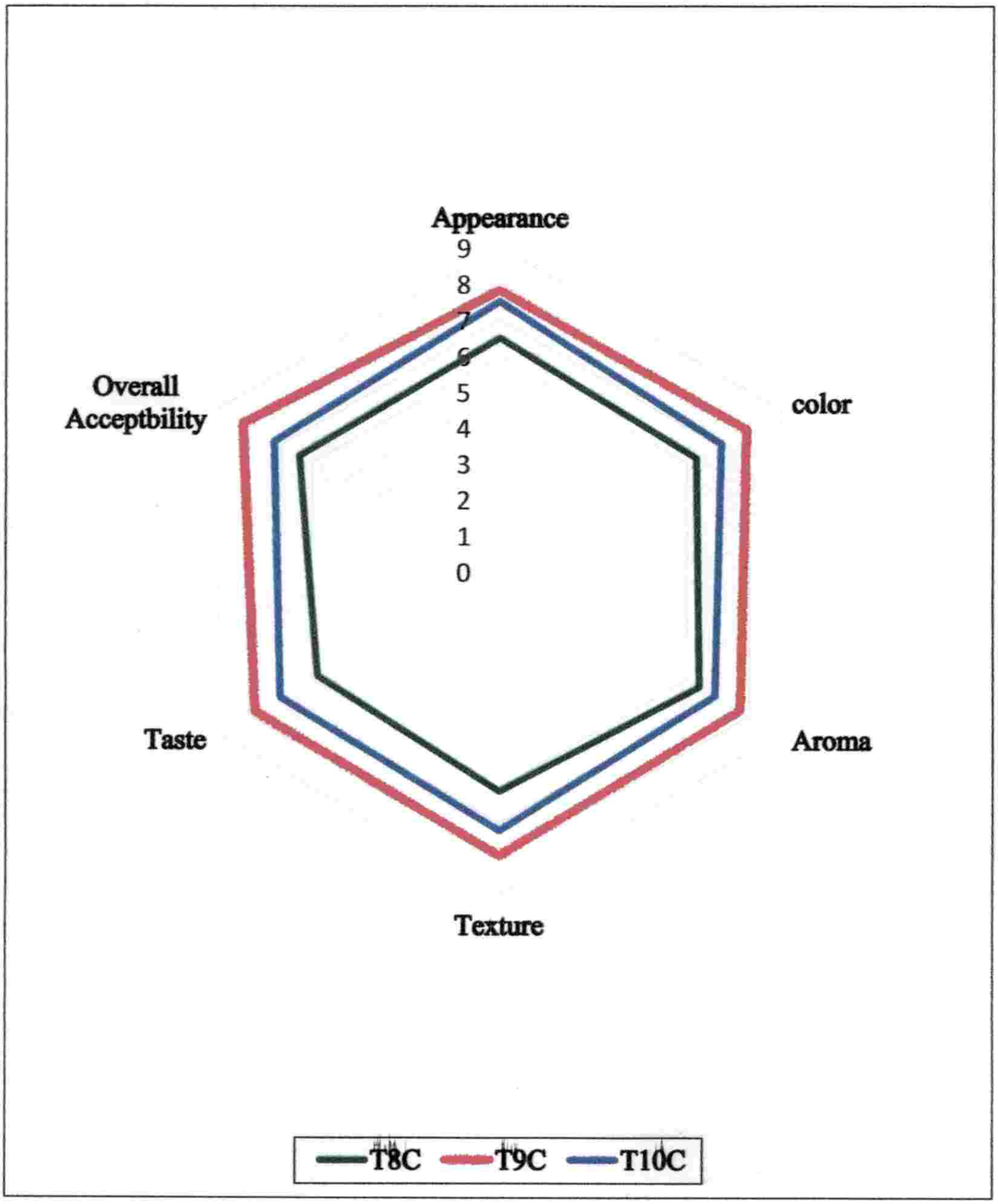
Sensory evaluation revealed that the mean rank value for appearance of *koozha* jackfruit rind crispies ranged between 10.15– 20.55. From Kruskal- Wallis test it was analyzed that, T_9 obtained the first rank with the mean rank value of 19.68 after control (25.33) while T_8 got the last rank with mean rank value of 11.70.

Sensory evaluation revealed that the mean rank value for color of *varikka* jackfruit rind crispies ranged between 9.80– 21.20. The results after analysis showed

Graph: 14 Sensory evaluation of *varikka* jackfruit rind crispies



Graph: 15 Sensory evaluation of *koozha* jackfruit rind crispies



that T_4 obtained the first rank with the mean rank value of 21.20, after control (24.52). While T_1 got the last rank with mean rank value 9.80.

Sensory evaluation revealed that the mean rank value for color of *koozha* jackfruit rind crispies ranged between 10.20– 21.05. The results after analysis showed that T_9 obtained the first rank with the mean rank value of 21.05 after control (24.52), while T_3 got the last rank with mean rank value of 10.20.

Sensory evaluation further revealed that the mean rank value for aroma of *varikka* jackfruit rind crispies ranged between 14.15– 18.20. From Kruskal- Wallis test it was analyzed that T_4 obtained the first rank with the mean rank value of 18.20 after control (22.20), while T_3 got the last rank with mean rank value 14.15.

Sensory evaluation revealed that the mean rank value for aroma of *koozha* jackfruit rind crispies ranged between 12.60– 19.60. It was analyzed statistically that T_9 obtained the first rank with the mean rank value of 19.60 after control (22.20), while T_3 got the last rank with mean rank value of 12.60.

From the evaluation of texture, it was found that T_4 got the highest mean rank value of 20.90 for this attribute after the control (25.70). From the evaluation of texture it was found that T_9 got the highest mean rank value 20.15 for this attribute after the control (25.70).

Sensory evaluation revealed that the mean rank value for taste of *varikka* jackfruit rind crispies ranged between 13.15– 20.70. From Kruskal- Wallis test it was analyzed that, T_4 obtained the first rank with the mean rank value of 20.70 after control (26.20).

Sensory evaluation revealed that the mean rank value for taste of *koozha* jackfruit rind crispies ranged between 11.70– 20.20. From Kruskal- Wallis test it was analyzed that, T_9 obtained the first rank with the mean rank value of 20.20 after control (26.20).

Overall acceptability values revealed that T_4 obtained the highest mean rank value of 22.95 after control (25.90), while T_3 got the last rank with mean rank value

9.65. From the statistical analysis of values for overall acceptability of *koozha* rind crispies, it was noted that T_9 obtained the highest mean rank value of 22.40 after control (25.90).

5.8.2 Physical characteristics of *Papad*

The physical characteristics such as yield, dried weight, thickness, diameter of raw and fried forms, expansion percentage, color, bulk density, texture and oil absorption were ascertained. The total number of *papads* obtained out of 100g of the composite flour was 16 for T_5P and 15 for T_{10}P.

Rice flour, having a greater water absorption capacity than the other cereal flours, when blended with black gram flours, produced *papads* of a quality comparable to that of black gram *papads* (Bhattacharya, 1998).

The unit weight of a dried *papad* T_{10}P (4.6g) was higher than dried T_5P (4.5g). Irrespective of the cultivars, there was no significant difference in the thickness of the raw jackfruit rind *papad*, but there was a difference in the thickness of the fried *papad*. This could be due to an increase in the starch content when rind flour was mixed into rice flour. The starch undergoes gelatinization during frying and thereby produces greater expansion and thickness (Bhattacharya, 1998). There was no significant difference between T_5P and T_{10}P in the diameter of raw and fried jackfruit rind *papad* .Higher expansion was observed in T_{10}P (39.1 %) and lower expansion in T_5P (33.3 %). The colour observed for T_5P was yellowish orange and T_{10}P was brownish orange in color. The difference in the color of the *papad* may be due to the higher polyphenol content in *koozha* jackfruit rind flour. There was no significant difference in the bulk density of T_5P and T_{10}P. The bulk density values were 0.37 (g/cm^3).

The work of penetration (2.923 Nmm), work of cutting (2.923 Nmm), cohesiveness (-0.0478 N), and crunchiness (0.953 Nmm) was higher in T_5P whereas stringiness was higher in T_{10}P (-30.589 Nmm), which may be attributed to the higher fibre content in *koozha* flour. Oil uptake by the jackfruit rind *papad* was significantly different between T_5P and $T_{10}P$. The oil uptake of T_5P was 5.30 per cent and $T_{10}P$ was 4.65 per cent which may be attributed to the difference in protein composition.

Beuchat (1976) has suggested that it involves physical entrapment of oil in which several nonpolar side chains of proteins could bind the hydrocarbon chains of fat. Based on this suggestion, it may be inferred that *varikka* rind flour has lower oil absorption capacity than rice flour, because of the availability of less nonpolar side chains in their protein molecules (Sathe et al. 1982).

5.8.3 Physical characteristics of the crispies

The total amount of crispies obtained out of 1Kg of the composite flour was 880g from T_4C and 890g from T_9C. When the yield was analyzed statistically, there was no significant difference in the yield between T_4C and T_9C which was made of *varikka* or *koozha* jackfruit rind flour. This shows that the difference in cultivars does not affect the yield of the product.

Irrespective of the cultivars, there was significant difference in the thickness of the jackfruit rind crispies of T_4C (12.52 mm) and T_9C 13.3 mm). The thickness of T_9C was higher than T_4C. Expansion capacity of the products differed with cultivars owing to the difference in functional chararacteristic. There was no significant difference in the bulk density of T_4C and T_9C. The bulk density of T_4C was 0.14 (g/cm^3) and T_9C 0.137 (g/cm^3).

The change in the colour of the crispies which was observed visually showed that the colour observed for T_4C was brown and T_9C was dark brown in color. It could be due to the higher polyphenol content of the *koozha* jackfruit rind flour.

The result shows that there was significant difference between T_4C and T_9C. The crispiness (35.818 Nmm), cohesiveness (-0.0257 N) and crunchiness (24.774 Nmm) was higher in T_4C than T_9C whereas work of penetration (7.558 Nmm), work of cutting (7.558 Nmm) and stringiness (-9.008 Nmm) was higher in T_9C than T_4C which may be attributed to higher content of fibre content of *koozha* rind flour.

5.9 STORAGE STABILITY OF THE PRODUCTS

Storage stability of the products is an essential component in consumer acceptance and marketing.

5.9.1 Microbial profile

Microbial contamination and quality of food varies according to the control over food spoilage microorganisms and conditions that destroy them or prevent their growth and multiplication during preparation, processing, preservation and marketing (Tiwari and Grewal, 1999). In certain cases, the microflora may increase in number due to the inadequate or lacking processing facilities, with subsequent handling, resulting in food borne infections to the consumer (Barrett, 1986). Mould growth was observed in Indian commercial *papads* at about 18 percent moisture level (Balasubrahmanyam *et al.,* 1960).

Balasubrahmanyam *et al.* (1974) studied the factors responsible for changes in colour and pH of *papads* during storage under accelerated conditions. The insect infestation and mould growth in South Indian *papads* can be prevented by using fumigation was reported by Narasimhan *et al.,* 1972).

Microbial analysis of jackfruit rind flour

In $1x10^{-6}$dilution and $1x\ 10^{-7}$ dilution up to 3 months of storage, no bacterial colonies were found to appear in *koozha* and *varikka* jackfruit rind flours. But, after the third month of storage in *varikka* jackfruit rind flour, 2 colonies of fungi were observed in $1x\ 10^{-4}$ dilution. When the analysis was conducted at monthly intervals, no actinomycetes and coli form colonies were found for three months of storage. The fungal growth of the rind flour after the third month of storage could be due to the increase in the moisture content.

Microbial analysis of jackfruit rind *papad*

During the analysis conducted at monthly intervals there was no detection of bacterial, fungal, actinomycetes and coliform colonies up to the storage of two months.

After the third month of storage, in dilutions of 3×10^{-6}, 1×10^{-7}, bacterial colonies and in dilutions of 5×10^{-4}, 3×10^{-5}, fungal colonies were observed in T_5P which was made of *varikka* jackfruit rind flour. Whereas in $T_{10}P$ i.e., *papad* made of *koozha* jackfruit rind flour, in dilutions of 2×10^{-6}, 1×10^{-7}, bacterial colonies and in dilutions of 3×10^{-4}, 2×10^{-5}, fungal colonies were observed. The rice flour present in *papad* could be absorbing moisture that leads to the microbial growth in the *papads*

Microbial analysis of jackfruit rind crispies

During the analysis conducted at monthly intervals there was no detection of bacterial, fungal, actinomycetes and coliform colonies up to the storage of three months. This could be due to the reduced moisture content of the crispies, since it had undergone high temperature and pressure processing.

5.10 COST ANALYSIS OF THE STANDARDIZED PRODUCTS

The cost of the product was calculated based on the cost of production (Fixed cost and variable cost). Cost of production of unit *papad* was Rs. 0.54 and with 10 % profit it would cost Rs. 0.60. Cost of similar products (rice *papad*) in the market is Rs. 1.50. Hence the B: C ratio of the jackfruit rind *papad* is 1: 2.5.

Cost of production of crispies (55 g) was Rs. 7.45 and with 10 per cent profit, it costs Rs. 8.12. Cost of a similar product (kurkure) in the market is Rs. 10. Hence the B: C ratio of the jackfruit rind crispies is 1: 1.2.

This shows that, both the products developed from jackfruit rind are economically suitable for the production and promotion in the market. This could provide immense benefit to farm women and small scale processing units, along with bringing about value addition of this under exploited raw material from jackfruit.

Summary

6. SUMMARY

The present study entitled, "Value added products from jackfruit rind" was aimed at developing value added products from the rind flour of raw jackfruit (cv. *koozha* and *varikka*). The developed products viz. jackfruit rind *papad* and crispies were studied in depth for their physico-chemical properties, functional qualities, sensory qualities, nutritional profile, shelf life and cost of production. The major findings of the study are summarized below.

Rind of jackfruit is generated as waste after the consumption of its bulbs and seeds. Though value addition of the bulbs and seeds of the fruit is well known and is being popularized across the state, it is claimed through scientific results that, there is immense scope of finding alternate uses for the unutilized rind also.

This study aimed to utilize the fiber rich jackfruit rind in the development of value added products *viz, papad* and crispies from two cultivars, *Koozha* and *Varikka*. Raw mature jackfruits of 90-105 days of cultivar *Koozha* and *varikka* after fruit set with optimum visible maturity indices were selected for the rind separation from the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram.

Raw matured jackfruits are suitable for the better yield of jackfruit rind, because the thickness of the rind reported to diminish with ripening of the fruit. Jackfruit rind flour was processed according to the method standardized by Feili (2014).

The functional quality analysis of jackfruit rind flour revealed that there was significant difference at 5 % level in the water absorption index, oil absorption index, foaming capacity, and swelling power of the *cv. Varikka* and *Koozha* flours. However there was no significant difference in percentage solubility, gelation concentration and rehydration ratio.

The nutrient analysis of jackfruit rind flour showed significant differences at 5 % level, among raw and ripened *varikka* and *koozha* rind flours. Raw *Koozha* jackfruit rind flour showed higher content of crude fiber (18g/ 100g) and dietary fiber (13.56g/ 100g). It had low content of carbohydrate (29 g/100g) and fat (1.84 g/100g) which would suit diabetic patients.

The chemical composition of jackfruit rind flour showed significant differences at 5 % level among raw and ripened *varikka* and *koozha* rind flours. Raw *Koozha* jackfruit rind flour had higher tannins (0.088 g/100g) which could be the source of bitterness of the product. It also had higher content of polyphenols (2 g/100g) that could be responsible for the enzymatic browning of rinds and had lower peroxide value (0.5 g/100g), which could be the reason for better keeping quality of this rind type. Pectin content was found to be higher (27.5 g/100g) in ripe *varikka* jackfruit rind flour, which is a limiting factor in the production of dehydrated and extruded products as it affects the extrusion quality of the products.

The various treatments selected for the formulation of *papads* and crispies with rice flour, *varikka* jackfruit rind flour and black gram flour respectively in the pre-determined proportions were, T1 (50:50:0), T2 (50:40:10), T3 (60:30:10), T4 (70:20:10), T5 (80:10:10) and control (100:0:0).

Similarly, the treatments selected for the formulation of *papads* and crispies with, rice flour, *koozha* jackfruit rind flour and black gram flour respectively in the pre-determined proportions were, T6 (50:50:0), T7 (50:40:10), T8 (60:30:10), T9 (70:20:10), T10 (80:10:10) and control (100:0:0).

Jackfruit rind *papad* was processed by the standardized procedures of Kamath (2008). Based on the sensory evaluation it was found that T5 and T10 were the best combinations respectively for *cv. Varikka* and *cv. Koozha* based *papads*.

Jackfruit rind crispies were processed at CTCRI (Incubation centre) by the standard procedures of Veena (2015). Based on the sensory evaluation, it was found that T4 and T9 were the best combinations for *cv. Varikka* and *cv. Koozha* based crispies respectively. Out of the 10 treatments for the development of *varikka* and *koozha* jackfruit rind based crispies, T1, T2, T6 and T7 were unable to be extruded, which is presumed to be due to the high fiber and pectin content, that affects the extrusion quality.

The standardized *papads* (T_5P, $T_{10}P$) and crispies (T_4C, T_9C) had significant differences in their nutrient content at 5 % level. Among the four products developed *Koozha papad* and crispies revealed lower carbohydrate (69 g/100g), starch (3.98 g/100g) and fat content (1.02 g/100g) and were rich in crude fiber (0.9 g/100g) and dietary fiber (0.78 g/100g).

The physical characteristics of the jackfruit rind *papads* (T_5P and $T_{10}P$) has shown significant difference at 5 % level in the expansion percentage, thickness after frying and oil uptake and no significant difference in yield, diameter, diameter expansion and bulk density, whereas for crispies, there was significant difference in the thickness and no significant difference for yield and bulk density.

Iron content in *Koozha* jackfruit rind *papad* was highest (0.117 mg/100g) followed by *koozha* crispies. Sodium content (6.28g/ 100g) was higher in *Varikka* crispies which could be due to the adjuncts added to it. There was no significant difference in the potassium content of all the products. *Koozha* crispies were found to be high in total anti-oxidant activity.

Texture analysis of the standardized products had shown significant difference at 5 % level in values for work of penetration, work of cutting, cohesiveness, stringiness and crunchiness. Crispiness of crispies was found to be significantly different (T_4C and T_9C) at 5 % level.

Storage stability of the jackfruit rind flour and the standardized products were assessed by their microbial load. The results revealed that rind flour and rind *papads* was detected with fungus after 3 months of storage, whereas in the case of crispies no microbes were detected till 3 months. Sensory evaluation of the product conducted at equal intervals for 3 months did not show any difference in their taste and overall acceptability.

Storage stability of fresh cut rinds were analyzed at different storage temperatures (4° C and - 18° C). *Koozha* rinds deteriorated in visual quality within a week and turned more brown than *varikka* which retained its colour for over 10 days. The browning of *koozha* rinds is presumed to be due the polyphenol content in it. In order to control browning of the rinds, different pre-treatments were carried out with 1 % citric acid, 1 % sugar solution, 1 % salt solution and 1 % lime juice. Out of which citric acid was found to be effective among the four treatments. Thus the pretreatment for enhancing quality of raw matured jackfruit rind was also identified.

The cost of the product was calculated based on the cost of production (Fixed cost and variable cost). Cost of production of unit *papad* was Rs. 0.54 and with 10 % profit it costs Rs. 0.6. Cost of similar product (rice *papad*) in the market is Rs. 1.5. Hence the B: C ratio of the jackfruit rind *papad* is 2.5.

Cost of production of crispies (55 g) was Rs. 7.45 and with 10 % profit it costs Rs. 8.12. Cost of similar product (kurkure) in the market is Rs. 10. Hence the B: C ratio of the jackfruit rind crispies is 1.2.

This study on the utilization and value addition of jackfruit rind concludes that products (*papad* and crispies) developed from *koozha* rind flour were high in nutrients and had better sensory qualities and shelf-life.

The outcome of this work envisages immense benefits to farm women and small scale processing units, by bringing about value addition of this under exploited raw material from jackfruit, growing in abundance in the state.

References

7. REFERENCES

Abano, E. E. and Samamoah, L.K. 2011. Effects of different pretreatments on drying characteristics of banana slices. *J. Eng. Appl. Sci.* 6 (3): 121 – 129.

Abbey, B. W. and Ibeh, C. O. 1988. Functional properties of raw and heat processed cowpea flour. *J. Food Sci.* 53: 1775 – 1777.

Abdelghafor, R. F., Mustafa, A. I., Ibrahim, A. M. H., and Krishnan, P. G. 2011. Quality of bread from composite flour of sorghum and hard white winter wheat. *Adv. J. Food Sci. Tech* 3: 9-15.

Adebowale, Y. A. and Lawal, S. 2003. Functional and physico chemical properties of six Mucuna species. *Afr. J. Biotechnol.* 4(12):1461-1468.

Adejuyitan, J. A., Otunola, E. T., Akande, E. A., Bolarinwa, I. F., and Oladokun, F. M. 2009. Some physicochemical properties of flour obtained from fermentation of tigernut (*Cyperus esculentus*) sourced from a market in Ogbomoso, Nigeria. *Afr. J. of Food Sci.* 3(2): 51-055.

Ajila, C. M., Naidu, K. A., Bhat, S. G., and Prasada Rao, U. 2007. Bioactive compounds and antioxidant potential of mango peel extract. *Food Chem.* 105:982-988.

Albanese, D., Cinquanta, L., and Matteo, M. D. 2007. Effects of an innovative dipping treatments on the cold storage of minimally processed Annurca apples. *Food Chem.* 105: 1054–1060.

Alesiani, D., Canini, A., Abrosca, B. D., Della, M., Fiorentino, A., and Mastellone, C. 2010. Antioxidant and antiproliferative activities of phytochemicals from Quince (Cydonia vulgaricus) peels. *Food chem.* 118: 119- 207.

Alonso, R., Rubio, L. A., Muzquiz, M., and Marzo, F., 2001. The effect of extrusion cooking on mineral bioavailability in pea and kidney bean seed meals. *Anim. Feed Sci. Technol.* 94(1-2): 1-13.

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Inc., Arlington. P: 73- 74.

Aremu, M.O., Olaofe, O., Akintayo, E.T., and Adeyeye, E.I. 2006. Foaming, Water Absorption, Emulsification and Gelation Properties of Kersting's Groundnut (Kerstingiella geocarpa) and Bambara Groundnut (Vigna subterranean) Flours as Influenced by Neutral Salts and Their Concentrations. *Pakist. J. Nutr.* 7 (1): 194-201. ISSN 1680-5194.

Arina, A. J. and Azrina, A. 2016. Comparison of phenolic content and antioxidant activity of fresh and fried local fruits. *Int. Food Res. J.* 23(4): 1717-1724.

Asquieri, E. R., Rabelo, A. M. D. S., and Silva, A. G. M. 2008. Fermented jackfruit: study on its physicochemical and sensorial characteristics. *Ciência e Tecnologia de Alimentos*, 28(4): 881-887.

Azad, A. K. 2000. Genetic diversity of jackfruit in Bangladesh and development of propagation methods. Ph.D. Thesis (unpublished), submitted to University of Southampton, UK.

Balasurbrahmanyam, N., Murthy, H. B. N., Srinivasan, V. R., Anandaswamy, B. Raju, P. V., and Iyengar, N. V. R. 1960. Packaging of moisture sensitive cereal products- *Papads*. *Food Sci.* 9: 281.

Balasurbrahmanyam, N., Venkatesh, K.V.L., and Shurpalekar, S. R. 1974. Changes in colour and acidity of blackgram *papads* during storage. *J. Food Sci. Technol.* 11: 79.

Barkama, A., Drabenstott, M., and Novack, N., 2001. The new US meat industry. *Econ. Rev.Fed. Reserve Bank of Kansas City*, *86*(2): 33.

Barrett, N. J. 1986. Communicable disease associated with milk and dairy products in England and Wales (1983-1984). *J. Infect.* 12: 265-272.

Beuchat, L. R. 1977. Functional and electrophoretic characteristics of succinylated peanut flour protein. *J. Agric. Food Chem.* 25: 258.

Bhandari, V. S, Panchapakesan, A., Shankar, N., and Kumar, H. G. A. 2103. Production of Bioethanol from Fruit Rinds by Saccharification and Fermentation. *Intern. J. Sci. Res. Eng. & Technol.* (IJSRET). 2(6): 362- 365.

Bhatia, S., Siddappa, G. S., and Giridhari, L. 1956. Product development from the fruits. *Indian J. Agric.* 25: 408.

Bhattacharya, S. and Narasimha, H. V. 1998. Characterization of *papad* from different blends of cereals with blackgram. *J. Food Qual.* pp. 157-166.

Björck, I. and Asp, N. G. 1983. The effects of extrusion cooking on nutritional value a literature review. *J. Food Eng.* 2(4): 281-308.

Blanco, S. F., Sarabia, E. R. F., Acosta-Aparicio, V. M., Blanco-Blanco, A., Gallego-Juárez, J. A. 2006. Food drying process by power ultrasound. *Ultrasonics Sonochem.* 44: 523-527.

Bradford, M. M. 1976. A rapid and sensitive method for qualifying of microgram qualities of protein utilizing the principle of protein – dye binding. *Ann. Biochem.* 72: 248.

Brnčić, M., Tripalo, B., Ježek, D., Semenski, D., Drvar, N. and Ukrainczyk, M., 2006. Effect of twin-screw extrusion parameters on mechanical hardness of direct-expanded extrudates. *Sadhana*, 31(5): 527-536.

Burci, M. L., da Silva, B. C., de Oliveira, M., Dalarmi, L., Zanin, W. M. S., Miguel, G. O., Dias, G. F.J., and Miguel, D.M. 2015. Determination of antioxidant, radical scavenging activity and total phenolic compounds of Artocarpus heterophyllus (Jackfuit) seeds extracts. *J. of Med. Plants Res.* 8(40): 1013-1020.

Buzby, J. C., Hodges, R. J., and Bennett, B., 2011. Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. *J. Agric. Sci.* 149: 37-45.

Chowdhury, M. G. F., Miaruddin. M., Rahman, M., Islam, M. S., and Tariqul islam, A. F. M. 2009. Study on the effect of preservative on the storage quality of spiced *papads*. *J. Innov. dev. strategy.* 3(1): 30-33.

Chrips, N. R., Balasingh, G. R., and Kingston, C. 2008. Nutrient constituents of neglected varieties of *Artocarpus heterophyllus*. Lam. from Kanyakumari district, South India. *J. Basic and Applied Biol.* 2(3&4): 36-37.

Coffman, C.W. and Garcia, V. V.1977. Functional properties and amino acid content of protein isolate from mung bean flour. *J. Food Technol.* 12: 473-484.

Corner, E. J. H. 1938. Notes on the systematics and distributions of Malayan phanerogams II. The jack and the chempedak. Gardens' Bulletin Straits Settlements 10: 56-81.

Corzo, O., Bracho, A. N., Pereira, A., and Vasquez, A. 2008. Weibull distribution for modeling air drying of coroba slices. *J. Food Sci. Technol.* 41(6): 1108-1115.

DAC (Department of Agriculture and Cooperation) 2014. *Area of horticultural crop.* Horticultural division. p.104

Das, I., Das, S. K., and Bal, S. 2004. Specific energy and quality aspects of infrared (IR) dried parboiled rice. *J. Food Eng.* 62: 9-14.

De Escalada Pla, M. F., Ponce, N. M., Stortz, C. A., Gerschenson, L. N., and Rojas, A. M. 2007. Composition and functional properties of enriched fibre products obtained from pumpkin (Cucurbita moschata Duchesne ex Poiret). *Lebensmittel-Wissenchaft undTechnologie* 40: 1176-1185.

Dengate, H. N. 1984. Swelling, pasting, and gelling of wheat starch. *Adv. Cereal Sci. Technol.* USA, Pp. 49-82.

Dennis, S. 1999. Improving solar food dryers. *Home Power Magazine*. 69: 24-34.

Dhanavade, M. J., Jlkute, C. B., Ghosh, J. S., and sonawane, K.D. 2011. Study of antimicrobial activity of lemo (citrus lemon L.) extract. *Br. J. Pharmacol. Toxicol.* 2(3): 119-122.

Diamante, L. M. 2009. *Vacuum- dried jackfruit: jackfruit in its hippest form.* Series No. 8, Dept. of food science and technology, Leyte state university, 259p.

Dutta, H., Paul, S. K., Kalita, D., and Mahanta, C.L. 2011. Effect of acid concentration and treatment time on acid–alcohol modified jackfruit seed starch properties. *Food Chem.* 128: 284–291.

Eastman, J., Orthoefer, F., and Solorio, S. (2001). Using extrusion to create breakfast cereal products. *Cereal Foods World.* 46: 468–471.

Elevitch, C. R. and Manner, H. I., 2006. *Artocarpus heterophyllus* (jackfruit). *Species Profiles Pac. Isl. Agrofor.* pp. 1-25.

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., and Attia, H. 2011. Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: Rev. *Food Chem.,* 124: 411-421.

El-Ramady, H. R., Domokos-Szabolcsy, É., Abdalla, N. A., Taha, H.S., and Fári, M. 2015. Postharvest management of fruits and vegetables storage. *Sustain. Agric. Rev. Elsievier.* pp. 65-152.

Ethiraj, S. and Suresh, E. R., 1992. Studies on the utilisation of mango processing wastes for production of vinegar. *J. food sci. technol.* 29(1): 48-50.

FAO [Food and Agricultural Organization, Geneva] 2010 [on-line]. Available: www.fao.org/production/faostat.

Feili, R., Zzaman, W., Nadiah, W., Wan, A., and Tajul, A. 2013. Physical and sensory analysis of high fiber bread incorporated with Jack fruit rind flour. *Food. Sci. Technol.* 1(2): 30-36.

Firibu, K, Saalia, R. D., and Phillip S. 2011. Degradation of aflatoxins by extrusion cooking: effects on nutritional quality of extrudates. LWT. *Food Sci. Technol.* 44: 1496-1501.

Fishman, M. L., Chau, H. K., Hoagland, P. D. and Hotchkiss, A. T., 2006. Microwave-assisted extraction of lime pectin. *Food Hydrocolloids*, 20(8): 1170-1177.

Foo, K. Y. and Hameed, B. H. 2012. Factors affecting the carbon yield and adsorption capability of the mangosteen peel activated carbon prepared by microwave assisted K2CO3 activation. *Chem. Eng. J.* 180: 66-74.

Gajanana, T. M., Gowda, I. N. D., and Reddy, B. M. C. 2010. Exploring market potential and developing linkages– A case of underutilized fruit products in India. *Agric. Econ. Res. Rev.*, 23: 437- 443.

Galbe, M. and Zacchi, G. 2007. Pretreatment of lignocellulosic materials for efficient bioethanol production. *Biofuels* Springer Berlin Heidelberg. Pp. 41-65.

Gandhi, A. P., Barat, G. K., and Das, N. B. 1974. Studies on the production of fungal amylases. *Myopathol. Mycol.* 52: 307-311.

Giami, S. Y., Amasisi, T., and Ekiyor, G. 2004. Comparison of breadmaking properties of composite flour from kernels of roasted and boiled African breadfruit (*Treculia africana decne*) seeds. *J. of Raw Mater. Res.* 1: 16-25.

Giwa, E. O. and Abiodun, I. V. 2010. Quality characteristics of biscuits produced from composite flours of wheat and quality protein maize. *Afr. J. Food Sci.* 1 (5): 116-119.

Gomez, S., Joseph, P. M., Sheela, K. B., Sruthi, C. V., and Linju, L. 2015. Variability in fruiting season and quality attributes of jackfruit (Artocarpus heterophyllus Lam.) accessions of Kerala. *Int. J. Trop. Agric.* 33(2): 1249-1255.

Gopalan, A., Rocha-Rinza, T., Christiansen, O., Rajput, J., Rahbek, D. B., Andersen, L. H., Bochenkova, A.V., Granovsky, A. A., Bravaya, K. B., Nemukhin, A.V., and Christiansen, K. L. 2009. Gas phase absorption studies of photoactive yellow protein chromophore derivatives. *J. Phys. Chem.* 113(34): 9442-9449.

Gupta, K. R. Gupta, D., Mann, S., and Sood, A. 2011. Phytochemical, nutritional and antioxidant activity evaluation of seeds of jackfruit (*Artocarpous heterolphyllus* Lam.). 2: 4.

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., and Meybeck, A. 2011. *Global food losses and food waste.* Rome: FAO. Pp. 1-38.

Hanway, J. J. and Heidel, H. 1952. *Soil analysis method* [Lecture notes]. Soil Testing Laboratory Iowa Agriculture, Iowa State College. 57: 1–31

Haq, N. 2006. Jackfruit (*Artocarpus heterophyllus).* Southampton Centre for Underutilised Crops. Southampton, U.K. University of Southampton.

Hasmadi, M., Noorfarahzilah, M., Lee, J. S., Sharifudin, M. S., and Mohd Fadzelly, A.B. 2014. Applications of composite flour in development of food products. *Int. Food Res. J.* 21(6).

Heldman, D. R. and Taylor, T. A. 1997. Modelling of food freezing. In: Hung, (Ed.), *Quality of frozen foods,* New-York:Chapman & Hall Publishing. International Thomson Publishing Co. pp.51-64.

Hseu, Z. Y. 2004. Evaluating heavy metal contents in nine composts using four digestion methods. *Bioresource Technol.* 5:53–9.

Igbabul, B. D., Amove, J., and Twadue, L. 2015. Effect of fermentation on the proximate composition, antinutritional factors and functional properties of cocoyam (*Colocasia esculenta)* flour. *Afr. J. Food Sci. Technol.*, 5(3): 67-74.

Ioannou. I and Ghoul. M. 2013.Prevention of enzymatic browning in fruit and vegetables *Eur. Sci. J.* 9: 30 ISSN: 1857 – 7881.

Iwe, M. O. 2003. Functional property of the cissu gum *cissu populnea . J. Agric. Sci. technol.* 3: 68-71.

Johnson, I. T. 2001 Antioxidants and Antitumor properties, in Antioxidants in food, *porkory J.* CRC press, Boca Raton, 100.

Jones, D., Chinnaswamy, R., Tan, Y., and Hanna. 2000. Physico chemical properties of ready-to-eat breakfast cereals. *Cereal Foods World.* 45:164-168.

KAU (Kerala Agricultural University) 1999. Research Report – 1996-1997. Directorate of Research, Kerala Agricultural University, Thrissur, pp.89-91.

Kaymak-Ertekin, F. 2002. Drying and rehydrating kinetics of green and red peppers. *J. Food Sci.* 67(1): 168-175.

kays, I. and Ghoul, M. 1999. Prevention of enzymatic browning in fruit and vegetables *Eur. Sci. J.* 9(30): 312 – 341.

Kim, J. H., Tanhehco, E. J., and Ng, P. K. W. 2006. Effect of extrusion conditions on resistant starch formation from pastry wheat flour. *Food Chem.* 99: 718-723.

King, A. J. 2005. High pressure processing of corn and wheat Starch. Available: http://www.kb.osu.edu/dspace/bistream/Alexa

Kinsella, J. E. 1976. Functional properties of protein in food- A survey. *Crit. Rev Food Sci. Nutr.* 5: 219- 225.

Kittipongpatana, O. S. and Kittipongpatana, N. 2011: Preparation and physicochemical properties of modified jackfruit starches. LWT – *Food Sci. Technol.* 44: 1766–1773.

Koh, P. C., Leong, C. M., and Noranizan, M. A. 2014. Microwave-assisted extraction of pectin from jackfruit rinds using different power levels. *Int. Food Res. J.* 21(5): 2091-2097.

Konopacka, D., Jesionkowskal, K., Klewicki, R., and Bonazzi, C. 2009. The effect of different osmotic agents on the sensory perception of osmo-treated dried fruit. *J. Hortic. Sci. Biotechnol.* 8: 80–84.

Koukounaras, A., Diamantidis, G. and Sfakiotakis, E. 2008. The effect of heat treatment on quality retention of fresh-cut peach. *Postharvest Biol. Technol.* 48(1): 30–36.

Kratchanova, M., Pavlova, E., and Panchev, I. 2004. The effect of microwave heating of fresh orange peels on the fruit tissue and quality of extracted pectin. *Carbohyd. Polym.* 56(2): 181-185.

Krishna, V., Desa, A., and Khairil, I. M. 2006. Biohydrogen generation from jackfruit peel using anaerobic contact filter. *Int. J. Hydrogen Energy*. 31: 569- 579.

Krishnan., Anu G., Jayalekshmi, G., Joseph., Elizebeth., Sabu., and Susan, T. 2015. Assessment of physico-chemical properties of jackfruit collections from Kuttanad region of Kerala. *Asian J. Hort.* 10(2): 262-266.

Krokida, M. K., Karathanos, V. T., Maroulis, Z. B., and Kouris, D. M. 2003. Drying kinetics of some vegetables. *J. Food Eng.* 59: 391-403.

Kumar, K. A., Narayani, M., Subanthini, A., and Jayakumar, M. 2011. Antimicrobial activity and phytochemical analysis of citrus fruit peels- Utilization of fruit wastes. *Int. J. Eng. Sci. Technol.* 3: 5414- 5420.

Lakshminarayan, N. G. 2017. Jackfruit based value added products. Available at https://www.linkedin.com/ pulse/ jackfruit-based-value-added-products-n-g-lakshminarayan. 02 May 2017].

Lavelli, V. and Caronni, P. 2010. Polyphenol oxidase activity and implications on the quality of intermediate moisture and dried apples. *Eur. Food Res. Technol.* 231(1): 93-100.

Leach, H. W., Mc Cowen, L. D., and Schoch, T. J. 1959. Structure of the starch granule. Swelling and solubility patterns of various starches. *Cereal Chem.* 36:534–544.

Lee W. H. and Ismail, I. 2012. Antioxidant activity, total phenolics and total flavonoids of Syzygiumpolyanthum (Wight) Walp leaves. *Int. J. Med. Arom. Plants*. 2(2): 219-228.

Lee, P. and Willis, P., 2010. *Waste Arisings in the Supply of Food and Drink to Households in the UK.* Waste & Resources Action Programme (WRAP).

Lima, A. G. B., Queiroz, M. R., and Nebra, S. A. 2002. Simultaneous moisture transport and shrinkage during drying of solids with ellipsoidal configuration. *J. Chem. Eng.* 86: 85–93.

Limbo, S. and Piergiovanni, L. 2006. Shelf life of minimally processed potatoes Part 1. Effects of high oxygen partial pressures in combination with ascorbic and citric acids on enzymatic browning. *Postharvest Biol. Technol.* 39: 254–264.

Limongi, D., Rosanasilva, S., and Mottin, I. 2012. Production of pizza dough with reduced fermentation time. *Ciênc. Technol. Aliment.* Campinas. 32(4): 701-709.

Lin, M. J. Y., Humbert, E. S., and Sosulski, F. W. 1974. Certain functional properties of sunflower meal products. *J. Food Sci.* 39(2): 368-370.

Lindley, M. G., 1998. The impact of food processing on antioxidants in vegetable oils, fruits and vegetables. *Trends in Food Sci. & Technol.* 9(8-9): 336-340.

Livia, T. 2015. Study on Water Resistance of Polypropylene/Sisal Fiber Wood-Plastic Composites. *China Plastics.* 26: 76-80.

Loos P. J., Hood, L. F., and Graham, H. D., 1981. Isolation and characterization of starch from breadfruit. *J. Cereal Chem.* 58 (4): 282-286.

Love, K. and Paul, R. E. 2011. Jack fruit. *J. Food Sci. Nutr.* 19 (4): 1 – 7.

Madhavan, N. 1994. More fruits less processing. The Hindu daily, October 22 p.6.

Makkar, H. P., Becker, S., Abel, H., and Szeglet, C. 2006 Degradation of condensed tannins by rumen microbes exposed to quebracho tannins (QT) in rumen simulation technique (RUSITEC) and effects of QT on fermentative processes in the RUSITEC. *J. Sci. Food and Agric.* 69:495–500. http://dx.doi.org/10.1002/jsfa.2740690414.

Manikandan, S., Maran, J. P., Nivetha, C. V., and Dinesh, R. 2017. Ultrasound assisted extraction of bioactive compounds from *Nephelium lappaceum* L. fruit peel using central composite face centered response surface design. *Arabian J. chem.* 10: 1145-1157.

Menges, H.O. and Ertekin, C. 2006. Mathematical modeling of thin layer drying of Golden apples. *J. Food Eng.* 77: 119-125.

Miaruddin, M. Chowdhury, M. F. Rahman, M. M., and Shahjahan, M. 2006. Standardization of spiced *papads* preparation from different pulses. *Bangladesh J. Agric. Res.* 31(4): 681-687

Moncur, M. W. 1985. Floral ontogeny of the jackfruit, *Artocarpus heterophyllus* Lam. (Moraceae). *Aust. J. Bot.* 33(5): 585-593.

Mondal, C., Remme, R. N., Mamun, A. A., Sultana, S., Ali, M. H., and Mannan, M. A. 2013. Product Development from Jackfruit (*Artocarpus heterophyllus*) and Analysis of Nutritional Quality of the Processed Products. *IOSR J. Agric. Vet. Sci.* 4(1): 76-84.

Motevali, A., Minaei, S., Khoshtaghaza, M. H., Kazemi, M., and Nikbakht, A. M., 2010. Drying of pomegranate arils: comparison of predictions from mathematical models and neural networks. *Int. J. Food Eng.*, 6(3): 15.

Murcia, M. A. 2009. Antioxidant activity of minimally processed (in modified atmospheres), dehydrated and ready-to-eat vegetables. *Food Chem. Toxicol.* 47: 2102-2110.

Narasimhan, K. S., Shurpalekar, S. R., and Venkatesh, K. V. L. 1972. Use of fumigants in prevention of insect infestation and mould in *papad*. *J. Food Sci. Technol.* 9: 134

Narayana, K. and Narasinga Rao, M. S. 1982. Effect of partial proteolysis on the functional properties of winged pea (Psophocarpus tetragonolobus) flour. *J. Food Sci.* 49: 944 - 947.

Nellemann, C. 2009. *The environmental food crisis: the environment's role in averting future food crises: a UNEP rapid response assessment* (Ed.). UNEP/ Earth print.

NHB (National Horticulture Board). 2015. Horticultural Statistics at a Glance 2015. Available at http://nhb.gov.in/ PDFViwer.aspx?enc=3ZOO8K5CzcdC/Yq6 HcdIxC0U1kZZenFuNVXacDLxz28= [02 May 2017].

Nikmaram, N., Kamani, M. H. and Ghalavand, R., 2015. The effects of extrusion cooking on antinutritional factors, chemical propertiesand contaminating microorganisms of food. *Int. J. Farming Allied Sci.* 4(4): 352-354.

Noor Aziah, A. A. and Komathi, C. A., 2009. Physicochemical and functional properties of peeled and unpeeled pumpkin flour. *J. Food Sci.* 74(7).

Noorfarhzilah., A., Mohamad Noor, A. Y., and Ho, L. H. 2014. Physicochemical and organoleptic properties of cookies incorporated with legume flour. 19(4): 1539-1543.

Nunjundaswamy, A. N. and Mahadeviah, M. 1993. *Fruit processing. Advances in Hort.* 4. In: Chadha, K. L. and Pareek, O. P (eds.). Malhotra Publishing House, New Delhi, pp.1835-1875.

Nwokolo, E. 1985. Nutritional quality of the seeds of the African breadfruit (*Treculia Africana Decne*). *Trop. Sci.* 27: 39 – 47.

Odoemelam, S. A. 2000. Chemical composition and functional properties of conophor nut flour (*Tetracarpidium conophorum*) flour. *Int. J. Food Sci. Tech.* 38: 729-734.

Oladele, A. K. and Aina, J. O. 2011. Chemical composition and functional properties of flour produced from two varieties of tiger nut (*Cyperusesculentus*). *Afr. J. Biotechnol.* 6 (2): 2473-2476.

Olivas, G. I. and Barbosa-Canovas, G. V. 2005. Edible coatings for fresh-cut fruits. *Crit. Rev. Food Sci. Nutr.* 45(7-8): 657-670.

Onwuka, C. F. I. 1986. Gliricidia sepium as dry season feed for goat production in Nigeria. In: Haque, I., Jutzi, S., and Neate, P. J. H. (eds.), Potentials of forage legumes in farming systems of sub-Saharan Africa. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 533-539.

Oppong., David., Eric., Arthur., Samuel., and Osei. 2015. Proximate Composition and Some functional properties of Soft Wheat Flour *Int. J. Innovative Res. in Sci. Eng. and Technol.* 4(2).

Osundahunsi, O. T. 2009. Scanning electron microscope study and pasting properties of ripe and unripe plantain. *J. Food Agric. Environ.* 7(3/4): 182-186.

Padma, P. N., Anuradha, K., Nagaraju, B, Kumar, V. S., and Reddy, G. 2012. Use of Pectin Rich Fruit Wastes for Polygalacturonase Production by Aspergillus awamori MTCC 9166 in Solid State Fermentation. *J. Bioproces. Biotechniq.* 2:2.

Pardeshi, I. L., Arora, S., and Borker, P. A. 2009. Thin-layer drying of green peas and selection of a suitable thin-layer drying model. *J. Drying Technol.* 27: 288–295.

Pedroza-Islas, R., Aguilar-Esperanza, E., and Vernon-Carter, E. J. 1994. *Obtaining pectins from solids wastes derived from mango (Mangifera indica) processing.* In AICHE symposium series 90(300), New York, pp. 36-41.

Peumansa, J. W., Hauseb, B., Els J. M., and Dammea, V. 2000. The galactose-binding and mannose-binding jacalin-related lectins are located in di¡erent sub-cellular compartments *FEBS Letters* 477:186-192.

Piga, A., D'Aquino, S., Agabbio, M., Emonti, G., and Farris, G. A. 2000. Influence of storage temperature on shelf-life of minimally processed cactus pear fruits. *LWT-Food Sci. Technol.* 33: 15–20.

Prabha, M. S. and Rangaiah, G. S. 2014. Citric acid production using artocarpus heterophyllus and its waste with alcohol as a stimulant. *Int. J. Life sci. Bt and pharm. Res*. 3(4): 74-82.

Prabhakar, D. R., More, S., Shivashankar, S., Mallesh., and Babu, N. G. 2016. Physico-chemical and Sensory Evaluation of Sorghum-Finger Millet *Papad* Butti. *Intl. J. Food. Ferment. Technol.* 6(2): 387-395.

Prakash, O., Kumar, R., Mishra, A. and Gupta, R. 2009. *Artocarpus heterophyllus* (Jackfruit): an overview. *Pharmacognosy Rev*. 3(6), 353-358.

Prieto P., Pineda M., Anguilar M. 1999. *Anal. Biochem.* 269, 337.

Prusky, D. 2011. Reduction of the incidence of postharvest quality losses, and future prospects. *Food Security*. 3(4): 463-474.

Pua, C. K., Hamid, A. N. S. Rusul, G., and Rahman, A. R. 2007. Production of drum dried jack fruit (Artocarpus heterophyllus Lam.) powder with different combination of soy lecithin and Gum Arabic. *J. Food Eng*. 78(2): 630 – 636.

Rahman, A. M., Huq, E., Mian, A. J. and Chesson, A., 1995. Microscopic and chemical changes occurring during the ripening of two forms of jackfruit (*Artocarpus heterophyllus* L.). *Food Chem.* 52(4): 405-410.

Rahman, M., Alamgir, K., and Farid, A. 1999.Comparative study of physical and elastic properties of jute and glass fiber. Pilot Plant & Process Development Center of Bangladesh Council of Scientific and Industrial Resource. Bangladesh.

Ramírez, L. 2001. *Globalization and livelihood diversification through non-traditional crops: The Mexico case.* Overseas Development Institute, London, United Kingdom. 4 p.

Rana, S. S., Pradhan, R. C., and Mishra, S. 2018. Optimization of chemical treatment on fresh cut tender jackfruit slices for prevention of browning by using response surface methodology. *Int. Food Res J.* 25(1): 196-203.

Ravani, A. and Joshi, D. 2013. Mango and it's by product utilization–A review. *Energy (kcal)*, 74: 44.

Ravani, P., Dasgupta, K., Quinn, R. R., Zarnke, K. B., Rabi, D. M., Daskalopoulou, S. S., Rabkin, S. W., Trudeau, L., Feldman, R. D., Cloutier, L., and Prebtani, A. 2014. The 2014 Canadian Hypertension Education Program recommendations for blood pressure measurement, diagnosis, assessment of risk, prevention and treatment of hypertension. *Can. J. Cardiology*. 30(5): 485-501.

Reed, J. D. 1986. Relationships among soluble phenolics, insoluble proanthocyanidins and fiber in East African browse species. *J. Range Manage*. 39:5- http://dx.doi.org/10.2307/3899675.

Rengsutthi, K. and Charoenrein, S. 2011. Physico-chemical properties of jackfruit seed starch (*Artocarpus heterophyllus)* and its application as a thickener and stabilizer in chilli sauce. *LWT – Food Sci. Technol.* 44: 1309–1313.

Riaz, M. N. and Aldrich, G., 2007. *Extruders and expanders in pet food, aquatic and livestock feeds*. AgriMedia.

Ridoutt, B. G., Juliano, P., Sanguansri, P., and Sellahewa, J. 2010. The water footprint of food waste: case study of fresh mango in Australia. *J. Cleaner Prod.* 18(16-17): 1714-1721.

Rodriguez-Ambriz, S. L., Islas-Hernandez, J. J., Agama- Acevedo, E., Tovar, J., and Bello-Perez, L A. 2008. Characterization of a fibre rich powder prepared by liquefaction of unripe banana flour. *Food Chem.* 107: 1515-1521.

Rosen, J. C. and Kader, A. A. 1989. Postharvest. Physiology and quality maintenance of sliced pear and strawberry fruits. *J. Food Sci.* 54: 656- 659.

Roy, S. and Lingampeta, P. 2014. Solid wastes of fruits peels as source of low cost broad spectrum natural antimicrobial compounds-furanone, furfural and benezenetriol. *Int. J. Res. Eng. Technol*, 3: 273-279.

Sabbatini, S. B., Sanchez, H. D., Torre, M. A., and Osella, C. A., 2014. Design of a premix for making gluten free noodles. *Int. J. Nutr. Food Sci.* 3(5): 488–492.

Sadasivam, S. and Manikkam, A. 1992. *Biochemical methods of agricultural sciences*. Wiley eastern Ltd, New Delhi, p 8.

Sai-Ut, S., Ketnawa, S., Chaiwut, P., and Rawdkuen, S. 2009. Biochemical and functional properties of proteins from red kidney, navy and adzuki beans. *Asian J. Food and Agro-Ind.* 2(4): 493-504.

Sathe, S. K., Deshpande, S. S. and Salunkhe, D. K. 1982. Functional properties of winged bean proteins. *J. of Food Sci.* 47: 503-508.

Schieber, A., Stinzing, F. C., and Care, R. 2001. Byproducts of plant food processing as source of functional compounds- Recent developments. *J. Food Sci. Technol.* 12 (11): 401-413.

Senadeera, W., Bhandari, B. R., Young, G., and Wijesinghe, B. 2005. Modelling dimensional shrinkage of shaped foods in fluidized bed drying, *J. Food Processing and Preserv.* 29: 109-119.

Sexena, A., Bawa, A. S., and Raju, P. S. 2012. Effect of minimal processing on quality of jackfruit (*Artocarpus heterophyllus* L.) bulbs using response surface methodology. *Food Bioprocess Technol.* 5(1): 348–358.

Shahanas, E., Panjikkaran, T. S, Aneena, E. R., and Sharon C. L. 2015. Standardisation and quality evaluation of spreads using fruit extracts and tender coconut pulp *Int. J. Res. Develop. Org.* 1(8): 1-14.

Shanmugam, P. K., Rangaswami, G and Gurney, E. H. 1992. Preservation of fruits and vegetables. *Trop. Agric.* 68: 1150-1153.

Sharma, N., Bhutia, S. P., and Aradhya D. 2013. Food processing and technology process optimization for fermentation of wine from jackfruit (*Artocarpus heterophyllus* Lam.). 4(2): 46-49.

Shruthy, P. 2005. Utilisation of jackfruit (*Artocarpus Heterophyllus* . Lam.) for product development and by product recovery. Ph.D thesis, Kerala Agricultural University, Thrissur, pp. 1-2.

Siddiq, M., Nasir, M., Ravi, R., Dolan, K. D., and Butt, M. S., 2009. Effect of defatted maize germ addition on the functional and textural properties of wheat flour. *Int. J. Food Properties*. 12(4): 860-870.

Simal, S., Garau, C., Femenia, A., and Rossello, C. 2005. Drying of red pepper (Capsicum annuum): Water desorption and quality. *Int. J. Food Eng*. 1(4):10–22.

Singh B. P. and Kumbhar B. K. 2001. Osmotic dehydration of fruits and vegetables - A review. *Indian Food Ind*. 12(1): 20-27.

Singh, S., Gamlath, S., and Wakeling L. 2007. Nutritional aspects of food extrusion: a review. *Int. J. Food Sci and Technol*. 42: 916–929.

Singh, S., Rai, R. R., Rai, M., and Chaurasia, N. S. 2009. Comparative osmotic diffusion treatment and drying of bitter Gourd (*momordica charantia* l.) slices. *J. Veg. Sci*. 36(2): 209-213.

Singh, U., Subrahmanyam, N., and Kumar, J. 1991. Cooking quality and nutritional attributes of some nely developed cultivars of chickpea (Cicer arietinum). *J. Sci. Food and Agric*. 55(1): 37-46.

Sreerama, Y. N., Sashikala, V. B., Pratape, V. M., and Singh, V. 2012. Nutrients and anti-nutrients in cowpea and horse gram flours in comparison to chickpea flour: evaluation of their flour functionality. *Food Chem*. 131: 462-468.

Steel, G. D. and Torrie, J. H. 1960. *Principles and procedures of statistics,* McGraw-Hill book company, Inc., New York, Toranto, London, pp.134-145.

Sudha, M. L., Vetrimani, R., and Leelavathy, K. 2007. Influence of fiber from different cereals on the rheological characteristics of rice flour dough and on biscuit quality. *Food. Chem.* 100: 1365 – 1370.

Sun, J. M., Richardo-Da-Silvia, I., and Spranger. 1988. Critical factors of vanillin assay for catechins and proanthocyanidins, *J. Agric. Food Chem.* 46: 4267–4274.

Sundarraj, A. A. and Ranganathan, T. V. 2017. Phytochemical screening and spectroscopy analysis of jackfruit (artocarpus integer thumb.) Peel. *Int. Res. J. Pharm.* 8 (9): 151-159.

Taiwo, K. A. Ade-Omowaye, B. I. O., Angersbach, A., and Knorr, D. 2001. Use of pulsed electric field pre-treatment to improve dehydration characteristics of plant based foods. *Trends in Food Sci. Technol.* 2(8): 285-295.

Talib, M. Z. M., Nordin, M. F. M., Puspasari, I., Tasirin, S. M., Daud, W. R. W., Gariépy, Y., and Raghavan, G. S. V. 2013. Quality changes of red pitaya (*Hylocereus undatus)* slices dried in hot air, microwave-hot air and microwave-vacuum dryers. *Iranica J. Energy Environ.* 5(3): 313-322.

Talpade, N. N., Pawar, V. S., Sontakke, M. D., Syed, H. M., and Farooqui, A. S. 2018. Formulation and organoleptic evaluation of *papad* prepared with incorporation of gardencress seed powder (*Lepidium sativum* L.) *J. Pharmacognosy Phytochem.* 7(2): 2989-2992.

Thimmiah, S. K. 1999. Standard Methods of Biochemical Analysis. Standard kalyani publishers, New Delhi, 545p.

Tiwari, R. P. and J. S. Grewal. 1999. Studies on the effect of preservatives on the keeping quality of Rasmalai. *J. Food Sci. Technol.* 36(1): 84-87

Tsay, T. T. and Lin, Y. 2004. Evaluation of Asteraceae plants for control of Meloidogyne Incognita. *Adv. Biochem. Eng. Biotechnol.* 108: 41-65.

Tumaalii, F. and Wootton, M. 1988. Breadfruit production, utilisation and composition a review. *Food Technol. Austr.* 36:464–465.

Turkmen, N., Sari, F. and Velioglu, Y. S., 2005. The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. *Food chem.* 93(4): 713-718.

Udensi, E. A. and Okoronkwo, K. A. 2006. Effect of traditional processing on the physicochemical properties of Mucuna *cochinchinensis* and *Mucuna Utilis* flours. *J. Agric. Food Technol. Environ.* 1: 133-137.

Ukkuru, M. and Pandey, S. 2005. *Project Report on Viable Technology for Exploitation of Jackfruit for Product Diversification and Product Recovery*. NARP (SR) Kerala Agricultural University, Thrissur.

Umesh, J. B., Shrimant, P. N., *and* Bapat, V.A. 2010. Evaluation of antioxidant capacity and phenol content in jackfruit (*Artocarpus heterophyllus Lam.*) fruit pulp. *Plant Food. Hum. Nutr.* 65:99–104.

Ushimaru, P. I., Silva, M. T., Stasi, L. C., Barbosa, L., and Fernandes, A. 2007. Antibacterial activity of medicinal plant extracts. *Brazilian J. Microbiol.* 38: 717- 719.

Veena, K. 2015. Development of an extruded product from raw jackfruit. M.Sc. (FS & N) thesis, Kerala Agricultural University, Thrissur, 78p.

Ventour, L. 2008. *The food we waste.* Report prepared by WRAP, Banbury. Available at:http://www.ifr.ac.uk/waste/Reports/WRAP%20The%20Food%20We%20 Waste.p df, accessed December 2012.

Vidyavati, H. G., Mushtari, J., Vijayakumari, J., Gokani, S. S., and Begum, S. 2004. Utilization of finger millet in the preparation of *papad. J. Food sci. Technol.* 41: 379-382

Vikashkandari. and Sanjay, Gupta. 2012. Bioconversion of vegetable and fruit peel wastes in viable product. *J. Microbiol. Biotech. Res.* 2: 308-312.

Vrac, N. and Gurna, M. 1994. Effect of fluidized bed drying on properties of dehydrated apples. *Nahrug.* 38: 149 – 157.

Waterhouse, A. 2002. Determination of total phenolics. In: *Current protocols in food analytical chemistry* (Ed Wrolstad, R. E). John Wiley and Sons, New York, Units I1.1.1-I1.1.8.

Wu, H., Wang, Q., Ma, T. and Ren, J. 2009. Comparative studies on the functional properties of various protein concentrate preparations of peanut protein. *Food Res. Int.* 42: 343-348.

Yapo, B.M. 2009. Biochemical characteristics and gelling capacity of pectin from yellow passion fruit rind as affected by acid extractant nature. *J. agric. Food chem.* 57(4): 1572-1578.

Zhang, L., Tu, Z. C., Xie, X., Wang, H., Wang, H., Wang, Z. X., Sha, X. M., and Lu, Y. 2017. Jackfruit (*Artocarpus heterophyllus* Lam.) peel: A better source of antioxidants and a glucosidase inhibitors than pulp, flake and seed, and phytochemical profile by HPLC-QTOF-MS/MS. *J. Food Chem.* 1: 234, 303-313.

Zuniga, A. G., Arnoldo, A. A., Rodrigues, R. M., Lima, S. S., and Feitosa, A.C. 2004. The air drying behavior of osmotically dehydrated for (*Artocarpus integrifolia*) slices. *Proceedings of the 14 th international Drying Symposium* (IDS 2004), 22-25 August 2004, Sao Paulo. Brazil, pp. 2120-2126.

Abstract

VALUE ADDED PRODUCTS FROM JACKFRUIT RIND

By

THARANI.S

(2016-16-004)

Abstract of the Thesis

Submitted in partial fulfillment of the

Requirements for the degree of

MASTER OF SCIENCE IN COMMUNITY SCIENCE

(Food science and Nutrition)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF COMMUNITY SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2018

ABSTRACT

The study entitled "Value added products from jackfruit rind" was carried out at the Department of Community Science, College of Agriculture,Vellayani during the period 2016-2018. The objective framed for this study is, to develop value added Ready- to- Cook (RTC) dehydrated products from Jack fruit rind and to assess their qualities. Thus two RTC dehydrated products namely Jackfruit rind based *papad* and crispies.

Raw mature jack fruits *cv. Koozha* and *Varikka*, (90-105 days after fruit set) were selected for this study. The functional quality analysis of jackfruit rind flour revealed that there was significant difference at 5 % level in the water absorption index, oil absorption index, foaming capacity, and swelling power of the *cv. Varikka* and *Koozha* flours.

Raw *Koozha* jackfruit rind flour showed higher content of crude fiber and dietary fiber. It had low content of carbohydrate (29 g/100g) and fat (1.84 g/100g). Raw *Koozha* jackfruit rind flour had higher tannins (0.088 g/100g) which could be the source of bitterness of the product. It also had higher content of polyphenols (2 g/100g) that could be responsible for the enzymatic browning of rinds and had lower peroxide value (0.5 g/100g), which could be the reason for better keeping quality of this rind type. Pectin content was found to be higher (27.5 g/100g) in ripe *varikka* jackfruit rind flour, which is a limiting factor in the production of dehydrated and extruded products as it affects the extrusion quality of the products.

The various treatments selected for the formulation of *papads* and crispies with rice flour, *varikka* jackfruit rind flour and black gram flour respectively in the pre-determined proportions were, T1 (50:50:0), T2 (50:40:10), T3 (60:30:10), T4 (70:20:10), T5 (80:10:10) and control (100:0:0). Similarly, the treatments selected for the formulation of *papads* and crispies with, rice flour, *koozha* jackfruit rind flour and

black gram flour respectively in the pre-determined proportions were, T6 (50:50:0), T7 (50:40:10), T8 (60:30:10), T9 (70:20:10), T10 (80:10:10) and control (100:0:0).

Jackfruit rind *papad* was processed by the standardized procedures of Kamath (2008) and crispies were processed at CTCRI (Incubation centre) by the standard procedures of Veena (2014). Based on the sensory evaluation it was found that T5 and T10 were the best combinations for *papad* whereas, T4 and T9 for crispies of *cv. Varikka* and *cv. Koozha* respectively.

Among the four products developed *Koozha papad* and crispies revealed lower carbohydrate (69 g/100g), starch (3.98 g/100g) and fat content (1.02 g/100g) and were rich in crude fiber (0.9 g/100g) and dietary fiber (0.78 g/100g). Iron content in *Koozha* jackfruit rind *papad* was highest (0.117 mg/100g) followed by *koozha* crispies. Sodium content (6.28g/ 100g) was higher in *Varikka* crispies which could be due to the adjuncts added to it. *Koozha* crispies were found to be high in total anti-oxidant activity.

The physical characteristics of the jackfruit rind *papads* (T_5P and T_{10}P) has shown significant difference (at 5 % level) in the expansion percentage, thickness after frying and oil uptake and yield, diameter, diameter expansion and bulk density has no significant difference, whereas for crispies, there was significant difference in the thickness and no significant difference for yield and bulk density.

Storage stability of fresh cut rinds were analyzed at different storage temperatures (4° C and - 18° C). *Koozha* rinds deteriorated in visual quality within a week and turned more brown than *varikka* which retained its colour for over 10 days. In order to control enzymatic browning of the rinds, different pre-treatments were carried out. The results shown that, 1 per cent citric acid was found to be effective among the four treatments. Storage stability of the jackfruit rind flour and the standardized products were assessed by their microbial load. The results revealed that rind flour and rind *papads* was detected with fungus after 3 months of storage, whereas in the case of crispies no microbes were detected till 3 months.

Cost of production of unit *papad* and crispies (55 g) with 10 % profit was Rs. 0.6 and 7.45 respectively. The B: C ratio of the jackfruit rind *papad* and crispies was 2.5 and 1.2 respectively.

This study on the utilization and value addition of jackfruit rind concludes that products (*papad* and crispies) developed from *koozha* rind flour were higher in nutrients and had better sensory qualities and shelf-life.

Appendices

APPENDIX – I

Scorecard for sensory qualities of the developed products

Product: *Varikka* jackfruit rind *papad* Date:

Tested by: Sign:

Parameters	T_1P	T_2P	T_3P	T_4P	T_5P
Appearance					
Colour					
Aroma					
Texture					
Taste					
Ovaerall acceptability					

Please rate the scores hedonically to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like nor dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX – II

Scorecard for sensory qualities of the developed products

Product: *Koozha* jackfruit rind *papad* Date:

Tested by: Sign:

Parameters	T_6P	T_7P	T_8P	T_9P	$T_{10}P$
Appearance					
Colour					
Aroma					
Texture					
Taste					
Ovaerall acceptability					

Please rate the scores hedonically to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like nor dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX – III

Scorecard for sensory qualities of the developed products

Product: *Varikka* jackfruit rind crispies Date:

Tested by: Sign:

Parameters	T_3C	T_4C	T_5C
Appearance			
Colour			
Aroma			
Texture			
Taste			
Ovaerall acceptability			

Please rate the scores hedonically to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like nor dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX – IV

Scorecard for sensory qualities of the developed products

Product: *Koozha* jackfruit rind crispies Date:

Tested by: Sign:

Parameters	T_8C	T_9C	$T_{10}C$
Appearance			
Colour			
Aroma			
Texture			
Taste			
Ovaerall acceptability			

Please rate the scores hedonically to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like nor dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1