Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein.

ANILA, H.L.
(2015 - 24 - 001)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

DOCTOR OF PHILOSOPHY IN COMMUNITY SCIENCE
(Food Science and Nutrition)

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF COMMUNITY SCIENCE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2018

DECLARATION

I, hereby declare that this thesis entitled **''Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein''** 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 : 22/11/2018

Anila, H. L.
(2015 - 24 - 001)

CERTIFICATE

Certified that this thesis, entitled **"Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein"** is a record of research work done independently by **Ms. Anila, H.L (2015 - 24 - 001)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani
Date : 22/11/2018

Dr. Suma Divakar
Major Advisor, Advisory Committee
& Professor
Department of Community Science
College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Anila. H. L (2015 - 24 - 001)** a candidate for the degree of **Doctorate of Philosophy in Community Science (Food Science and Nutrition)** agree that this thesis entitled **"Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein"** may be submitted by **Ms. Anila. H. L. (2015 - 24 - 001)** in partial fulfilment of the requirement for the degree.

Dr. Suma Divakar
(Chairperson, Advisory Committee)
Professor
Department of Community Science
College of Agriculture, Vellayani

Dr. K.S. Meena Kumari
Professor and Head
Department of Agrl. Microbiology
College of Agriculture, Vellayani

Dr. Rari John
Professor and Head
Department of Community Science
College of Agriculture, Vellayani

Dr. Aparna. B (Sr.Sc)
Assistant Professor
Department of Soil Science & Agrl. Chemistry
College of Agriculture, Vellayani

Dr. Beela. G.K
Associate Professor
Department of Community Science
College of Agriculture, Vellayani

EXTERNAL EXAMINER

Dr. Anooja Thomas. K
Associate Professor
Department of Home Science
CMS College, Kottayam

ACKNOWLEDGEMENT

I am grateful to "Almighty god" who provided me the strength to fulfill the task in a satisfactory manner. I am indebted for the numberless blessings that God showers upon my life.

Let me place on record of my profound feeling of gratitude and sincere thanks to my chairperson of the advisory committee, Dr. Suma Divakar, Professor, Department of Community Science for her valuable and affectionate guidance, constant encouragement and unfailing patience throughout the course of this research work and in the preparation of the thesis. This work would not have been possible without her help and support.

I express my sincere gratitude to Dr. Rari John Professor and Head, Dr. Beela, G.K. Associate Professor and Members of advisory committee and also Dr. Anitha Chandran Assistant Professor in my Department, for the timely advice, friendly approach and guidance at all the stages of research work.

I am grateful to My teacher Dr. Mary Ukkuru, former Professor and Head, Department of Community Science, for her valuable suggestions, ever willing help and constant criticism which had been rendered whole heartedly throughout my research work. I extend my sincere gratitude to Dr. P. V. Nandini, former Professor and Head , Department of Community Science, for her valuable suggestions and timely guidance during the entire course of the work.

I wish to express my gracious thanks to Dr. Nirmala, C. former Professor and Head and Dr.Prasanna kumari, Associate Professor and also my MSc. Chairperson; Department of Community Science for her whole hearted co operation, help and blessings during the course of the study and period of investigation.

My heartfelt thanks to Dr. K .S. Meena Kumari, Professor and Head, Department of Agricultural Microbiology for her keen interest, immense help, constructive suggestions, timely support and co operation rendered throughout the course of this research endeavor. I am thankful to Dr. Aparna, B. Assistant Professor, Department of Soil science and Agricultural Chemistry, for her guidance and critical evaluation during the course of my work.

I greatly acknowledge the patron of College of Agriculture, the Dean for providing me all necessary facilities from the university during the whole course of the study.

I would like to extend my diligent thanks to Mr. Austin, P., Dr. Renju, Dr. Nimisha, Bindu and all other staff of Athmic Biotech Solutions Pvt.Ltd. for their ineffable support for the timely completion of laboratory works. Moreover, I extend my thanks to Mahadevan sir, technical staff at Govt. Ayurveda College, Thiruvananthapuram for accomplishing faultless chromatography estimation of oligosaccharides. I am ineffably thankful to Mrs.Viji, Department of Agricultural Microbiology for her keen interest and immense help throughout the course of this research endeavor.

I sincerely thank the facilities rendered by the Library of College of Agriculture, Vellayani.

I also extend my acknowledgement to non teaching staff of the Department of Community Science, Mrs. Sheeba, Mrs. Manju and Mr. Binu for the help rendered to me during the course of study.

My loving thanks to my seniors and juniors, Archana, Soumya, Smitha, Thushara, Nisha, Gayathri, Krishnasree, Krishnendu, Lucy, Athira, Mini Mary, Manju, Preethi, Siji,, Bency , Shubha, Tharani, Aiswarya, Gayathri, Thasleema, Meghna, Aparna, Malavika, Meera, Archana, Gayathri, Sharada, Nishandh and Gokul for their loving support and encouragement throughout my research work.

From the depth of my heart I thank my dear friends Arya, Anju, Maheswari, siji, Ammu, Gayathri, Reshma, Feba, Nithya, Saima, Stephy for their indispensable help, love, moral support and constant encouragement.

My heartfelt thanks to my dear friend Sonia for her great support, help, love and care, who had delivered me good encouragement during difficult times.

My wholehearted cheers to my best friend Prabhath for his help, support and constant inspiration which has gone a long way in aiding me to astound the snags I had to face during the course of my work.

Words fail to express my love and gratitude from the depth of my heart to my loving mother, Mrs. Lalithambika.G., father, Mr. Hari. P., my lovable brother Anoop. H.L. and my dear cutee Gowri and especially thanks to all my cousins and relatives. The love, support, patience and constant encouragement given by them was a real source of inspiration without which I could not have completed this research endeavor.

I thank all those who extended help and support to me during the course of my work.

Anila, H.L

INDEX

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AACC	American Association for Clinical Chemistry
AIA	Amylase Inhibitor Activity
AOAC	Association of Official Agricultural Chemists
BAPNA	N- Benzoyl- DL- arginine-4-nitroanilide hydrochloride
CAC	Codex Alimentarius Commision
CD	Critical Difference
Cfu	Colony Forming Units
CHDs	Coronary Heart Diseases
CMV	Cytomegalovirus
CRD	Completely Randomised Design
CVDs	Cardiovascular Diseases
DFRC	Derivatization followed by reductive cleavage
DMPD	N,N-dimethyl p-phenylendiamine
DMSO	Dimethyl sulphoxide
DNA	Deoxyribonucleic acid
DPPH	2,2-diphenyl-1-picrylhydrazyl
EDTA	Ethylene Diamine Tetra Acetic Acid
EFSA	European Food Safety Authority
EMB	Eosin Methylene Blue
ESM	Enriched Soup mix
FOS	Fructo Oligosaccharide
FSSAI	Food Safety and Standards Authority of India

GAE	Gallic Acid Equivalents
GalU	Galactosidase Units
GOS	Galacto Oligosaccharide
HDLC	High Density Lipoprotein Cholesterol
HIV	Human Immunodeficiency Virus
HPTLC	High Performance Thin Layer Chromatography
IC_{50}	Half maximal inhibitory concentration
IDF	Insoluble Dietary Fibre
IOM	Institute of Medicine
IU	International Units
JFBF	Jackfruit bulb flour
JFL	Jackfruit lectin
JFSF	Jackfruit seed flour
Kcal	Kilo calories
LDLC	Low-Density Lipoprotein Cholesterol
LDPE	Low Density Polyethyelene
MBC	Maximum Bacterial Concentration
NA	Nutient agar
NADH	Nicotinamide adenine dinucleotide
NBT	Nitro blue tetrazolium
NIH	National Institutes of Health
OVQ	Overall Visual Quality
PMS	Phenozine metho sulphite
PP	Polypropylene
RB	Rose Bengal

Rf	Retention Factor
RFOs	Raffinose family oligosaccharides
ROS	Reactive oxygen species
RTS	Ready To Serve
SDF	Soluble Dietary Fibre
SEm	Standard error of the mean
SOD	Super oxide dismutase
TCA	Trichloro acetic acid
TIA	Trypsin Inhibitory Activity
TVP	Textured vegetable protein
USDA	United State Department of Agriculture
VZS	Varicella Zoster Virus
WAI	Water Absorption Index
WHO	World Health Organization

Introduction

1. INTRODUCTION

Jackfruit or *Panasa* scientifically known as *Artocarpus heterophyllus* Lam. belongs to the family Moraceae. The fruit is the gigantic syncarp and is known as the largest fruit of the world. It is an indigenous fruit crop of Kerala and is widely grown as an important tree in Kerala's homesteads. It is also seen as a shade crop in many coffee plantations. It is popularly known as the poor man's fruit in the eastern and southern parts of India. As no fertilizer is applied to the jackfruit tree maintained in homesteads, it also has the potential to be identified as a therapeutic fruit grown organically in Kerala by default. Jackfruit (*Artocarpus heterophyllus*) is commonly grown in home gardens of tropical and subtropical countries.

It is a nutritious fruit, rich in vitamin A, B, and C, K, Ca, Fe, protein and carbohydrate. Due to the high levels of carbohydrate, jackfruits were used to supplement other staple foods, in times of scarcity in some regions. This fruit can be consumed in raw and ripe forms. Therefore, it has an important place in the context of food security (Barua and Boruah, 2004).

Jackfruit also contains useful antioxidant compounds that play a vital role in maintaining human health and preventing diseases (Chandrika *et al.*, 2004). Jackfruit seed contains manganese, magnesium and two major lectins namely jacalin and artocarpin. Jacalin has been proved to be useful for the evaluation of immune status of patients infected with human immunodeficiency virus 1 (Haq, 2006). Nualla *et al.* (2009) pointed out that jackfruit seeds contain phenolic compounds and non resistant starch. It is a rich source of phytochemicals including phenolic compounds and therefore, offers opportunities for the development of value added products such as nutraceuticals with various food applications to enhance health benefits (Umesh *et al.*, 2010).

Jackfruit exists in innumerable types or forms with respect to fruit characteristics. These types differ widely among themselves in the bearing size, shape, quality and period of maturity. Being a cross pollinated crop, wide variations are observed for all important qualitative characteristics like fruit size, shape, colour, yield, flowering season, period of maturity etc. There is also wide variability in sweetness, acidity, flavour and taste (Panday, 2005).

Considering its nutritional and health benefits, there is need to promote this fruit for health and prevention of lifestyle diseases. Since systematic documentation of nutrient/ chemical constituents is lacking, an evaluation of nutrient and phytochemical profile of local varieties would enlighten the health conscious population of Kerala, regarding the nutritive and health excellence of this fruit.

It is reported that 60 - 70 percentage of jackfruits are wasted in India. A number of factors limit the potential exploitation of this fruit, the major reason being unorganized supply chain management. Although a lot of indigenous postharvest handling methods and value added products are available, systematic production is lacking to cater to the demand. Besides, harvesting cutting and cleaning of the fruit is cumbersome making the fruit highly neglected

Anti-nutritional factors are naturally occurring compounds that classified under a broad group of secondary metabolites. They are the compounds that are present in human or animal foods which cause anti-nutritional effects and anti-physiological effects such as gastrointestinal discomforts, impaired reproductive function or reduced immunocompetence (Zakarial *et al.*, 2011). Jackfruit bulbs and seeds contain several oligosaccharides such as raffinose and stachyose, which can cause flatulence for humans, and these substances will also create a darker color during flour processing. Wichienchot *et al.* (2010) reported that one of the problems in processing jackfruit seed into become food raw material, is the oligosaccharides content. These oligosaccharides include raffinose, stachyose and verbascose which are difficult to be digested because the small intestines of

mammals do not have the enzymes which can degrade these oligosaccharides. When these oligosaccharides pass into large intestine, after fermentation by intestine microflora, it produces gas and cause flatulence. Hence this study also focuses on measures to improve digestibility that would help to enhance the consumption of this fruit.

Jackfruit is commonly consumed in its fresh state or minimally processed form. There are many jackfruit-based products present in the market, which include canned slice fruit and vacuum-dried. Due to the increasing consumer demand towards ready-to-eat, healthy products, jackfruit can be one of the potential sources, for the production of value-added products. The demand for convenience foods among the literate consumers is on the rise around the globe. In order to incorporate the fruit based nutritional benefits, it has become important to develop newer and novel foods with the consumer acceptance. With this aim an attempt was made to develop a jackfruit based textured vegetable protein (TVP) and thus makes jackfruit more popular among the health conscious people.

Review of literature

2. REVIEW OF LITERATURE

The literature reviewed for the present study entitled ''Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein'' is presented under the following subheads:-

2.1. Nutrients and Bioactive compounds in jackfruit

The Greek word 'Bio' means life and 'active' in latin means dynamic (Bernard and Dromard, 2011). Kris *et al.* (2002) reported that bioactive compounds are extra nutritional constituents that typically occur in small quantities in foods.

''Bioactive compounds'' are essential and non-essential compounds that can have an effect on human health (Biesalski, 2009). Nahlar (2013) defined bioactive compounds as non-nutritional components of food claimed to have beneficial health effects; normally this does not include the essential nutrients. A bioactive compound is a compound that has an effect on a living organism, tissue or cell. In the field of nutrition, bioactive compounds are distinguished from essential nutrients. While nutrients are essential to the sustainability of a body, the bioactive compounds are not essential, since the body can function properly without them, or because nutrients fulfil the same function. Bioactive compounds are not essential like nutrients but have a positive effect on health.

The Office of Dietary Supplements at the NIH (2004) has defined bioactive compounds as constituents in foods or dietary supplements, other than those needed to meet basic human nutritional needs, which are responsible for changes in health status.

Plant products are considered to be important components of a diet for good health. Fruits and vegetables have been shown to exert protective effect on the body (Cox *et al.*, 2000). Fruits and vegetables contains a number of

compounds known as phytochemicals which have been found to be responsible for their effects and these include, carotenoids, alkaloids, vitamins, minerals and polyphenols. Research shows that phenolic compounds such as flavonoids and phenolic acids exhibit antioxidant properties (Wang and Lin, 2000). The recent focus of research is on detection of such bioactive compounds in foods. Their application ranges from medicinal foods, agriculture, food science up to nano bioscience.

Consumption of flavonoids in humans was inversely correlated with mortality from coronary heart diseases (CHDs) and with the incidence of myocardial infarction (Hertog *et al.*, 1993). Dietary flavonoid intake was also inversely associated with CHD mortality. The total intake of flavonoids (quercetin, myricetin, kaempferol, luteolin, and ficetin) was inversely associated with the LDL cholesterol and plasma total cholesterol concentrations (Arai *et al.*, 2000). Many epidemiological studies have examined the role of bioactive compounds and increased dietary intake of fruits and vegetables in the prevention of cardiovascular diseases (CVDs) (Esmaillzadeh and Azadbakht, 2008).

Bioactive compounds extracted from jackfruit shows antioxidant, anti-diabetic, anti-atherosclerotic, antibacterial, antiviral, antifungal and anti-inflammatory activity. The functional components of jackfruit are observed to reduce the various diseases, such as lowering blood pressure, preventing heart disease and strokes, preventing bone loss and improving muscle and, nerve function, reducing homocysteine levels in the blood. The potassium in the jackfruit is found to help in lowering blood pressure and reversing the effects of sodium that causes a rise in blood pressure, that affects the heart and blood vessels. This helps in preventing heart disease and strokes. The functional components for this action includes their high pottssium and B_6 levels (Fernando *et al.*, 1991).

Different groups of bioactive compounds are phenolic compounds, alkaloids, flavanoids, saponins, lectins, lignins, prebiotics and tannins. However a

major branch of scientists (Solomon and William, 2003; Liu, 2013) state that bioactive compounds include vitamins, minerals, fiber, fatty acids, carotenoids along with flavonoids, phytosterols, prebiotics. Jackfruit is widely accepted by consumers, researchers and food industries due to the presence of bioactive compounds (Dutta *et al.,* 2011; Swami *et al.,* 2012).

Jack fruit is referred to as the poor man's fruit is highly nutritive seasonal food rich in carbohydrates, proteins, fats, fibre, calcium, phosphorous, iron, carotene and thiamine. Fructose, glucose and sucrose are the major sugars present in jack fruit. The presence however varies with variety, cultural practices and environment.

Recently, (Chrips *et al.* 2008) observed that the protein and carbohydrate concentration of different varieties of jackfruit seed isolated from the fruits growing in Kanyakumari district of India. The protein concentration of jackfruit seed varities were as follows : Nettadivarika(6.8%) > Mondan (6.5%) > Venkanni (6.0%) > Valayan (5.9%) > Chemparethy (5.3%); while that for the carbohydrate was Mondan (42.8%) > Valayan (42.5%) > Nettadivarika (40.3%) > Venkanni (40.2%) > Chemparethy (37.4%).

The yellowish bulbs constituting the perianth portion of the fruit are fleshy, fibrous, and rich in sugars as well as carotenoids. It is considered a rich source of carbohydrates, minerals, carboxylic acids, dietary fiber, and vitamins such as ascorbic acid and thiamine. Different classes of flavonoids are abundant in the jack fruit plant (Lin *et al.*, 2000; Wei *et al.*, 2005). A major protein, Jacalin has been isolated from jackfruit seeds which possessed immunological properties (Silva *et al.*, 2006).

Studies have shown that jackfruit contain many classes of compounds such as carotenoids, flavanoids, volatile acids sterols and tannins, and that their concentration changes with the variety (Wong *et al.*, 1992; Lu and Lin, 1993;

Venkataraman, 2001; Chandrika *et al.*, 2004; Ong *et al.*, 2006; Arung *et al.*, 2007).

Wong *et al.* (1992) reported that the jackfruits contained forty five volatile components of which thirty two were novel. The esters, which impart the desired flavor to the fruit were found in high concentrations (31.9%). The kernel is reported to contain β-carotene, α-carotene, β-zeacarotene, α-zeacarotene and β-carotene-5,6α-epoxide and a dicarboxylic carotenoid and crocetin (Chandrika *et al.*, 2004). Recent studies have also shown that the key carotenoids present in jackfruit are all-*trans*-lutein (24–44%), all-*trans*-β-carotene (24–30%), all-*trans*-neoxanthin (4–19%), 9-*cis*-neoxanthin (4–9%) and 9-*cis*-violaxanthin (4–10%). However, both qualitative and quantitative differences were seen in the fruits harvested from different varieties of trees (Dayal and Seshadri, 1974; Lin *et al.*, 1995; Faria *et al.*, 2009). Jagdeesh *et al.* (2010) reported that carotenoids are known to impart yellowish-red color to many foods and their ratio is supposed to render the jackfruit the various yellow to orange shades of color.

Jackfruit plant is also reported to contain artocarpine, artocarpetin, artocarpetin A, cycloheterophyllin, artonins A, artonins B, morin, dihydromorin, oxydihydroartocarpesin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, artocarpesin, artocarpetin, norartocarpetin, cycloartinone and artocarpanone (Pavanasasivam *et al.*, 1973; Ko *et al.*, 1998; Lampe and Chang, 2007; Prakash *et al.*, 2009).

Soong and Barlow (2014) have evaluated antioxidant properties of jackfruit seeds and confirmed that 70 per cent contribution of the total antioxidant activity was due to the phenolic content.

The jackfruit has 0.36 mg GAE/100 g content of total phenol (Wongsa and Zamaluddien, 2005).

The alkaloids and flavonoids in jackfruit seed were characterized. The analysis portrayed the fact that *A. heterophyllus* seeds contained alkaloids;

quinine, tomatine and nicotin (Okoye *et al.*, 2012). These alkaloids can be used in the eradication of disease causing germs. The analysis also revealed that the seeds contained myricetine, kaempferol, gossypetine, quercetine and isoliamnetine as the major types of flavonoids (Okoye, 2016).

Qualitative and quantitative phytochemcial analysis of A. heterophyllus seeds indicated the presence of alkaloids 0.55±0.012%; flavonoids 0.41±0.02%; tannins 0.240±0.001%; saponins 2.74±0.02%; phenols 0.08±0.001% (Ong *et al.*, 2006; Silva *et al.*, 2006; Ajayi, 2008; Baliga *et al.*, 2011)

A colorimetric study conducted by Gupta *et al.* (2011) reported that Dichloromethane; methanol (1;1) solvent system (Phenolic content : 2.12 µg ; flavonoid content ; 457.1 µg) was able to extract more bioactive compounds in comparison to acetone solvent system (Phenolic content : 1.45 µg ; flavonoid content ; 290.6 µg). Prasad *et al.* (2012) reported that all the plant extracts of jackfruit contained bioactive compounds such as tannins, alkaloids, carbohydrate and cardiac glycosides that were commonly extracted by using water, petroleum ether, hexane and acetone solvents.

Artocarpanones a group of flavonoids extracted from jackfruit Inhibited melanin production in B16 melanoma cells and tyrosinase enzyme activity and was found to be a good remedy for hyperpigmentation in human skin (Kagan *et al.*, 2002). Nobre *et al.* (2007) observed antioxidant activity in tannin compounds whereas Sreevidya and Mehrotra (2003) observed antimicrobial and antiviral properties along with antioxidants.

Quinine a type of alkaloid used for treatment of malaria was also identified in jackfruit; 3-hydroxyquinine one of the metabolites of quinine had potential anti-malarial activity, which also stimulated insulin secretion and antipyretic activity. Isoprenoid- substituted flavonoids such as Artocarpin, cudraflavone, 6-prenylapigenin, kuwanon C, norartocarpin, albanin A, cudraflavone, brosimona 1 and artocarpanone extracted from jackfruit showed cytotoxicity against melanoma cells (Arung *et al.*, 2006).

A study conducted by Thulyathan *et al.* (2002) reported that the seed lectin showed stronger hemagglutination activity and antioxidant activity compared to testa lectin.

Flavonoids and phenolic compounds extracted from jackfruit exhibited high antioxidant and free radical scavenging activities; they had iron chelating and reducing powers and prevented the progress of various oxidative stresses (Shanmugapriya *et al.*, 2011). Gupta *et al.* (2011) reported that alkaloids in jackfruit showed analgesic, antispasmodic and antibacterial activities.

The bioactive volatile compounds such as Isopentyl isovalerate (28.4 %), Butyl isovalerate (25.6 %), Palmitic acid (8.3 %), Ethyl isovalerate (6.2 %) were also isolated from jackfruit (Maia *et al.,* 2004). Srinivasan and Kumaravel (2016) isolated a group of volatile bioactive compounds from jackfruit; squalene, campesterol, stigmasterol, lanosterol and γ-sitosterol which were identified through GC-MS/MS. These compounds belonged to fatty acids, steroids and terpernoid groups and showed pharmacological activities.

all-trans-β-carotene a type of carotenoid extracted from jackfruit is an important anti oxidant, it is observed to prevent several chronic degenerative diseases such as cancer, inflammation, cardiovascular diseases, cataract and age-related macular degeneration (Krinsky *et al.*, 2003; Stahl and Sies, 2005). Main carotenoids found in jackfruit were all-trans-lutein (37.02 µg/ 100g), all-trans-β-carotene (29.55 µg/ 100g), All-trans-neochrome(0.88 µg/ 100g),all-trans-luteoxanthin (2.06 µg/ 100g) and cis-Luteoxanthin (0.34 µg/ 100g) (Faria *et al.*, 2009).

Jackfruit seeds comprised of up to 10 per cent to 12 per cent of the total weight of the fruit. These seeds were found to be rich sources of starch (22%) and dietary fiber (3.9%) which are important for the health.

Lignans, isoflavones, saponins and all other phytonutrients possess anticancer, antihypertensive, antioxidant, antiulcer and anti-aging properties;

which were identified in the Jackfruit seeds. The seeds may be either roasted or boiled to be eaten or may be boiled and preserved as syrup to be taken orally. It was reported that boiled Jackfruit seeds also contain proteins (31.1%), carbohydrate (66.2%) and crude lipids (1.3%) which are highly nutritious and excellent enough for human health. It can be prepared in many ways to make a healthy snack (Mukprasirt and Sajjaanantakul, 2004). Jackfruit seeds contain phenolic compounds (Soong and Barlow, 2004). About 6.03 mg/g of non reducing sugar were extracted from the seeds that were prebiotic (Nuallaong *et al.*, 2009).

2.2. Health promoting properties of jackfruit

Jackfruit is a sweet and delicious fruit with many health benefits. It contains high amounts of carbohydrate and calories that provides energy instantly. It is rich in antioxidants which protects from cancer, ageing and degenerative diseases. One hundred gram of edible jackfruit bulbs provides 95 calories. The fruit is made of soft, easily digestible bulbs with simple sugars like fructose and sucrose that when eaten replenishes energy and revitalizes the body right away (Ko *et al.*, 2003).

Kumar *et al.* (2002) stated that, daily consumption of jackfruit both in processed form or as whole fruit can strengthen bones and prevent osteoporosis. Magnesium, found in large amounts in jackfruit, absorbs calcium in the body and contributes to strengthening of bones and prevention of bone related disorders like osteoporosis.

Rahman *et al.* (2005) stated that jackfruit acts as a laxative and relieves constipation due to high fiber content. It also cleans up colon thus preventing from colon cancer.

Studies proved that jackfruit is a best food to slow down ageing process, it also keeps skin moisture level high and protects from skin disorders.

Jack fruit is a rich source of potassium which is required to maintain electrolytic balance and hence helps to lower high blood pressure and decreases the risk of stroke and heart attack (Selvaraj and Pal, 2009).

Jagtap *et al.* (2010) reported that jackfruit is an excellent source of vitamin C, which increases immunity to protect against common diseases like cough, cold and flu. It provides vitamin C, which is about 13.7 mg or 23 per cent of RDA. Consumption of foods rich in vitamin C helps the body to develop resistance against infectious agents and scavenge harmful free radicals.

Jackfruit extracts possess anti inflammatory and antibacterial activity (Khan *et al.*, 2003; Wei *et al.*, 2005). *Artocarpus heterophyllus* possess numerous medicinal properties such as antibacterial, antioxidant, antidiabetic, anti-inflammatory, anti-diuretic, immunomodulatory and have been useful in the treatment of fever, skin diseases, convulsions, constipation, ophthalmic disorders and snake bite (Prakash *et al.*, 2009).

2.2.1. Antioxidant activity

Nature has been a resource of medicinal agents for thousands of years and an impressive number of modern drugs have been isolated from natural sources, many based on their use in traditional medicine. Free radicals are the main reason in lipid peroxidation, highly reactive free radicals and oxygen species are present in biological systems from a wide variety of sources (Cheeseman and Scater, 2003). Free radical oxidative stress caused a wide variety of clinical disorders. A serious imbalance between the production of free radicals and the antioxidant defense system is responsible for oxidative stress (Nakiboglu *et al.*, 2007). Antioxidants exert their mode of action by suppressing the formation of reactive oxygen species either by inhibition of enzymes or by chelating trace elements (Subhashini *et al.*, 2011).

The antioxidant properties of prenyl flavones, cycloheterophyllins, artonins A and B extracted from jackfruit, inhibited iron induced lipid

peroxidation, scavenged DPPH and scavenged peroxyl radicals (Ko *et al.*, 1998). Toda and Shirataki, (2006) reported that the flavonoids such as prenylated flavonoids and prenyl isoflavones were isolated from jackfruit and showed stronger inhibitory effects on lipid peroxidation by interaction with hemoglobin and hydrogen peroxide. Increased concentration of glucose in the blood leads to its binding to hemoglobin which may result in the formation of the reactive oxygen species. This process is known as glycation (Vijay and Vimukta, 2014). Jackfruit extracts were used as a compounds to inhibit the haemoglobin glycation it was revealed that an increase of haemoglobin glycation concentration can be inhibited by increasing the jackfruit extract concentration. From this study it was also found that the IC_{50} of jackfruit extracts was 56.43 per cent (Agung *et al.*, 2015).

In antioxidant activities of the methanolic extract of *Artocarpus heterophyllus* seed (ATS), total phenolic content, total antioxidant activity, scavenging of 1, 1-diphenyl-2picrylhydrazyl (DPPH) radical were used to evaluate antioxidant potential of ATS. In DPPH method, ATS showed moderate antioxidant potentiality in a dose dependent manner with the IC50 value of 116.04 µg/ml. The phenolic content of methanol extract of ATS was 437± .006 mg of GAE / gm of dried extract .Total antioxidant capacity of ATS was found to be 170.75± .001 mg/gm equivalent of ascorbic acid (Munira, 2014).

2.2.2. Antidiabetic activity

Diabetes Mellitus is one of the five leading causes of deaths and debilitating diseases in the world. One hundred and fifty million people were suffering from diabetes, which was almost five times more than the estimates one decade ago and it may double in the year 2030 (Kannan *et al.*, 2012;Vijay and Vimukta, 2014).

Fernando *et al.* (1991) confirmed the hypoglycemic effects of the aqueous decoction of jackfruit leaf in both rats and humans and observed it to be effective.

Kotowaroo *et al.* (2006) have shown that aqueous leaf extracts inhibited α-amylase activity in vitro. β -sitosterol extracted from jackfruit positively influenced diabetic state by lowering fasting blood glucose levels by cortisol inhibition (Mcanuff *et al.*, 2005). Phytosterols such as Campesterol, Stigmasterol, Lanosterol, γ-Sitosterol and Cholestan-3-ol, 2-methylene-, (3β,5α) extracted from jackfruit helped in lowering fasting blood glucose levels by cortisol inhibition (Devaraj and Jialal, 2006).

2.3.3. Anticarcinogenic activity

Prenylated flavones, artonins M and E showed significant cytotoxicity against leukemia cells and human oral epidermoid carcinoma (Suhartati *et al.*, 2001). Jacalin, a type of lectin extracted from jackfruit had cancer cell binding properties, as revealed in benign and malignant lesions of the breast and thyroid cancer cells (Zuraidah and Sakinah, 2014).

Arung *et al.* (2006) reported that the extract of *Artocarpus heterophyllus* was one of the strongest inhibitors of tyrosinase activity. The isolated artocarpanones from jackfruit, inhibited both mushroom tyrosinase activity and melanin production in B16 melanoma cells. This compound is a strong remedy for hyperpigmentation in human skin.

The methanolic extract of the leaves possess significant inhibitory effects on the primary cariogenic bacteria. Bioactivity guided fractionated studies have shown that this effect was mediated by 6-(3-methyl-l-butenyl)-5,2′,4′-trihydroxy-3-isoprenyl-7-methoxyflavone (artocarpin) and 5,7,2′,4′-tetrahydroxy-6-isoprenylflavone (artocarpesin). Detailed evaluation have shown that both artocarpin and artocarpesin possessed antimicrobial activities on various strains of *S. mutans*, *S. sobrinus*, *S. rattus*, *S. cricetus*, *S. sanguis*, *L. casei* and the Actinomyces in the range of 3.13–12.5 μg/ml (Sato *et al.*, 1996).

Arung *et al.* (2006) investigated the cytotoxic effects of the isoprenoid-substituted flavonoids isolated from the methanolic extract of the jackfruit wood

on B16 melanoma cells. Studies have shown that artocarpin exhibited potent cytotoxic activity on cultured human T47D breast cancer cells *in vitro* (Arung *et al.*, 2010).

2.2.4. Antimicrobial activity

Isoprenyl flavones, such as artocarpin and artocarpesin extracted from jackfruit inhibited the growth of primary cariogenic bacteria at a concentration of 3.13 – 12.5 µg/ml and exhibited the growth inhibitory effect on plaque forming *Streptococci* (Khan *et al.*, 2003). Antimicrobial activity was evident from the inhibitory effects against the test organisms: *Staphylococcus aureus*, *Atopic dermatitis*, *Malassezia globsin*, *Trichophyton microsporum* and *Propionibacterium*.

Jackfruit lectin (JFL) from *Artocarpus heterophyllus* has been found to have inhibitory activity in vitro with a cytopathic effect toward herpes simplex virus type HSV-2. Varicella zoster virus (VZS) and cytomegalovirus (CMV) (Wetprasit *et al.*, 2000).

Isolated flavonoids such as cycloartomunins, artonins A and B, artocarpanones, hetero flavanones and dihydro isocycloartomanin inhibited the release of beta glucoronidase and histamine and had anti-inflammatory activity (Wei *et al.*, 2005; Fang and Yen, 2008).

The extract of jackfruits had antiviral activity (480µg/ml) against human rotaviruses (inhibition rate was 99.2%) (Goncalves *et al.*, 2005; Trindade *et al.*, 2006). It should be noted that tannins and alkaloids were the important compounds which were responsible for the antibacterial activity.

Khan *et al.* (2003) and Karthy *et al.* (2009) studied the antibacterial effects of the crude methanolic extracts of bark of stem and root, leaves, fruits and seeds on *Bacillus cereus, Staphylococcus albus, Streptococcus faecalis, Escherichia coli, Salmonella typhymurium* and *Serratia marcescens*.

2.2.5. Antidiarrheal Activity

Diarrhea is one of the main causes of infant death especially in third world country. Diarrhea affects the smooth life style due to the huge discomforts associated, although it is not life threatening for adults (Saito *et al.*, 2002).

However, twenty percent of total children die from diarrhea before the age of five in developing countries. There are some synthetic drugs available for diarrheal treatment although most of them have side effects like uncomfortable bowl movement, uneasiness etc. A continuous search, therefore, for an alternative treatment is still urged (Nester *et al.*, 1998).

Jackfruit extract was studied for antidiarrheal property using castor oil in mice. At the doses of 200 and 400 mg/kg body weight, the extract reduced the frequency and severity of diarrhea in test animals throughout the study period. Altogether, these results suggest that the ATS could be used as a potential antidiarrhoeal agent along with its antioxidant potentiality (Munira, 2014).

2.3. Antinutrients in plant foods

Anti-nutrients are the component of nature, that protects the plants so as to live long enough to effectively reproduce. They function as the immune system of the plant, offering protection from the radiation of the sun, foraging by animals and from invasion by bacteria, viruses, or fungi (Barbara, 2009). According to Duenas *et al.* (2009), anti-nutrients may occur naturally in plants as secondary metabolites, protecting plants from viral and fungal attack analogous to the immune system of animals or anti-nutrients may also be produced in large amounts, as a direct result of some adverse environmental condition.

The most important of anti nutrient factors/ antiphysiological substances in legumes include protease inhibitors, phenolic substances, non-protein amino acids, lecithins, saponins, flatulence produces and non-starch polysaccharides (Vidivel and Janardhanen, 2001; Olguin *et al.*, 2003).

Robin and Ross (1996) highlight that antinutrients are not something to be alarmed, about since most foods typically have one or more antinutrients and that the issue is their concentration and type of antinutrient and whether that specific antinutrient profile will adversely affect health. All plants have some anti-nutrient properties, soybean plant is especially rich in these chemicals (Pusztai, 1991). If they are not removed by extensive preparation such as fermentation or soaking, soybeans can become one of the worst foods a person can eat (Preet and Punia, 2000)

2.4. Types of antinutrients in plant foods

2.4.1. Phytates

According to Robin and Ross (1996), phytic acid is a major metabolite in all mature seeds and grains and is the primary storage form of phosphorus in these plant components. The terms phytic acid, phytate and phytins refer to free acids, salts, and calcium/magnesium ionic salts respectively and in cereals and legumes phosphorus is present in significant amounts as phytin (myo-inositol hexaphosphate). Phytates are phosphorus compounds found mainly in cereal grains, legumes, nuts (Nancy and Bill, 2006). Phytic acid occurs naturally through out the plant kingdom and in particular soybean, rapeseed and cotton seed (Joel, 2011). Whole soybeans have been reported to contain 1-2 per cent phytic acids and the major part of the phosphorus contained within phytic acid are largely unavailable to animals due to the absence of the enzyme phytase within the digestive tract of monogastric animals (Christine and Rosalind, 2006; Ramakrishna *et al*., 2006).

Sandberg (2002) notes that all legumes contain phytates (also known as phytic acid) to some extent, but soybean is particularly rich in this anti-nutrient. Phytate works in the gastrointestinal tract by tightly binding is minerals such as copper, iron, magnesium calcium and particularly strong to zinc, a mineral that supports wound healing, protein synthesis, reproductive health, nerve function, and brain development. According to Teucher *et al*. (2004) reduced bioavailability

of minerals from phytate rich sources depends on several factors, which include the nutritional status of animals/humans, the concentration of minerals and phytates in the foodstuffs, the ability of endogenous carriers in the intestinal mucosa to absorb essential minerals bound to phytates and other dietary substance.

Phytic acid also inhibits the action of gastrointestinal trysinase, trypsin, pepsin, lipase and amylase (Khare, 2000). Phytic acid, or its naturally occurring form, phytin (a mixed magnesium and potassium salt of phytic acid), forms insoluble precipitates with several divalent metal cations (including Ca^{2+}, Fe^{3+}, and Zn^{2+}), (Robin and Ross, 1996). Deshpande (2002) highlights that phytic acid has six reactive phosphates and meets the criterion of chelating agent. Thus phytate is largely blamed for complexing dietary essential minerals especially zinc and copper in legumes and cereals and rendering them poorly available to monogastric animals.

Potential beneficial effects of phytate relate to its ability to lower blood glucose response to starchy foods by inactivating amylase enzyme; lowering plasma cholesterol and levels of triacylglycerols by binding to zinc and thus lowering the ratio of plasma zinc to copper which is known to dispose humans to cardiovascular diseases (Shahidi, 1997).

2.4.2. Trypsin inhibitors

Trypsin inhibitors inhibits the function of trypsin enzyme, causing pancreatic hypertrophy and dietary loss of cysteine (Shimelis and Rakshit, 2007). Lack of proper irrigation may increase the activity of trypsin inhibitor (Salunkhe and Kadam,1989). Trypsin inhibitors are proteins that interfere with nutrient absorption by reducing the activity of proteolytic enzymes trypsin and chymotrypsin (Wouters *et al.*, 2008; Rasha *et al.*, 2011). The amount and activity of trypsin inhibitors in the diet has been shown to be inversely related to the availability of energy and protein (Krogdahl *et al.*, 1994). Proteases are enzymes (e.g trypsin and chymotrypsin) in human gastric juices that break down protein.

42

Trypsin helps to regulate secretions from the pancreas. When trypsin is inhibited by protease inhibitors, the pancreas does not receive the signals it needs to slow down. Protease inhibitors are found in nearly all cereal grains and legumes (Ramakrishna *et al.*, 2006). However, there is a lot of variability. For example, the amount of trypsin inhibitory activity in wheat is only 1.5 per cent of the inhibitory activity found in soybeans (Nancy and Bill, 2006; Khattab and Arntfield, 2009). The antinutrient activity of protease inhibitors is associated with growth inhibition and pancreatic hypertrophy. Trypsin inhibitors in soybean give rise to inactivation and loss of trypsin in the small intestine, thus triggering the release of cholecytokinin and induction of pancreatic synthesis of excess trypsin and burden on sulphur containing amino acids required by the body (Yamamoto *et al.,* 1994; Shahidi, 1997; Clemente and Domoney, 2001).

2.4.3 Raffinose Family Oligosaccharides

Oligosaccharides of the raffinose-series (namely raffinose, verbascose and stachyose) are major components in many food legumes and the antinutritional activity of grain legumes is frequently associated with the presence of these oligosaccharides (Fredrikson *et al.,* 2002; Sandberg, 2002). Raffinose-series of oligosaccharides are not hydrolysed in the upper gut due to the absence of α-galactosidase. In the lower intestine they are metabolised by bacterial action, producing methane, hydrogen and carbon dioxide, which lead to flatulence and diarrhoea (Mitsou *et al.*, 2010). Raffinose-series oligosaccharides are thus a major factor limiting the use of grain legumes in monogastric diets (MI IL, 2004).

Raffinose family oligosaccharides (RFOs) are complex sugars containing chains of α galactose which are unable to be digested in the human upper intestine due to the absence of α galactosidase, the enzyme required to break the links in the α galactose chains (Akinyele and Akinlosotu, 1991; Barampama and Simard, 1994; Guillon and Champ, 2002; Shimelis and Rakshit, 2007).

Wichienchot *et al.* (2010) reported that the major carbohydrates of white and red-flesh pitayas (dragon fruit) were glucose, fructose and some

oligosaccharides (total concentrations of 86.2 and 89.6 g/kg, respectively). The molecular weight distribution of the extract was affected by the extraction solvent. The maximum oligosaccharides content (27.40%), which included fractions with molecular weights of 273–275, 448–500 and 787–911 Da, were obtained using 80% ethanol extraction at room temperature (28 ± 2 °C).

2.5. Present consumption pattern and challenges in utilization of jackfruit

Jackfruit is considered to be an underutilized fruit just like most of the fruits that get wasted due to ignorance, lack of post harvest technology and gaps in supply chain systems. Jackfruit contains more protein, calcium, iron, vitamins and other essential nutrients, when compared to the common fruits. A wide gap in the marketing of jack fruits and its value added products can be fully explored for additional income as well as food security. Encouragement should be given to the marketing as well as for the protection of value added food products from this underutilized fruit tree. Young fruit is cooked as a vegetable/ pickled or canned. Pulp of ripe fruit is eaten fresh and made into delicacies like halwa, varatty, jam, jelly etc. Recently more products like flavoured icecream, jackfruit honey etc. has come to the market. Number of factors limits the potential exploitation of the fruit, the major reason being unorganized supply chain management. In Kerala, 50,000 tonnes of raw jackfruit is sent to major cities as vegetables, when the state is short of fruits and vegetables. The biggest curse is that it is difficult to harvest, cut and peel. Skill is lacking to cut and tackle the latex of the fruit. Its large size makes it more unmanagable and perishable in nature. Absence of strong marketing system is a major hindrance. Although a lot of indigenous postharvest handling methods and value added products are available, systematic production is lacking to cater to the demand. Besides harvesting, cutting and cleaning of the fruit is cumbersome making the fruit highly neglected. Shreepadre (2015) recommended three manthras for overcoming these challenges; promoting Ready To Cook products (RTC), Ready To Eat products (RTE) and value addition.

While fresh consumption of jack bulbs is limited, processing and value addition is also negligible. In many cuisines, immature and mature jack fruits are relished in various forms of dishes. But the half ripened and ripened fruits are mostly fed to cattle. It has been reported to increase milk yield of cattle. Thus, the full potential of jack fruit has not been realised by the local folk of most regions in our country. The huge post harvest loss of the fruits paves way for the loss of nutrients in the fruit that would otherwise nourish the consumers. Thus, jack fruit is a commercially an unexploited fruit and there exists no awareness among the farmers about its potential. Trading the fresh fruits (kappa) as organic jack to mundies in cities like Mumbai and Pune would fetch high profits. The immature fruits can be sold in ready to use chopped form, packed in LDPE pouches, as in case of mushrooms. The mature bulbs can be blanched and packed for sale as vegetable in the super markets. The pulp of ripe fruits can be preserved in tins and sold in Indian markets and also to ethnic population in international markets. Besides this, a number of value added products can be prepared from all stages of maturity of a jack fruit. And these products have got a wide range of keeping quality and market (Devi *et al*., 2014).

Apart from its use as a table fruit, jack is a popular fruit for preparation of pickles, chips, jack leather and papad. The fruit has got good potential for value addition into several products like squash, jam, candy, halwa etc. The ripe bulbs can be preserved for one year in sugar syrup or in the form of sweetened pulp. The unripe mature bulbs can be blanched and dehydrated for further use through out the year. Its seeds are rich sources of starch and are considered a delicacy during season. Jackfruit can be an answer to the food security problem of our population.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled ''Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein'' was conducted as three experiments and the methodology adopted is discussed under the following heads.

3.1. Nutrient content, chemical composition and the antioxidant activity of the selected types of jackfruit

3.2. Analysis of measures for reducing antinutrients in raw jackfruit

3.3. Development of raw jackfruit based textured vegetable protein

3.1. NUTRIENT CONTENT, CHEMICAL COMPOSITION AND THE ANTIOXIDANT ACTIVITY OF THE SELECTED TYPES OF JACKFRUIT

3.1.1. Selection and collection of jackfruit

Jackfruit or *Panasa* scientifically known as *Artocarpus heterophyllus* Lam. belongs to the family Moraceae. This fruit is the gigantic syncarp and is known as the largest fruit of the world. It is an indigenous fruit crop of Kerala and is widely grown as an important tree in Kerala's homesteads. As no fertilizer is applied to jackfruit trees maintained in homesteads, it also has the potential to be identified as a therapeutic fruit, grown organically in Kerala by default.

Four varikka types namely Muttom varikka, Then varikka, Sindoor and Chembikalom varikka and a Local cv Koozha types were selected for the study. Analyses of both the ripe and raw stages were done. Seeds and bulbs were analysed separately.

Sindoor type was collected from RARS, Kottarakkara and Then varikka from Mithranikethan, Vellanad. All the other types were collected from the Instructional farm of Vellayani and also from the adjacent home yards. The quality parameters of the selected types were evaluated with respect to nutrients, antinutrients, bioactive compounds and also their antioxidant activity.

Local cv Koozha type was selected for the analysis of measures for reducing antinutrients in raw jackfruit and also for development of raw jackfruit based textured vegetable protein.

Raw bulbs and seeds were taken from fruits of 12 week maturity, along with the following manifestations, such as flattening of spines, colour change from green to pale green, hollow sound, last leaf in the stalk turning yellow. Similarly ripened bulbs and seeds were selected based on all the above manifestations along with yellowing of skin and development of aroma by 14 weeks.

3.1.1.1. Statistical Design and details of treatments

Experimental design : Completely randomized design (CRD)
Number of treatments : 5 x 2 x 2
Number of replication : 3

Types

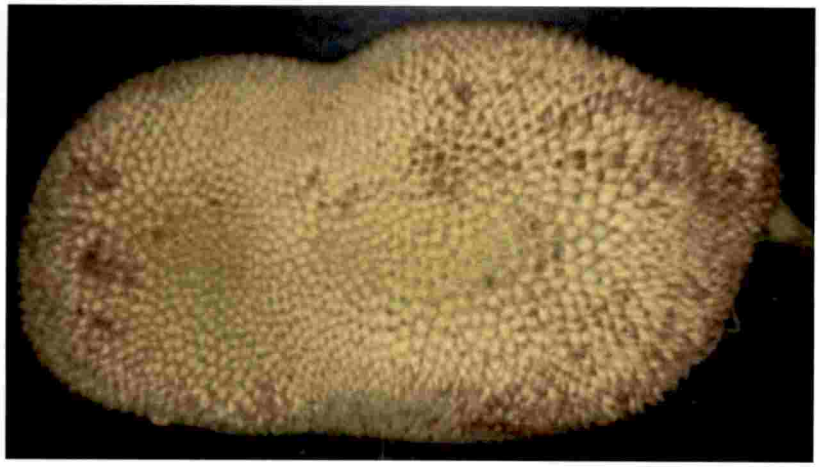
T_1 Muttom varikka
T_2 Then varikka
T_3 Sindoor
T_4 Chempikalom varikka
T_5 Local cv koozha

Stages

S_1 Raw
S_2 Ripe

Edible Portion

E_1 Bulb
E_2 Seed



Muttom Varikka

Raw Bulbs

Raw Seeds

Ripe Bulbs

Ripe Seeds

Plate 1. Raw and ripe stages of bulbs and seeds of Muttom varikka

Then Varikka

Raw Bulbs

Raw Seeds

Ripe Bulbs

Ripe Seeds

Plate 2. Raw and ripe stages of bulbs and seeds of Then varikka

Sindoor

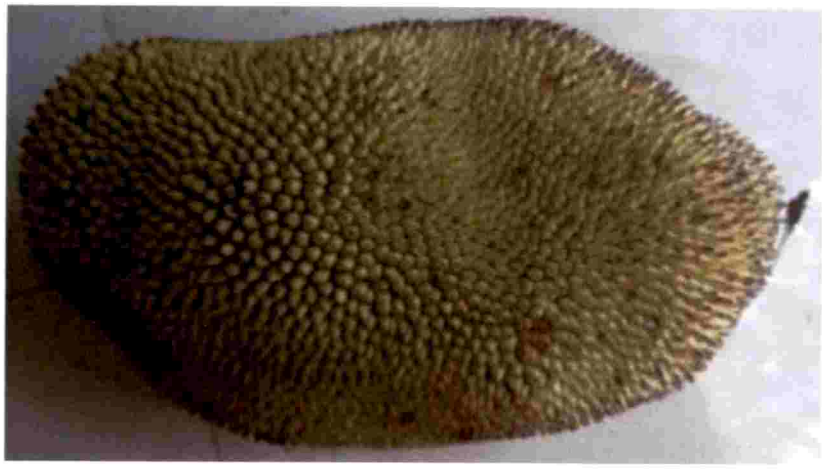
Raw Bulbs

Raw Seeds

Ripe Bulbs

Ripe Seeds

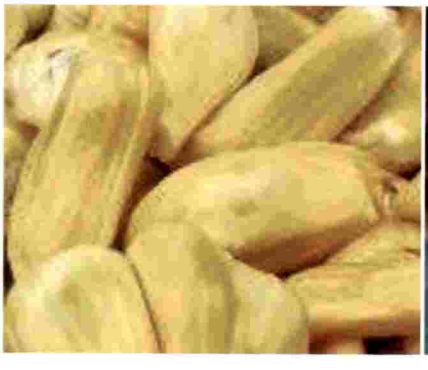
Plate 3. Raw and ripe stages of bulbs and seeds of Sindoor



Chempikalom varikka

Raw Bulbs

Raw Seeds



Ripe Bulbs

Ripe Seeds

Plate 4. Raw and ripe stages of bulb and seeds of Chempikalom varikka

Local cv Koozha

Raw Bulbs

Raw Seeds

Ripe Bulbs

Ripe Seeds

Plate 5. Raw and ripe stages of bulbs and seeds of Local cv Koozha

3.1.2. Assessment of chemical and nutritional composition

In the present study macro and micro nutrients of the selected types were determined. Nutrients levels of total carbohydrate, protein, vitamin C and β carotene were estimated. Minerals levels of calcium, phosphorus, sodium, potassium, iron, magnesium, copper, zinc and selenium were also ascertained. Besides in this study, levels of bioactive compounds such as alkaloids, flavanoids, lycopene, saponins, tannins, polyphenols, lectins and lignins were also estimated. Antioxidant activity such as total antioxidant activity, DPPH radical scavenging activity, hydroxyl radical scavenging activity and super oxide radical scavenging activity were also ascertained. Apart from the above nutrients, moisture and dietary fibre were estimated in the selected types of jackfruit.

3.1.2.1. *Proximate Composition*

The proximate composition of foods includes moisture, dietary fibre, protein, carbohydrate and lipid content (Emelike *et al.*, 2015). This assessment is applicable in the food industry for product development, quality control or regulatory purposes.

3.1.2.1.a. *Total carbohydrate*

Carbohydrates are one of the main nutrients and are needed in large amounts by the body. The role of carbohydrates is to provide energy, as they are the body's main source of fuel, needed for physical activity, brain function and operation of the organs. All the cells and tissues in our body need carbs, and they are also important for intestinal health and waste elimination. Once in the body, carbohydrates are easily converted to fuel.

In the present study, the total carbohydrates of selected jackfruits were estimated by using anthrone reagent and incubating the samples in boiling water bath and recording the absorbance at 630 nm using a spectrophotometer against a blank reagent according to the method described by Hedge and Hofreiter (1962).

3.1.2.1.b. *Protein*

Proteins are complex organic compounds and are the building blocks of life. The basic structure of protein is a chain of amino acids. They provide energy for the body. Protein is an important component of every cell in the body. Protein is also important for growth and development in children, teens and pregnant women.

Nitrogen content of the jackfruit sample were estimated by using micro Kjeldahl's wet digestion method. The major source of nitrogen is proteins and in most proteins, nitrogen constitute 16 per cent of the total make up. The nitrogen values were multiplied by the factor 6.25 to get the crude protein content (AOAC, 2000).

3.1.2.1.c. *Fibre*

Although dietary fibre is not a 'nutrient', it is nevertheless an important component of our diets. Dietary fibre or 'roughage' comprises the edible parts of plant that cannot be digested or absorbed in the small intestine and passes into the large intestine intact.

Fibre content of the jackfruit samples were determined according to AACC method (2000). After the acid and alkali treatments, the residue obtained after final filtration was weighed, incinerated, cooled and weighed again. The weight loss was noted to get the fibre content.

3.1.2.1.d. *Moisture*

Moisture content influences the taste, texture, weight, appearance, and shelf life of foodstuffs. Even a slight deviation from a defined standard can adversely impact the physical properties of a food material. For example, substances which are too dry could affect the consistency of the end product.

Moisture content was estimated by the method of AOAC (1990). This method measures the weight lost by foods due to evaporation of water. About 5 g of the sample was weighed in to a moisture dish, previously dried in the oven and weighed. The dish was placed in the oven at 130^0c + 2^0c for 2 hours. Then it was cooled in a dessicator and weighed, the process was repeated at 30 minutes intervals until the difference between two consecutive weights was less than one milli gram.

3.1.2.2. *Vitamins*

3.1.2.2.a. *β carotene*

Beta-carotene is a type of carotenoid that is found in plants. It is known as pro vitamin A carotenoid because it needs to be converted to active vitamin A by the body. Vitamin A is needed for healthy skin and mucus membranes, also for invigorating immune system and vision.

β carotene was estimated by the method of Sadasivam and Manickam (2008). This method was based upon the separation of the biologically active carotenoid pigments from the total carotenoid pigments using acetone and ether and read colorimetrically at 452 nm.

3.1.2.2.b. *Vitamin C*

Vitamins are essential to maintain normal metabolic processes and homeostasis within the body. The amount of specific vitamins required by an individual varies considerably and it is influenced by factors such as body size, growth rate, physical activity and pregnancy. Epidemiological data have revealed the preventive and curative role of vitamin C on certain diseased conditions in the body though controversies still persist. Vitamin C is effective in protecting against oxidative damage in tissues and also suppressing formation of carcinogens like nitrosamines.

Vitamin C was estimated by the titrimetry method of Sadasivam and Manickam (2008) using dichloroindophenol dye.

3.1.2.3. *Minerals*

Minerals are vital to health and are basically the spark plugs of life, or keystones to our health. Like vitamins and amino acids, minerals are essential for regulating and building the trillions of living cells which makes up the body. They help draw chemical substances in and out of the cells and keep the blood and tissue fluids from becoming either too acidic or too alkaline. It helps to retain and maintain water necessary for life's processes in the body. Minerals are the catalysts that keep the body's '*battery*' going and hold its '*charge*.' Minerals compose about 4 per cent of the human body. Human body cannot produce minerals so it has to be obtained through food.

Wet digestion method (dry as well as fresh samples) was used for analysing minerals like P, Ca, Cu, Fe, S, Mg, Al, K, Na, Se and Zn. The biological materials were oxidized with diacid (HNO_3-$HClO_4$ mixture in the ratio of 4:1). The acids were partially removed by volatilization where as the soluble mineral constituents remained dissolved in nitric acid.

3.1.2.3.a. *Total Minerals*

Total mineral content of food stuffs represents the inorganic residue remaining after destruction of organic matter. The process of combustion evaporates moisture and oxidizes the organic matter to vanish in air. The incombustible residue is the total mineral content. For determining total mineral content of the samples, 5 g of the samples were accurately weighed in a silica crucible, that was previously dried in the air oven. The crucible was heated gently on the flame till it got charred, this was followed by incinerating strongly in a muffle furnace at $550+10^0$c till grey ash was formed. The contents were cooled in desiccators and weighed. The process of heating in the muffle furnace, cooling and weighing was repeated at 30 minutes intervals.

3.1.2.3.b. *Calcium*

Calcium is a chemical element that is essential for living organisms, including humans. It is the most abundant mineral in the body and vital for good health. The calcium content in jackfruit samples were estimated using Ethylene Diamine Tetra Acetic Acid (EDTA) titration method, after wet digestion of the samples using di - acid mixture and expressed as mg in 100 g^{-1}(Hesse,1971).

3.1.2.3.c. *Phosphorus*

Phosphorus is a mineral that makes up 1 per cent of a person's total body weight. It is the second most abundant mineral in the body. It is present in every cell of the body. The main function of phosphorus is in the formation of bones and teeth. It plays an important role in the utilization of carbohydrates and fats. It is also needed by the body to synthesise protein for the growth, maintenance and repair of cells and tissues. Phosphorus also helps the body to make ATP, a molecule the body uses to store energy.

The phosphorus content in jackfruit samples were estimated by Spectronic 20 (AOAC, 2005).

3.1.2.3.d. *Sodium*

Sodium is an element that is crucial for the body to function properly. It is important for fluid distribution, maintaining blood pressure, cellular work and electrical activity.

The sodium content in jackfruit samples were digested using the diacid mixture and estimated by flame photometer method using sodium chloride solution as standard (Jaiswal, 2003).

3.1.2.3.e. *Potassium*

Potassium is the most important cation in human body; it is also called the mineral of the heart. It regulates blood pressure and maintains normal fluid

balance, It is important for the nervous system and heart muscle. Potassium acts as an electrolyte and therefore directly affects the heart muscle cells and nerve impulse function. Therefore cardiac contractions change when potassium level changes.

The potassium content in jackfruit samples were estimated using Atomic absorption spectrophotometer AOAC (2005).

3.1.2.3.f. *Iron*

Iron, an essential mineral, that forms an integral part of enzymes and proteins which are necessary for vibrant health. It plays a crucial role in delivering oxygen throughout the body.

For the determination of iron, ferric iron in acid solution was made to react with potassium thiocyanate to form an intense red compound, ferric thiocynate. The compound was then extracted with an organic solvent, iso-amyl alcohol and measured colorimetrically at 540nm.

3.1.2.3.g. *Magnesium*

Magnesium is one of the most important minerals found in human body, which is involved in cellular energy production, enzyme activity and regulation of nerve impulses. Magnesium is important for muscular and nervous system activity and also for the bone structure.

The magnesium content in jackfruit samples were estimated by Atomic absorption spectrophotometer (AOAC, 2005).

3.1.2.3.h. *Copper*

Copper is one of the relatively small group of metallic elements which are essential for human health. These elements, along with amino and fatty acids as well as vitamins, are required for normal metabolic processes. However, as the

body cannot synthesize copper, the human diet has to supply regular amounts for absorption.

For the determination of copper, sodium diethyl-dithiocarbanate was made to react with the slightly acidic ammonia-cal solution of Cu to produce a brown colloidal suspension of cupric-diethyl-dithio-carbanate. The suspension was extracted with an organic solvent and the colour extracted was measured spectrophotometrically at 440 nm (AOAC, 2005).

3.1.2.3.i. *Zinc*

Zinc is an important mineral that is found in every single cell of the body. Zinc plays a crucial role in supporting optimal immune system function. White blood cells which help to fight off infection depends on zinc for their development and activation. A deficiency of zinc can result in diminished amounts of white blood cells and reduced ability to fight infections and heal wounds.

The zinc content in jackfruit samples were estimated by Standard flame emission photometer (AOAC, 2005).

3.1.2.3.j. *Selenium*

Selenium is an extremely vital mineral for the human body as it increases immunity, takes part in antioxidant activity that helps to defend against free radical damage and inflammation and also plays a key role in maintaining healthy metabolism.

The selenium content in jackfruit samples were estimated by Atomic absorption spectrophotometer (AOAC, 2005).

Table 1. Analytical procedures for minerals

Minerals	Methods
Total minerals	Sadasivam and Manickam (1992)
Calcium	Titrimetry (Hesse, 1971)
Phosphorus	Spectronic 20 (AOAC, 2005)
Sodium	Spectronic 20 (AOAC, 2005)
Potassium	Spectronic 20 (AOAC, 2005)
Iron	Spectronic 20 (AOAC, 2005)
Magnesium	Titrimetry (AOAC, 2005)
Manganese	Atomic absorption Spectrophotometer (AOAC, 2005)
Copper	Atomic absorption Spectrophotometer (AOAC, 2005)
Zinc	Atomic absorption Spectrophotometer (AOAC, 2005)
Selenium	Atomic absorption Spectrophotometer(AOAC, 2005)

3.1.2.4. *Bioactive Compounds*

Plant products are considered to be the most important components of diet for a good health. Fruits and vegetables have proved to exert protective effect of different dimensions (Cox *et al.*, 2000). Fruits and vegetables contain number of compounds known as phytochemicals which have been found to be responsible for physiological activities conventionally carned out by vitamins and minerals. Jackfruit is widely accepted by consumers, researchers and food industries, due to the presence of bioactive compounds (Dutta *et al.*, 2011; Swami *et al.*, 2012).

For the preparation of the sample extract, 25 g of fresh samples were taken and ground using mortar and pestle and the samples were extracted using 50 ml each of ethanol, methanol, acetone and distilled water as solvents to detect the secondary plant metabolites including alkaloids, flavanoids, lycopene, saponins, tannins, polyphenols, lectins and lignins using standard methods with slight modifications. These extracts were centrifuged at 5000 rpm for 20 minutes. The

supernatant extracts were kept overnight for incubation at room temperature and used for both qualitative and quantitative estimation of bioactive compounds.

3.1.2.4.a. *Qualitative Screening of Bioactive compounds*

Qualitative analysis for bioactive compounds such as alkaloids, flavanoids, lycopene, saponins, tannins, polyphenols, lectins and lignins was done to ensure their presence or absence in jackfruits samples. The sample extracts were subjected to preliminary phytochemical screening using the methods described by Evans (1996).

3.1.2.4.a.i. *Test for alkaloids*

For the screening of alkaloids, 1.0 ml of extract was mixed with 5 ml of dilute hydrochloric acid in a steam bath. The mixture was filtered and 1.0 ml of Mayer's reagent was added to 1.0 ml of filtrate in a separate tube. A cloudy slightly yellow colour indicated the presence of alkaloids.

3.1.2.4.a.ii. *Test for flavanoids*

To 3 ml of the sample extract in a test tube, 10 ml of ethyl acetate was added and heated over a steam bath for 3 minutes. The mixture was filtered and 4 ml of the filtrate was shaken with 1 ml of dilute ammonia solution. Appearance of yellow colouration indicated the presence of flavanoids.

3.1.2.4.a.iii. *Test for saponins*

Frothing test was used to determine the presence of saponins in the sample extract. 0.2 ml of extract was mixed with 5.0 ml of distilled water and shaken for 20 minutes. Persistence of foams indicated the presence of saponins.

3.1.2.4.a.iv. *Test for Tannins*

To 1.0 ml of plant extract, equal volume of ferric chloride ($FeCl_3$) or bromine water was added. Formation of reddish brown or greenish black precipitate indicated the presence of tannins.

3.1.2.4.a.v. *Test for poly phenols*

Dilute ammonia solution was added to the sample extract, the production of reddish to yellow colour indicated the presence of phenolic compounds.

3.1.2.4.b. *Quantitative estimation of Bioactive compounds*

Quantitative analysis of bioactive compounds such as alkaloids, flavanoids, lycopene, saponins, tannins, polyphenols, lectins and lignins were conducted to ensure their presence or absence in jackfruits samples.

3.1.2.4.b.i. *Alkaloids*

Alkaloids are one of the most diverse groups of secondary metabolites found in plants, marine organisms and microorganisms. Alkaloids, especially plants containing alkaloids, were used in the middle ages as a basic and practical cure for various ailments.

The sample extract (1mg) was dissolved in dimethyl sulphoxide (DMSO), to which 1ml of 2 N HCl was added and filtered. This solution was transferred to a separating funnel, to which 5 ml of bromocresol green solution and 5 ml of phosphate buffer were then added. The mixture was taken in 4 test tubes and shaken with 1, 2, 3 and 4 ml chloroform separately by vigorous shaking and collected in a 10-ml volumetric flask and diluted with chloroform. A set of reference standard solutions of atropine (20, 40, 60, 80 and 100 µg/ml) were prepared. The absorbance for test and standard solutions were determined against the blank at 470 nm with an UV/Visible spectrophotometer. The total alkaloid content was expressed as mg of AE/g of extract (Fazelshamsa *et al.*, 2008).

3.1.2.4.b.ii. *Flavanoids*

Flavanoids are biologically active low molecular weight secondary metabolites that are produced by plants, with over 10,000 structural variants now reported. Flavanoids are shown to exert beneficial effects in a multitude of diseased states, including cancer, cardiovascular disease, and neurodegenerative

disorders (Shirley, 2001). Many of the biological actions of flavanoids are due to their antioxidant properties and their reducing capacities through possible influences on intracellular redox status.

Total flavonoid content was measured by aluminium chloride colorimetric assay (Lee *et al.*, 2012). The reaction mixture consisted of 1 ml of extract and 4 ml of distilled water in a 10 ml volumetric flask. To the flask, 0.30 ml of 5 per cent sodium nitrite was added and after 5 minutes, 0.3 ml of 10 per cent aluminium chloride was mixed. Next, 2 ml of 1M Sodium hydroxide was treated and diluted to 10 ml with distilled water. A set of reference standard solutions of morin (20, 40, 60, 80 and 100 µg/ml) were prepared. The absorbance for test and standard solutions were determined against the blank at 510 nm with an UV/Visible spectrophotometer. The total flavonoid content was expressed as mg of ME/g of extract.

3.1.2.4.b.iii. *Lycopene*

Lycopene has a strong antioxidant effect and has been shown to be effective in neutralizing singlet oxygen, a very potent free-radical. Lycopene has been proposed to compounds that can cause DNA damage. It may also inhibit the growth of prostate cancer cells, reducing the risk of advanced disease and potentially the recurrence of disease.

For the determination of lycopene, three to four fruits were taken and homogenized in a blender, 5-10 g of this pulp was weighed. The pulp was extracted repeatedly with acetone using pestle and mortar until the residue was colorless. The acetone extract was pooled and transfered into a separating funnel containing 20ml petroleum ether. It was gently mixed. Twenty ml of 5 per cent Na_2SO_4 solution was added to this and shaken in a separating funnel. More petroleum ether was added for clear separation. The lower aqueous phase was separated out with 10 ml petroleum ether, 5-6 times until aqueous layer was colourless. The ether extract was pooled and washed with distilled water.

The ether extract was poured into a long beaker containing 10 g of anhydrous sodium sulphate. The ether extract was decanted into a 100 ml volumetric flask through a funnel containing cotton wool and a thick layer of anhydrous Na_2SO_4. The sodium sulphate slurry left in beaker was washed with ether, until it become colourless. The volume was made up to 100 ml and the absorption was read in a colorimeter at 503 nm, using petroleum ether as a blank.

3.1.2.4.b.iv. *Saponins*

Many plant based traditional medicines contain saponins, which can often account for their therapeutic action. It is believed that the natural role of these compounds in plants is to protect against attack by potential pathogens, which would account for their antimicrobial activity. Saponins are naturally occurring plant glycosides; which have a favourable effect on cholesterol; helps to boost the immune system; have an antioxidant effect and even support bone strength.

Determination of saponin contents in samples was determined as suggested by Obdoni and Ochuko (2001). Twenty gram of sample was taken in a conical flask and 100 ml of 20 per cent aqueous ethanol was added. Then the samples were heated over a hot water bath for 4 hours with continuous stirring at 55^0c. The mixture was filtered and the residues were extracted with 200 ml of 20 per cent ethanol. The combined extracts were reduced to 40 ml over water bath at about 90^0c. The concentrate was then transferred into a 250 ml separating funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. Then 60 ml of n- butanol was added. The combined n- butanol extracts were washed twice with 10 ml of 5 per cent aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to a constant weight and the saponin content was calculated as percentage.

3.1.2.4.b.v. *Tannins*

Tannins (commonly referred to as tannic acid) are water-soluble polyphenols that are present in many plant foods. Tannins have also been reported to exert other physiological effects, such as acceleration of blood clotting, reducing blood pressure, decreasing the serum lipid level, producing liver necrosis and modulating immune responses. Tannins are widespread in nature and are probably present in all plant materials.

Tannin like compounds reduce phosphotungstomolybdic acid in alkaline solution to produce a highly coloured blue solution, the intensity of which is proportional to the amount of tannins (Sadasivam and Manickam, 1992). Its extraction is based on this principle. A blank was prepared with water instead of the sample. Standard curve of tannic acid was used to estimate water soluble tannins and it was expressed as gram per g^{-1} of dry weight.

3.1.2.4.b.vi. *Polyphenols*

Polyphenols are the aromatic compounds with hydroxyl groups which are wide spread in plant kingdom occurring in all parts of the plants. The protective role of polyphenols against reactive oxygen and nitrogen species, UV light, plant pathogens, parasites and predators results in several beneficial biological activities giving rise to prophylaxis or possibly even to cure several prevailing human diseases, especially various cancer types (Dai and Mumper, 2010).

The colorimetry method was used to evaluate the level of phenols. Phenols react with phosphomolybdic acid in Folin- Ciocalteau reagent in alkaline medium and produce blue coloured complex (molybdenum blue). The absorbance of the blue colour developed was measured at 660 nm on double beam UV visible spectrophotometer. Total polyphenols were calculated with the help of standard curve of 0.1 mg/ml tannic acid and was expressed as gram in 100 g of dry weight.

3.1.2.4.b.vii. *Lectin*

Lectins are carbohydrate-binding proteins. These macromolecules are highly specific for sugar moieties.

As reported in the manual of food quality (AOAC, 1990), colorimetric method was adopted for the analysis of lectins. Here, the samples were ground into slurry and from this 1g of the slurry sample was weighed into a crucible. 10 ml of distilled water was added alongwith 1 ml of concentrated $H_2 SO_4$ and the mixture was allowed to stand for one hour. The prepared solution was made up to 50 ml using distilled water. From this extract 5 ml was pipetted into a test tube and 1 ml of Schiffs reagent was added. The absorbance was measured at 510 nm. The value of lectin in jackfruit samples was estimated from the standard curve of the lectin.

3.1.2.4.b.viii. *Lignins*

Lignins are obtained from various plants or biomass via a range of processes. Lignins are currently used to produce energy, great efforts are being made to find new applications of them, since they are relatively cheap. Since these readily available plant-derived materials are biocompatible, researches on their potential use in biomedical applications has increased in recent years. In many cases the application of lignins focused on their antioxidant capacity. The application of lignin studies included their antiviral and antitumor effects.

Lignins are phenolic polymers present in the cell walls of plants which are responsible together with cellulose, for the stiffness and rigidity of plant stems. The sample was refluxed with acid detergent solution to remove the water solubles and minerals other than the fibrous component. The left out material was weighed after filtration, dried, treated with 72 per cent H_2SO_4 filtered, dried and ashed. The loss of weight on ignition gives the amount of lignin.

3.1.2.5. Antinutrients

Anti-nutritional factors are compounds which reduces the nutrient utilization and/or food intake of plants or plant products that are used as human foods. Antinutrients in plant foods are responsible for deleterious effects related to the absorption of nutrients and micronutrients. However, some antinutrients may exert beneficial health effects at low concentrations. For example, phytic acid, lectins, tannins, saponins, amylase inhibitors and protease inhibitors have been shown to reduce the availability of nutrients and cause growth inhibition. However, when used at low levels, phytates, lectins, tannins, amylase inhibitors and saponins have also been shown to reduce the blood glucose and insulin responses to starchy foods and/or the plasma cholesterol and triglycerides. In addition, phytates, tannins, saponins, protease inhibitors, goitrogens and oxalates have been suggested to reduce cancer risks.

3.1.2.5.a. *Trypsin inhibitors*

Trypsin inhibitors occur in a wide range of foods. A trypsin inhibitor is a type of serine protease inhibitor that reduces the biological activity of trypsin. Trypsin is an enzyme involved in the breakdown of many different proteins. Therefore, protease inhibitors that interfere with its activity can have an antinutritional effect.

The trypsin inhibitor activity was measured indirectly by inhibiting the activity of trypsin (Kakade *et al.*, 1969). A synthetic substrate (BAPNA) was subjected to hydrolysis by trypsin to produce yellow coloured p- nitroanilide. The degree of inhibition of the yellow colour production was measured at 410 nm. Trypsin inhibition activity (inhibition per cent) was expressed in terms of number of trypsin units inhibited.

$$\text{Inhibition per cent} = \frac{(\text{Absorbance of control} - \text{Absorbance of sample})}{\text{Absorbance of control}} \times 100$$

3.1.2.5.b. *Oligosaccharides*

An oligosaccharide is characterised by a carbohydrate chain made up of 3-10 monosaccharides. In the foods we eat, oligosaccharides are often components of dietary fibre. Oligosaccharides are malabsorbed by the small intestine and therefore go on to undergo fermentation in large intestine. This naturally means that some gas and subsequent flatulence may be produced with the consumption of oligosaccharides. Oligosaccharides are generally classed as prebiotics, which are normally considered to be beneficial agents as they act as a source of food for the beneficial gut bacteria.

In this study, HPTLC method was used for estimating oligosaccharide content of the raw and ripe stages of both seeds and flakes of the different types of jackfruit. The level of Raffinose was ascertained being the prominent member of the oligosaccharide family.

3.1.2.6. Antioxidant activity

Antioxidants are compounds capable to either delay or inhibit the oxidation processes which occur under the influence of atmospheric oxygen or reactive oxygen species. They are used for the stabilization of polymeric products of petrochemicals, foodstuffs, cosmetics and pharmaceuticals. There is an increasing interest in antioxidants, particularly in those intended to prevent the presumed deleterious effects of free radicals in the human body, as well as the deterioration of fats and other constituents of foodstuffs (Molyneux,2004). Recently, antioxidants have attracted considerable attention in relation to free radicals and oxidative stress, cancer prophylaxis and therapy and longevity (Kalcher *et al.*, 2009).

3.1.2.6.a. *Total antioxidant activity*

Total antioxidant activity was determined using to the thiocyanate method (Oliveri, 2000). The ascorbic acid solution (100 mg/l) in 2.5 ml of pottassium

phosphate buffer (0.04 M, pH 7.6) was added to 2.5 ml of linoleic acid emulsion (50 ml linoleic acid emulsion containing Tween- 20, linoleic acid and potassium phosphate buffer). While, 5.0 ml of control contained 2.5 ml of linoleic acid emulsion and 2.5 ml of potassium phosphate buffer (0.04 M, pH 7.6). Each of these solutions were then incubated at 37^0c in a glass flask in the dark.

At 24 hour intervals during incubation, 0.1 ml of the incubated solution was added to 44.7 ml of 75% (v/v) ethanol and 0.1 ml of 30% (w/v) ammonium thiocyanate. Precisely 3 minutes later 0.1 ml of 0.02 M Fe Cl_2 in 3.5% (w/v) and HCl were added to the reaction mixture, the absorbance of red colour was measured at 500 nm in a spectrophotometer. The inhibition of lipid peroxidation in % was calculated as inhibition % = [(A0 – A1)/A0 X 100]

3.1.2.6.b. ***DPPH radical scavenging assay***

Radical scavenging activity of plant extracts against stable 2, 2diphenyl 2-picrylhydrazyl hydrate (DPPH) was determined with DPPH. This compound reacts with an antioxidant compound, which can donate hydrogen, and thereby reduce DPPH. The change in color (from deep violet to light yellow) was measured at 515 nm on a UV visible light spectrophotometer. The solution of DPPH in methanol 60μM was prepared fresh before UV measurements. 3.9 ml of this solution was mixed with 100 μl of test solution at various concentrations (200, 400, 600, and 800 μg). The samples were kept in the dark for 15 minutes at room temperature and the decrease in absorbance was measured. The experiment was carried out in triplicate. Ascorbic acid was used as a reference standard and dissolved in distilled water to make the stock solution with the concentration (1mg/1000μl). Control sample was prepared containing the same volume without any extract and reference ascorbic acid. 95% methanol was used as blank. Radical scavenging activity was calculated by the following formula.

% Inhibition = (Absorbance of Control at 0 minute - Absorbance of Test) / Absorbance of Control at 15 minutes x 100, Where C= absorption of control sample (t= 0 min), C= absorption of control (t=15 min), T=absorption of test solution.

3.1.2.6.c. *Hydroxyl radical scavenging activity*

Hydroxyl radical scavenging activity of methanolic, ethanolic, acetate and petroleum ether extracts of the samples were conducted using the deoxyribose method (Halliwell et al., 1996). The reaction mixture contained phophate buffer (20 mM, pH 7.4), (60 nM) deoxyribose (10 m M), hydrogen peroxide (1 mM), ferric chloride (1.04mM), EDTA, different amounts of powdered samples, (2 m M) and ascorbic acid. The reaction mixtures were incubated for 1 hour at 37^0c after which 17mM trichloro acetic acid (TCA) was added. The mixture was then boiled for 15 minutes ice cooled and measured for absorbance at 532 nm. Distilled water was used as a blank.

3.1.2.6.d. *Super oxide radical scavenging activity*

Super oxide radical scavenging activity was measured based on the method described by Robok and Gryglewski (1988). Superoxide radicals were generated in a PMS – NADH system via the oxidation of NADH and then assayed by the reduction of nitro blue tetrazolium (NBT). The superoxide radicals were generated in a reaction mixture containing 150 µM NBT, 468 µM NADH solution in sodium phosphate buffer in different concentrations of methanolic, ethanolic, acetate and petroleum ether extracts of the samples. To this 60 µM phenozine metho sulphite (PMS) solution was added. The reaction mixture was incubated for 5 minutes at 25^0c and the absorbance was measured at 560 nm.

3.2 ANALYSIS OF MEASURES FOR REDUCING ANTINUTRIENTS IN RAW JACKFRUIT

Antinutrients are chemicals which have been evolved by plants for their own defense. Among other biological functions this reduces the maximum utilization of nutrients especially proteins, vitamins, and minerals, thus preventing optimal exploitation of the nutrients present in food and decreases their nutritive value of these plant chemicals have been shown to be deleterious to health and some advantageous to human and animal health if consumed at appropriate amounts (Ugwu and Oranye, 2006). Jackfruit consumption is hindered by the fact that flatulence is caused by over consumption. The pre treated and milled raw jackfruit bulbs and seeds of cv koozha were subjected to the following treatments to reduce anti nutrients.

3.2.1. Selection of jackfruit

Jackfruit type, Local cv Koozha was selected for the study owing to its abundant availability and lower utilization. Raw mature jackfruits were collected from the Instructional farm, College of Agriculture, Vellayani and also from the adjacent home yards.

3.2.2. Pretreatment

Vegetables and fruits are subjected to several pretreatments after harvesting and before processing. The preliminary processing comprised of washing, peeling, cutting, separating of bulbs and seeds, blanching and drying of jackfruit bulbs and seeds to get the flour (JFBF & JFSF) (Veena Kumari, 2015).

Fresh fruits and seeds of jackfruits were washed under tap water to remove dust and dirt, it was then cut into several pieces and the bulbs were separated. As the fruit contains sticky latex, small quantity of vegetable oil was applied on hands before separating the flakes. The white arils or seed coat were peeled off manually. The spermoderm layer was removed by rubbing the seeds between the hands and washing then thoroughly under running water.

Selection of appropriate dimension of slices is an important factor prior to drying, because thicker slices will dry at a slower rate or may not dry fully. The raw material was cut in dimensions of 2.5 x 1 cm for bulb and 1.5 x 1 cm for seeds.

Blanching is a unit operation prior to freezing, canning or drying in which fruits or vegetables are heated for the purpose of inactivating enzymes, modifying texture, killing microorganisms, preserving colour, flavour and nutritional value and removing trapped air (Corcuera *et al.*, 2004). It is a mild heat treatment accomplished at a temperature below 212^0F for less than 2 to 3 minutes before drying. This process also helps in the removal of air from the food tissues to reduce oxidation, softening of tissues facilitates packing and also inactivation of anti nutritional properties.

Jackfruit bulbs and seeds were subjected to thermal treatment to inactivate antinutritional factors present in seeds. Then the blanched slices were dried below 50^0 C in the electric drier for 6-7 hours. Proper care was given to avoid the cross contamination from other foreign particles.

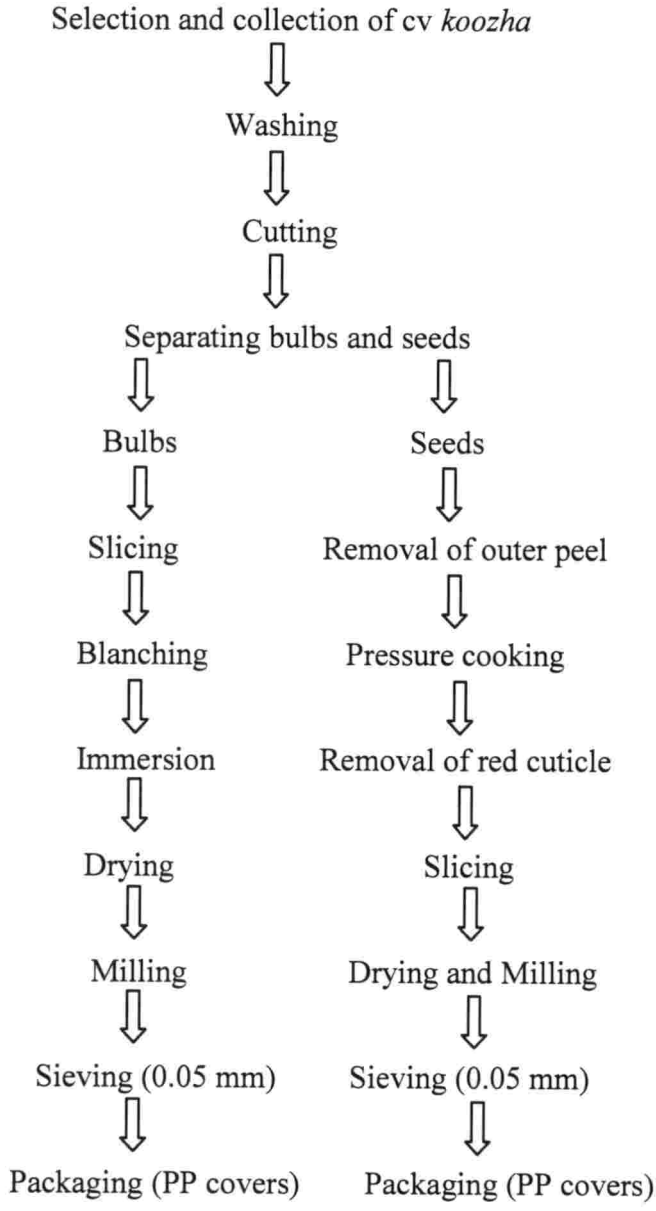
3.2.3. Milling

The dried jackfruit flakes and seeds were milled into fine flours separately. The flours were sieved through a 0.05 mm sieve properly and packed in PP covers for further analysis. Flow chart for the preparation of JFBF and JFSF are depicted in Figure 1. The flours were subjected to two types of treatments to assess the breakdown of oligosaccharides.

3.2.4. Treatment with enzyme α galactosidase

The enzyme α-Galactosidase catalyzes the hydrolysis of α-1,6-linked galactoside residues from simple oligosaccharides, such as melibiose, raffinose, and stachyose and the polysaccharides of galactomannans and guar gum. It also acts on glycoconjugates, glycoproteins and glycosphingolipids and is known to catalyze transglycosylation reactions, especially with higher substrate

Figure 1. Flow chart for preparation of JFBF and JFSF



concentrations (Silva *et al.*, 2006). Thus, interest in this enzyme stems from its potential biotechnological and medicinal applications. Currently, the most important industrial applications of α-galactosidase are related to the beet sugar industry, paper pulp industry, soya food processing and animal feed processing (Prashanth and Mulimani, 2005).

The enzyme α galactosidase was premixed with the dry flour of jackfruit seed and jackfruit bulb separately in the ratio 1:100 (Brain, 2013). The moisture level of the flour was varied from 25 – 200% (dough to batter stage). The hydrolysis was carried out for 90 minutes in both jackfruit bulb flour and seed flour. The products were evaluated for the breakdown of oligosaccharides. The details of variations in moisture content are explained below.

3.2.4.1. *Statistical Design and treatment details*

Experimental design : Completely randomized design (CRD)
Number of treatments : 8 x 2
Number of replications : 2

Treatments	**Moisture level (%)**
M_1	25
M_2	50
M_3	75
M_4	100
M_5	125
M_6	150
M_7	175
M_8	200

Edible Portion

E_1 Bulb (flour)
E_2 Seed (flour)

3.2.5. Treatment with *Saccharomyces cerevisiae*

As a part of reducing antinutrients in jackfruit, fermentation with *Saccharomyces cerevisiae* was adopted as the second method. Fermented foods with their microbial activity plays an essential role in conferring the required stability, safety and sensory properties to the product. On the nutritional side, fermentation helps in degradation of antinutritional factors and increase mineral bioavailability, protein digestibility and degradation of flatulence causing oligosaccharides.

To reduce the level of oligosaccharides, flours were to be made into batter and subjected to fermentation with *Saccharomyces cerevisiae* @ 5g/kg for 6 hrs, 8 hrs and 12 hrs (Krishnaja, 2014).

Best treatments were identified based on the level of oligosaccharide breakdown to be utilised for product development from both treatments.

3.2.5.1. *Statistical Design and treatment details*

Experimental design : Completely randomized design (CRD)
Number of treatments : 3x 2
Number of replications : 4

Treatments	**Time**
F_1	6 hrs
F_2	8 hrs
F_3	12 hrs

Edible Portion

E_1 Bulb

E_2 Seed

3.2.6. Quality comparison of Pretreated and treated flour

The powders of both experiments were tested for the breakdown of oligosaccharides.

3.2.6.1. *HPTLC estimation of Oligosaccharides (Raffinose μg g^{-1})*

High Performance Thin Layer Chromatography (HPTLC) is a commonly used method for the analysis of food bioactive oligosaccharides because it is available in all types of laboratories and does not require especially technically trained personnel. This method is popular due to its simplicity and adaptability and the availability of the equipment.

The concentration of Oligosaccharides (Raffinose) present in the jackfruit bulb flour and seed flour (pre treated) were compared with enzyme treated and yeast treated flours of jackfruit bulbs and seeds through High Performance Thin Layer Chromatography (HPTLC) analysis.

Raffinose (reference standard of 99 per cent purity) was procured from Sigma – Aldrich Chemie GmbH (Aldrich Division; Steinheim, Federal Republic of Germany). Isopropanol (purity 99 per cent), methanol (purity 99 per cent), toluene(purity 99 per cent), ammonia solution (95 per cent) were procured from Merck, India. All solvents were of HPLC grade and distilled water used was purified with Sartorius water purification unit (Arium 61315, made in USA).

3.2.6.1.a. *Extraction of sample*

Methanolic extract of treated and pre treated jackfruit bulb flour and seed flour was obtained by collecting filtrate (Whatmann No.41 filter paper) of ten gram powder added with 25 ml methanol, shaken in a rotary evaporator (30 rpm) over night at room temperature.

Plate 6. HPTLC instrumentation setup

Plate 7. Raffinose (Standard) used for HPTLC assay

3.2.6.1.b. *Mobile Phase*

Mobile phase selected for detection of oligosaccharide (Raffinose) was a mixture of isopropanol, methanol and toluene in the ratio of 8: 2: 4 and ammonia (1 drop), sonicated for 10 minutes.

3.2.6.1.c. *Stock Solution of Oligosaccharide (Raffinose)*

Stock solution of Raffinose (1000 $\mu g\ ml^{-1}$) was prepared by mixing 10 mg Raffinose reference standard and five millilitre methanol by thoroughly shaking it in a volumetric flask (10 ml) and making up to the mark using methanol.

3.2.6.1.d. *Working Standard Solution of Oligosaccharide (Raffinose)*

Working standard solution (1 to 30 $\mu g\ ml^{-1}$) was prepared by obtaining the aliquots (0.01 – 0.30 ml) from the stock solution of Raffinose and each of its volume made up to 10 ml with methanol.

3.2.6.1. e. *Operating System Conditions*

In HPTLC analysis, the samples were spotted in the form of bands of width six millimetre and 14 millimeter apart with a Camag microlitre syringe (Hamilton, Bonaduz, Switzerland) on pre- coated silica gel aluminium plate 60 F254 having 20x 10 cm dimensions (E. Merck, Darmstadt, Germany supplied by Anchrom Technologists, Mumbai.) using a Camag Linomat IV sample applicator (Muttenz, Switzerland).

Linear ascending development was carried out in 20x10 cm twin trough glass chamber (Camag, Muttenz, Switzerland) saturated with the mobile phase. The optimized chamber saturation time for mobile phase was 20 minutes at room temperature. The length of chromatogram run was 80 mm. Densitometric scanning was performed on Camag TLC scanner III in the reflectance fluorescence mode at 254 nm as well as 366 nm and was operated by CATS software (V3. Camag).

Plate 8. Samples extracted for HPTLC analysis

3.2.7. Antinutrient levels of selected treated flours

From these two measures to reduce antinutrients in raw jackfruit bulb flour and seed flour, the best treatment was selected and its tannin content, phytates and trypsin inhibitors were assessed.

3.2.7.1. *Tannins*

Tannins present in jackfruit were extracted by centrifugation after addition of methanol. Tannins when reacted with vannilin hydrochloric acid to form a coloured complex of resourcinol and the absorbance was read at 500 nm. A graph was plotted against standard gallic acid and amount of tannic acid was calculated. The detailed procedure is explained in 3.1.2.4.b.5.

3.2.7.2. *Phytates*

Phytic acid is found in most cereals and legumes at concentrations of 1-3 per cent of dry matter. It is also found in some fruits and vegetables. Since, phytates complex with zinc, iron, magnesium and calcium ions in the digestive tract, they can cause mineral ion deficiency in animals and humans. Phytates present in jackfruit samples were extracted by centrifugation with the addition of three per cent trichloroacetic acid, ferric chloride and sodium hydroxide. The precipitate was washed and dissolved using 3.20 N nitric acid followed by addition of 1.50 M potassium thiocyanate and the absorbance read at 480 nm (Wheeler and Ferrel, 1971).

3.2.7.3. *Trypsin inhibitors*

Trypsin inhibitors present in the treated flour was estimated as described in 3.1.2.5.a.

3.2.8. Storage studies of treated flour

Shelf life studies can provide important information to manufacturers and consumers to ensure a high-quality product during the storage period. Assessment

of shelf life quality is important since it determines the suitability of a particular ingredient for the product development. The shelf life quality of the treated powder was assessed in terms of moisture, peroxide value and microbial count. The above mentioned indicators were analysed initially and repeatedly on a monthly basis up to six months to ascertain shelf stability.

3.2.8.1. *Moisture*

Moisture content was estimated by the method of AOAC (1990). Moisture content of the samples were determined by oven drying. This method consisted of measuring the weight lost by foods due to evaporation of water. The procedure for assessing moisture content is explained in 3.1.2.1.d.

3.2.8.2. *Peroxide value*

Rancidity is brought about by the action of air (oxidative rancidity) or by microorganisms (ketonic rancidity) in oil. In oxidative rancidity oxygen is taken up by the fat with the formation of peroxides. The degree of peroxide formation and the time taken for the development of rancidity differ among oils. Peroxide value is a measure of the peroxides contained in the oil. The peroxides present were determined by titration against 0.10 *N* thiosulphate in the presence of KI with starch as indicator (Sadasivam and Manikam, 1992).

3.2.8.3. *Microbial count*

For analysing the microbial count, spread plating technique was adopted. Nutrient agar (NA), Rose Bengal (RB) and Eosin Methylene Blue (EMB) agar (Appendix I) medium were used for microbial analysis. Ten gram of the food product was transferred to 90 ml sterile water taken in a 150 ml flask under aseptic conditions in laminar air floor chamber. A uniform suspension was prepared by shaking the flasks in a rotary shaker for five minutes. Serial dilutions of 10^{-3} and 10^{-7}, the suspension were prepared in the sterile diluents. One ml aliquot of 10^{-3} and 10^{-7} dilutions were withdrawn using a sterile pipette and added to 9 ml of sterile diluents taken in test tubes. One ml of each dilution was poured

into a sterile petri dishes containing media, using a sterile pipette. Then it was spread evenly in all the directions. The whole procedure was done aseptically in a laminar airflow chamber. Then the plates were kept for incubation at room temperature. After 24 hours, colonies that appeared in the plates were counted. The microbial load of the treated flour was expressed as cfu/g of the product.

3.3. DEVELOPMENT OF RAW JACKFRUIT BASED TEXTURED VEGETABLE PROTEIN (TVP)

The best treatment was identified based in the level of oligosaccharides and was taken up for product development. For the preparation of TVP, processed jackfruit bulbs and seeds flour were processed with gluten and soya flour to form chunks.

3.3.1. Selection and optimization of raw ingredients for TVP

Along with jackfruit bulb flour and seed flour, gluten, soya flour and tapioca starch were selected as the other ingredients for the development of TVP. Gluten is a wheat protein which is extracted manually from wheat flour. Once extracted the dried wheat gluten is an insoluble high protein powder, which regains its original characteristics after rehydration and mixing. It has unique functionalities and can serve in many applications in food and feed products.

3.3.1.1. *Processing of gluten*

Wheat flour was mixed with water to form a dough and kept overnight in a water. The starch and other constituents dissolved into the water, while gluten remained insoluble. After the starch and gluten were separated, the gluten was washed thoroughly and dried (Anderson *et al.*, 2006). Readymade processed gluten powder is also available from the market. The processing of gluten is depicted in Figure 2.

Figure 2. Flow chart on Processing of gluten

Milled wheat grains

Dough making

Immersing in cold water (over night)

Washing and separating gluten

Drying

Powdering

3.3.1.2. *Processing of tapioca/ starch*

Due to its high binding property, tapioca starch was used in the development of TVP. Tapica was purchased from local market. It was washed in tap water to remove mud and dirt. The cleaned tuber was then peeled and cut into small pieces with a sharp knife. The pieces were taken to mixer grinder for grinding. The ground paste was mixed with excess water and stirred well and strained through filter. This was allowed to settle to get tapioca starch. The excess water was drained out. The sediment was collected, dried in sun to get fine tapioca starch. This was used as a binding agent for development of TVP.

3.3.1.3. *Processing of other ingredients*

Soya chunks were heated moderately, powdered and sieved. This ingredient was used in a constant ratio in all treatments.

Yeast culture was prepared using *Saccharomyces cerevisiae* and used for fermentation for 8 hours.

3.3.2. Development of jackfruit based Textured Vegetable Product (TVP)

Jackfruit based TVP was formulated by using the ingredients - jackfruit bulb flour and seed flour along with gluten, yeast and soya flour (in constant proportion) to form chunks. Totally eleven combinations of TVP were worked out and from this the best treatment was identified through sensory evaluation and was selected for quality analysis. The various treatments proposed are depicted in Table 2.

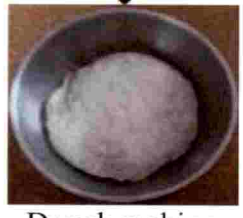
Cooking time, cooked weight and yield of the products were analysed. The selected treatment of TVP was packed in PP covers and stored at room temperature for further analysis. The processing steps involved in the development of TVP are detailed in Figure 3.

Figure 3. Flow chart for Development of TVP

Weighed ingredients based on combinations

Preparation of yeast culture

Addition of binding agent and yeast culture to the ingredients



Dough making

Shaping

Drying at 60^{0}c for 4-5 hours

Table 2. Treatments for the development of TVP

Sl.No.	Treatment	G	JFBF	JFSF
1	P_1	50	20	30
2	P_2	50	30	20
3	P_3	50	10	40
4	P_4	50	25	25
5	P_5	50	-	50
6	P_6	50	50	-
7	P_7	70	20	10
8	P_8	70	10	20
9	P_9	70	15	15
10	P_{10}	70	-	30
11	P_{11}	70	30	-

(G - Gluten, JFBF – Jackfruit bulb flour, JFSF- Jackfruit seed flour)

3.3.3 *Cooking characteristics*

Cooking leads to changes in physical and chemical properties of food. The chunks formed from the eleven treatments were subjected to cooking procedures to ascertain cooking time, cooked weight and sensory qualities. From these procedures the best treatment was identified.

3.3.3.1. *Appearance*

Appearance is the criteria for the desirability of any food product. The best treatment with respect to cooked appearance was identified by analyzing the scores of Overall visual quality (OVQ), using a 1-9 point scale where, 9 refers to excellent appearance, 7 to good, 5 to fair (limit of marketability), 3 to fair useable

Plate 9. TVP treatments

but not saleable and 1 to unusable, this evaluation was conducted by a panel comprising of 10 members (Yuan *et al.*, 2010).

3.3.3.2. *Cooking Time*

Cooking quality of TVP was analyzed according to Ojure and Quadrils method (2012). Ten grams of TVP was cooked in 300 ml of boiling water in a covered beaker. Doneness was determined by the removal of chunks every 2 minutes and pressing the chunks between 2 pieces of glass slides for testing chewiness. When the doneness was conformed, cooking was stopped by rinsing briefly in cold water.

3.3.3.4. *Cooked Weight*

Cooked weight of the chunks were analysed according to Omeire *et al.* (2015) method. They defined cooked weight as the weight gain of the chunks during the cooking, which indicates the amount of water that was absorbed and was therefore an index for the swelling ability of the chunks. Each treatment was cooked for optimum time and then the cooking weight was calculated and expressed in percentage.

3.3.4. *Sensory evaluation of TVP*

Sensory evaluation has an essential role in new product development with regard to its acceptability. The cooked TVP was presented to ten semi trained panelists. They evaluated the sensory characteristics viz; colour, appearance, flavour, texture, taste on a score card using a 9 point hedonic scale (Appendix II). The scores allotted were analyzed using statistical procedures to obtain a suitable conclusion.

3.3.5. *Quality analysis of TVP*

Quality is the ultimate criteria for the desirability of any food product. Quality assurance in food is an ordered set of planned and systematic analyses,

Plate 10. Visual quality of TVP treatments

necessary to provide adequate confidence regarding the processed products or services, satisfying the requirement of quality. The functional, nutritional and chemical composition alongwith shelf stability of the finalized product was ascertained using standard procedures.

3.3.5.1. *Functional quality analysis of TVP*

Functional properties describes how ingredients behave during preparation and cooking, how this in turn affects the finished food product in terms of how it looks, tastes and feels giving a total picture of quality. Functional qualities such as yield, texture, rehydration ratio and water absorption index were studied.

3.3.5.1.a. *Yield ratio of TVP*

Estimation of yield percent in food processing will be useful in determining cost of product. The yield per cent of the TVP was calculated on dry weight basis. To determine the yield per cent for TVP the following formula was used.

$$\text{Yield ratio} = \frac{\text{Weight of TVP obtained}}{\text{Weight of raw ingredients}} \times 100$$

3.3.5.1.b. *Texture*

It is generally accepted that texture is the main criterion for assessing overall quality of chunks. The texture of the TVP is a very important factor in shaping the consumers final evaluation of the product. Texture of the developed TVP was measured with respect to crispiness, hardness, toughness, firmness, work of penetration, rupture strength, work of cutting, cohesiveness, stringiness and crunchiness using a food texture analyzer.

The instrument had a microprocessor regulated texture analysis system interfaced to a personal computer. The instrument consisted of two separate modules; the test bed and the control console (keyboard). Both were linked by a

cable with low voltage signal. The texture analyzer measures force, distance and time hence provides a three dimensional product analysis.

The sample was kept on the platform of the instrument and was subjected to double compression by a cylindrical probe with 5 mm diameter. The test was conducted at a speed of 10 mm/s using 50 N load cell. The sample was subjected to a double compression of 40 per cent with trigger force of 0.5 kg during which various textural parameters were determined. From the force deformation curve, the firmness or hardness (peak force) and toughness (area under the curve) were determined.

3.3.5.1.c. *Rehydration Ratio*

About 10 g of the sample was mixed with 100 ml of distilled water and stirred for 5 minutes. The contents were filtered using a filter paper. The rehydrated sample was weighed (Ranganna, 1995).

$$\text{Rehydration Ratio} = \frac{\text{weight of sample}}{\text{Drained weight of sample}}$$

3.3.5.1.d. *Water Absorption Index (WAI)*

Water absorption index is the quantity of water absorbed by a known quantity of the food sample. Water absorption index was measured by the method of Beuchat (1997). A known volume of sample (1 g) and water (10 ml) were mixed in a centrifuged tube. The suspension was allowed to stand at room temperature. It was then centrifuged for 30 minutes. The volume of drained water and sediment was measured.

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

3.3.5.2. *Nutrient content and chemical composition of TVP*

Nutrient as well as chemical composition analysis refers to the process of determining the nutritional and chemical components in foods and food products.

The selected combination of TVP was analysed for nutrients as well as chemical components using standard procedures.

Table 3. Nutrient analytical procedures of TVP

Nutrient/ chemical composition	Method (References)
Energy (Kcal)	Gopalan *et al.* (1991)
Protein (g)	Sadasivam and Manickam (1992)
Carbohydrate (g)	Sadasivam and Manickam (1992)
Fat (g)	Sadasivam and Manikam (1992)
Moisture (g)	Sadasivam and Manickam (1992)
Fiber (g)	Sadasivam and Manickam (1992)
Total minerals (g)	Sadasivam and Manickam (1992)

3.3.4. Storage studies

Shelf life studies can provide important information to product developers enabling them to ensure that the consumers will see a high quality product for a significant period of time after production. Just as microorganisms can grow during storage, other changes too may occur in the composition of the food. This deterioration may make the food unacceptable to the consumer. Due to such cases the changes in the food during storage may make it unsafe, due to the nature of the compounds formed. To observe the keeping quality, the product was packed in PP covers and kept for shelf life analysis for three months.

3.3.4.1 *Moisture level of the TVP*

Moisture content is one of the most commonly measured properties of food materials. Stability and quality of a food product depends upon the moisture content present in it. There are legal limits to the minimum and maximum amount of water that must be present in certain types of foods. According to Codex Alimentarius Commision (2001), as a general rule, the moisture content is to be

less than 10 per cent, the lower the better. The procedure for assessing moisture content was explained in 3.1.2.1.d.

3.3.4.2 *Assessment of Microbial profile of the TVP*

Assessment of microbial profile is essential to ensure quality and safety of food product. The developed and stored TVP was analyzed for bacteria, fungi, yeast and actinomycetes growth using standard procedures. Nutrient agar (NA), Rose Bengal (RB) and Eosin Methylene Blue (EMB) were the media selected for culturing bacteria, fungi and coliforms respectively (Appendix I). Spread plating procedures were employed to estimate the population of viable micro organisms. After 24 hours colonies appearing in the plates were recorded. The microbial load of the TVP was expressed as cfu/g of the product. Assessment of microbial profiling was done as explained in 3.2.8.3.

3.3.5. Statistical Analysis

The data generated was analysed statistically using appropriate methods. Sufficient replications were maintained for analysis. The data generated from the samples were subjected to Completely Randomized Design (CRD) analysis. In organoleptic analysis, the different preferences as indicated by scores were evaluated by Kruskall- Wallis test to get the mean rank values for all the treatments.

Results

4. RESULTS

Results of the study entitled ''Profiling bioactive compounds and nutrients in jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein'' are presented under the following headings.

4.1. Nutrient content, chemical composition and the antioxidant activity of the selected types of jackfruit

4.2. Analysis of measures for reducing antinutrients in raw jackfruit

4.3. Development of raw jackfruit based textured vegetable protein

4.1. NUTRIENT CONTENT, CHEMICAL COMPOSITION AND THE ANTIOXIDANT ACTIVITY OF THE SELECTED TYPES OF JACKFRUIT

4.1.1. Selection and collection of jackfruit

For the purpose of nutrient and chemical profiling, four varikka types namely Muttom varikka, Then varikka, Sindoor and Chembikalom varikka and a Local cv Koozha types were selected. Analyses of both the ripe and raw stages of seeds and bulbs were analysed separately. Sindoor type was collected from RARS, Kottarakkara and Then varikka from Mithranikethan, Vellanad. All the other types were collected from Instructional farm attached to COA, Vellayani and also from the adjacent home yards.

4.1.2. Proximate Composition

Proximate and nutrient analysis of edible fruit and vegetables plays a crucial role in assessing their nutritional significance (Pandey *et al.*, 2006). In proximate analysis carbohydrate, protein, fat, fiber and moisture were analyzed. The results of proximate analysis showed variation in concentration/proportions of nutrients.

4.1.2.1. Total carbohydrate content

Table 4. Carbohydrate content of raw and ripe jackfruit types

Category	Carbohydrate (g/100g)
Jackfruit Types	
Muttom varikka	15.36
Then varikka	11.06
Sindoor	21.11
Chempikalom varikka	**34.69**
Local cv Koozha	21.24
SEm ±	0.065
CD	0.186
Stages	
Raw	18.76
Ripe	**22.63**
SEm ±	0.041
CD	0.117
Edible Portions	
Bulb	**21.00**
Seed	20.39
SEm ±	0.041
CD	0.117

Values are means of triplicates
SEm : standard error of the mean

Table 4 shows the carbohydrate levels in different types, stages of maturity and edible portions of jackfruit. The result showed that Chempikalom varikka had the highest carbohydrate content (34.69 g/100g) which was significantly different from others. The lowest carbohydrate content was seen in Then varikka (11.06 g/100g) followed by Muttom varikka (15.36 g/100g). While Sindoor recorded 21.11 g/100g which was on par with Local cv Koozha 21.24g.

In the case of stages of maturity, ripe jackfruit (22.63g/100g) contained significantly higher carbohydrate than raw stage of jackfruit (18.76g/100g), both these values were significantly different too. Carbohydrate content in edible portions showed that jackfruit bulbs had higher content (21.00g/100g) than jackfruit seed (20.39g/100g). The carbohydrate content of the various edible portions were also significantly different.

Table 5. Two way interaction effects of Types, Stages of maturity and Edible portions of jackfruit on their carbohydrate content

Parameters	Carbohydrate (g/100g)
Types X Stages	
T_1S_1	13.68
T_1S_2	17.05
T_2S_1	9.58
T_2S_2	12.53
T_3S_1	18.61
T_3S_2	23.61
T_4S_1	34.02
T_4S_2	**35.36**
T_5S_1	17.90
T_5S_2	24.58
SEm $\pm$	0.092
CD	0.262
Types X Edible portion	
T_1E_1	14.89
T_1E_2	15.84
T_2E_1	12.96
T_2E_2	9.15
T_3E_1	26.38
T_3E_2	15.84
T_4E_1	32.78
T_4E_2	**36.60**
T_5E_1	17.98
T_5E_2	24.50
SEm $\pm$	0.092
CD	0.262
Stages X Edible portion	
S_1E_1	19.64
S_1E_2	17.88
S_2E_1	22.36
S_2E_2	**22.90**
SEm $\pm$	0.058
CD	0.166

Values are means of triplicates

SEm : Standard error of the mean

Table 5 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion. In the first case (two way interaction of types and stages) the highest carbohydrate content was recorded for ripe stage of Chempikalom (35.36g) and the lowest carbohydrate content was reported in raw stage of Then varikka (9.58g). The carbohydrate content in raw stage of Chempikalom was 34.02g which was followed by Koozha ripe (24.58g), Ripe Sindoor contained 23.61g and raw Sindoor contained 18.61g. Next to this raw stage of Koozha recorded 17.90g which was on par with ripe stage of Muttom varikka (17.05g). The raw stage of Muttom varikka recorded 13.68 g and ripe stage of Then varikka recorded 12.53g.

In the case of interaction between types and edible portion, the highest value was recorded for Chempikalom seed (36.60g) and the lowest value was obtained for Then varikka seed (9.15g). The next highest carbohydrate content was recorded for the bulbs of Chempikalom varikka (32.78g) which was followed by bulbs of Sindoor (26.38g) and seeds of Local cv Koozha (24.50g). A decreasing order of carbohydrate content was seen in bulbs of Koozha (17.98g), seeds of Sindoor (15.84g), seeds of Muttom varikka (15.84g) and bulbs of Muttom varikka (14.89g) and bulbs of Then varikka (12.96g).

In the case of interaction between stages and edible portion, the highest carbohydrate content was recorded for ripe seeds (22.90g) followed by ripe bulbs (22.36g). The raw stages of bulb reported 19.64g carbohydrate and raw seeds contained 17.88g.The carbohydrate content in both raw and ripe stages of bulbs and seeds were significantly different too.

Table 6. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their carbohydrate content

Sl.No.	Types X Stages X Edible portion	Carbohydrate (g/100g)
T_1	$T_1S_1E_1$	14.64
T_2	$T_1S_1E_2$	12.71
T_3	$T_1S_2E_1$	15.14
T_4	$T_1S_2E_2$	18.97
T_5	$T_2S_1E_1$	12.12
T_6	$T_2S_1E_2$	7.05
T_7	$T_2S_2E_1$	13.81
T_8	$T_2S_2E_2$	11.25
T_9	$T_3S_1E_1$	21.85
T_{10}	$T_3S_1E_2$	15.37
T_{11}	$T_3S_2E_1$	30.91
T_{12}	$T_3S_2E_2$	16.32
T_{13}	$T_4S_1E_1$	32.14
T_{14}	$T_4S_1E_2$	35.90
T_{15}	$T_4S_2E_1$	33.42
T_{16}	$T_4S_2E_2$	**37.31**
T_{17}	$T_5S_1E_1$	17.45
T_{18}	$T_5S_1E_2$	18.35
T_{19}	$T_5S_2E_1$	18.52
T_{20}	$T_5S_2E_2$	30.64
SEm $\pm$		0.130
CD		0.371

Values are means of triplicates

SEm : standard error of the mean

Table 6. shows the three way interaction effects of types, stages and edible portion. Here the highest value was recorded for Chempikalom ripe seeds (37.31g/100g) which were followed by Chempikalom raw seeds (35.90g), Chempikalom ripe bulbs contained 33.42g and Chempikalom raw bulbs contained 32.14g carbohydrate. The lowest value was obtained for Then varikka raw seeds (7.05g/100g). In the case of Muttom varikkka the higher carbohydrate content was obtained for ripe seeds (18.97g), in the case of Then varikka, ripe bulbs contained 13.81g. In the case of Sindoor, ripe stages of bulbs contained 30.91g which was on par with ripe seeds of Koozha (30.64g).

4.1.2.2. Protein content

Table 7 shows the level of proteins in different types, stages of maturity and edible portion of jackfruit. The results show that Local cv Koozha had the highest protein content (5.09g/100g). The lowest protein content was seen in Muttom varikka (2.33g/100g) followed by Then varikka (3.71g/100g). Sindoor contained 4.15g/100g and Chempikalom varikka contained 4.22g. The protein content in these types were significantly different too. In the case of stages of maturity raw stages (3.98g/100g) contained higher protein than ripe stages (3.82g/100g), and the values were significantly different from each other. Protein content in the edible portions showed that seeds of jackfruit contained (4.74g/100g) had higher protein content than bulbs of jackfruit (3.06g/100g).

Table 7. Protein content in raw and ripe jackfruit types

Parameters	Protein (g/100g)
Effects of Jackfruit Types	
Muttom varikka	2.33
Then varikka	3.71
Sindoor	4.15
Chempikalom varikka	4.22
Local cv Koozha	**5.09**
SEm ±	0.007
CD	0.021
Effects of Stages	
Raw	**3.98**
Ripe	3.82
SEm ±	0.005
CD	0.013
Effects of Edible Portions	
Bulb	3.06
Seed	**4.74**
SEm ±	0.005
CD	0.013

Values are means of triplicates
SEm : standard error of the mean

Table 8 shows the interaction effect of types and stages of maturiy, types and edible portion and stages of maturity and edible portion (two way interaction). In the case of types and stages highest protein content was seen in raw stage of Local cv Koozha (5.13g/100g) followed by ripe stage of Local cv Koozha (5.06g/100g) and the lowest protein content was observed in ripe stage of Muttom varikka (2.17g/100g). The raw stage of Muttom varikka contained 2.50 g of protein. The protein content in raw stage of Chempikalom varikka was 4.52g while ripe stage of Chempikalom contained 3.93 g. This was followed by Sindoor ripe stage (4.29g) and Sindoor raw stage (4.01g). In the case of Then varikka the raw stage contained 3.78g and ripe stage contained 3.64g.

In the case of interaction between types and edible portion the highest value recorded for Koozha seed (5.87g) and the lowest value was obtained for Muttom varikka bulb (1.19g/100g). The next highest protein content was obtained for Chempikalom seed (5.27g) followed by seeds of Sindoor varikka (5.15g). The bulbs of Local cv Koozha contained 4.31g followed by seeds of Then varikka (3.91g). The protein content in bulbs of Then varikka was 3.50g which was on par with seeds of Muttom varikka (3.47g). The bulbs of Chempikalom contained 3.17g which was on par with bulbs of Sindoor (3.14g).

In the case of interaction between stages and edible portion, the highest protein content was obtained for raw jackfruit seeds (4.75g/100g) which was on par with ripe jackfruit seeds (4.72g). The raw stages of bulb contained 3.21g protein and ripe bulbs contained 2.91g. There was significant difference between both raw and ripe stages of jackfruits.

Table 8. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their protein content

Parameters	Protein (g/100g)
Types X Stages	
T_1S_1	2.50
T_1S_2	2.17
T_2S_1	3.78
T_2S_2	3.64
T_3S_1	4.01
T_3S_2	4.29
T_4S_1	4.52
T_4S_2	3.93
T_5S_1	**5.13**
T_5S_2	5.06
SEm $\pm$	0.010
CD	0.029
Types X Edible portion	
T_1E_1	1.19
T_1E_2	3.47
T_2E_1	3.50
T_2E_2	3.91
T_3E_1	3.14
T_3E_2	5.15
T_4E_1	3.17
T_4E_2	5.27
T_5E_1	4.31
T_5E_2	**5.87**
SEm $\pm$	0.010
CD	0.029
Stages X Edible portion	
S_1E_1	3.21
S_1E_2	**4.75**
S_2E_1	2.91
S_2E_2	4.72
SEm $\pm$	0.006
CD	0.019

Values are means of triplicates

SEm : standard error of the mean

Table 9. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their protein content

Sl.No.	Types X Stages X Edible portion	Protein (g/100g)
T_1	$T_1S_1E_1$	1.12
T_2	$T_1S_1E_2$	3.87
T_3	$T_1S_2E_1$	1.27
T_4	$T_1S_2E_2$	3.07
T_5	$T_2S_1E_1$	3.75
T_6	$T_2S_1E_2$	3.80
T_7	$T_2S_2E_1$	3.25
T_8	$T_2S_2E_2$	4.02
T_9	$T_3S_1E_1$	3.21
T_{10}	$T_3S_1E_2$	4.80
T_{11}	$T_3S_2E_1$	3.07
T_{12}	$T_3S_2E_2$	5.50
T_{13}	$T_4S_1E_1$	3.23
T_{14}	$T_4S_1E_2$	5.80
T_{15}	$T_4S_2E_1$	3.10
T_{16}	$T_4S_2E_2$	4.75
T_{17}	$T_5S_1E_1$	4.76
T_{18}	$T_5S_1E_2$	5.50
T_{19}	$T_5S_2E_1$	3.87
T_{20}	$T_5S_2E_2$	**6.25**
SEm $\pm$		0.015
CD		0.042

Values are means of triplicates

SEm : standard error of the mean

Table 9. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest protein content was obtained for Local cv Koozha ripe seeds (6.25g/100g) and the lowest value was obtained in Muttom varikka raw bulbs (1.12g/100g) followed by Muttom varikka ripe bulbs (1.27g/100g). The second highest protein content was obtained for Chempikalom raw seeds (5.80g/100g) followed by Sindoor ripe seeds (5.50g/100g) which were on par with Koozha raw seeds (5.50g/100g). The protein content obtained for Sindoor raw seeds was 4.80g which was on par with Koozha raw bulb (4.76g) and Chempikalom ripe seeds (4.75g).

4.1.2.3. Dietary fibre content

Table 10. Dietary fibre content in raw and ripe jackfruit types

Parameters	Dietary Fiber (g/100g)
Effects of Jackfruit Types	
Muttom varikka	1.34
Then varikka	1.30
Sindoor	1.35
Chempikalom varikka	1.53
Local cv Koozha	**1.82**
SEm ±	0.012
CD	0.034
Effects of Stages	
Raw	**1.50**
Ripe	1.44
SEm ±	0.008
CD	0.022
Effects of Edible Portions	
Bulb	**1.61**
Seed	1.33
SEm ±	0.008
CD	0.022

Values are means of triplicates

SEm : standard error of the mean

Table 10 reveals the dietary fibre content of different types, stages of maturity and edible portion of jackfruit. The result show that Local cv Koozha had the highest fibre content (1.82g/100g) followed by Chempikalom varikka (1.53g). The dietary fibre content of Sindoor was 1.35g which was on par with Muttom varikka (1.34g), which was again on par with Then varikka (1.30g/100g). In the case of stages of maturity, ripe stages had 1.44g and raw stage contained 1.50 g/100g, which were significantly different too. The dietary fibre content in the edible portions showed that jackfruit bulb (1.61g/100g) had higher content than jackfruit seed (1.33g/100g).

Table 11. Two way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their protein content

Parameters	Dietary Fibre (g/100g)
Types X Stages	
T_1S_1	1.27
T_1S_2	1.41
T_2S_1	1.41
T_2S_2	1.19
T_3S_1	1.55
T_3S_2	1.45
T_4S_1	1.37
T_4S_2	1.69
T_5S_1	**1.89**
T_5S_2	1.74
SEm ±	0.017
CD	0.049
Types X Edible portion	
T_1E_1	1.32
T_1E_2	1.37
T_2E_1	1.30
T_2E_2	1.29
T_3E_1	1.56
T_3E_2	1.14
T_4E_1	1.62
T_4E_2	1.44
T_5E_1	**2.24**
T_5E_2	1.40
SEm ±	0.017
CD	0.049
Stages X Edible portion	
S_1E_1	**1.64**
S_1E_2	1.36
S_2E_1	1.57
S_2E_2	1.30
SEm ±	0.011
CD	NS

Values are means of triplicates

SEm : standard error of the mean

Table 11 shows the interaction effects of types and stages, types and edible portion and stages and edible portion. With respect to types and stages, higher fibre content was observed in raw stages of Koozha (1.89g). The lowest fibre content was seen in ripe stages of Then varikka (1.19g).The fibre content in ripe stage of Local cv Koozha was 1.74g and ripe stage of Chempikalom varikka was 1.69g. The raw stage of Sindoor contained 1.55g and ripe stage contained 1.45g, which was on par with raw stage of Then varikka (1.41g) and ripe stage of Muttom varikka (1.41g).

In the case of interaction between Types and edible portion the highest value for fibre content was obtained for Koozha bulbs (2.24g) and the lowest value obtained for Sindoor seeds (1.14g). The second highest fibre content was obtained for bulbs of Chempikalom (1.62g) which was followed by Sindoor bulbs (1.56g). The seeds of Chempikalom contained 1.44g, followed by seeds of Koozha (1.40g) and which was on par with seeds of Muttom varikka (1.37g). In the case of Then varikka both bulbs (1.30g) and seeds (1.29g) were on par each other. In the case of interaction between stages and edible portion, the higher fibre content was obtained for raw bulbs (1.64g) followed by ripe bulbs (1.57g). The raw stages of seeds contained 1.36g while ripe seeds contained 1.30g. The dietary fibre content in both bulbs and seeds of ripe and raw stages were significantly different too.

Table 12. shows the interaction effect of types, stages and edible portion of jackfruit (Three way interaction). Here the highest value was obtained for Local cv Koozha raw bulbs (2.38g) which was followed by Koozha ripe bulbs (2.09g) and the lowest value was obtained for Sindoor ripe seeds (1.05g). The ripe stage of Chempikalom bulbs contained 1.93g which was on par with raw stage of Sindoor bulbs (1.88g).

Table 12. Three way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their dietary fibre content

Sl.No.	Types X Stages X Edible portion	Dietary Fibre (g/100g)
T_1	$T_1S_1E_1$	1.12
T_2	$T_1S_1E_2$	1.42
T_3	$T_1S_2E_1$	1.51
T_4	$T_1S_2E_2$	1.32
T_5	$T_2S_1E_1$	1.51
T_6	$T_2S_1E_2$	1.30
T_7	$T_2S_2E_1$	1.09
T_8	$T_2S_2E_2$	1.29
T_9	$T_3S_1E_1$	1.88
T_{10}	$T_3S_1E_2$	1.23
T_{11}	$T_3S_2E_1$	1.24
T_{12}	$T_3S_2E_2$	1.05
T_{13}	$T_4S_1E_1$	1.31
T_{14}	$T_4S_1E_2$	1.43
T_{15}	$T_4S_2E_1$	1.93
T_{16}	$T_4S_2E_2$	1.45
T_{17}	$T_5S_1E_1$	**2.38**
T_{18}	$T_5S_1E_2$	1.41
T_{19}	$T_5S_2E_1$	2.09
T_{20}	$T_5S_2E_2$	1.39
SEm $\pm$		0.024
CD		0.069

Values are means of triplicates

SEm : standard error of the mean

4.1.2.4. Moisture content

Table 13. Moisture content in raw and ripe jackfruit types

Parameters	Moisture (%)
Effects of Jackfruit Types	
Muttom varikka	64.86
Then varikka	68.44
Sindoor	64.00
Chempikalom varikka	**69.92**
Local cv Koozha	62.87
SEm ±	0.162
CD	0.462
Effects of Stages	
Raw	62.66
Ripe	**69.38**
SEm ±	0.102
CD	0.292
Effects of Edible Portions	
Bulb	**78.10**
Seed	53.94
SEm ±	0.102
CD	0.292

Values are means of triplicates
SEm : standard error of the mean

Table 13 shows the moisture content of different types, stages of maturity and edible portion of jackfruit. The results revealed that Chempikalom varikka had the highest moisture content (69.92%) followed by Then varikka (68.44%), Muttom varikka (64.86%), Sindoor (64.00%) and Local cv Koozha - 62.87%. There was significant difference between each type of jackfruit. In the case of stages of maturity, ripe stages of jackfruit (69.38%) had higher moisture content than raw stage of jackfruit (62.66%). There was significant difference between these two stages. Moisture content in edible portions showed that bulb of jackfruit (78.10%) had higher content than seed (53.94%).

Table 14. Two way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their moisture content

Parameters	Moisture (%)
Types X Stages	
T_1S_1	62.15
T_1S_2	67.56
T_2S_1	65.80
T_2S_2	71.07
T_3S_1	59.96
T_3S_2	68.03
T_4S_1	65.39
T_4S_2	**74.46**
T_5S_1	59.98
T_5S_2	65.76
SEm $\pm$	0.229
CD	0.654
Types X Edible portion	
T_1E_1	78.60
T_1E_2	51.11
T_2E_1	**80.26**
T_2E_2	56.61
T_3E_1	77.99
T_3E_2	50.00
T_4E_1	76.77
T_4E_2	63.08
T_5E_1	76.85
T_5E_2	48.89
SEm $\pm$	0.229
CD	0.654
Stages X Edible portion	
S_1E_1	73.03
S_1E_2	52.29
S_2E_1	**83.16**
S_2E_2	55.59
SEm $\pm$	0.145
CD	0.43

Values are means of triplicates

SEm : standard error of the mean

Table 14 shows the interaction effects of types and stages, types and edible portion and finally stages and edible portion (two way interaction). With respect to types and stages the highest moisture content was noticed in ripe stage of Chempikalom (74.46%) and the lowest moisture content was obtained by raw stage of Sindoor (59.96%). The second highest moisture content was observed in ripe stage of Then varikka (71.07%). The raw stage of Then varikka contained 65.80% moisture which was on par with ripe stages of Koozha (65.76%) and raw stage of Chempikalom (65.39%). The moisture content was also recorded for raw stage of Koozha (59.98%), raw stage of Muttom varikka (62.15%), raw stage of Then varikka (65.80%), ripe stage of Muttom varikka (67.56%) and ripe stage of Sindoor (68.03%).

In the case of interaction between types and edible portion the highest value was obtained by Then varikka bulbs (80.26%) and the lowest value obtained by Koozha seeds (48.89%). The second highest moisture content was noted in the bulbs of Muttom varikka (78.60%) which was on par with bulbs of Sindoor (77.99%). The bulbs of Chempikalom contained 76.77 per cent and their seeds contained 63.08 per cent of moisture content. In the case of interaction between stages and edible portion, the highest moisture content was observed in ripe bulbs (83.16%) followed by raw bulbs (73.03%). The raw stages of seeds contained 52.29 per cent and ripe seeds contained 55.59 per cent.

Table 15. recorded the three way interaction effects of types, stages and edible portion. Here the highest value was observed in Sindoor ripe bulbs (85.37%) followed by Then varikka ripe bulbs (85.01%). The second highest moisture content was observed in Chempikalom ripe bulbs (82.88%) which was followed by Muttom varikka ripe bulbs (81.42%) and Local cv Koozha ripe flakes (81.15%). The lowest value was observed in Local cv Koozha raw seeds (47.42%).

Table 15. Three way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their moisture content

Sl.No.	Types X Stages X Edible portion	Moisture (%)
T_1	$T_1S_1E_1$	75.79
T_2	$T_1S_1E_2$	48.52
T_3	$T_1S_2E_1$	81.42
T_4	$T_1S_2E_2$	53.71
T_5	$T_2S_1E_1$	75.52
T_6	$T_2S_1E_2$	56.09
T_7	$T_2S_2E_1$	85.01
T_8	$T_2S_2E_2$	57.13
T_9	$T_3S_1E_1$	70.62
T_{10}	$T_3S_1E_2$	49.30
T_{11}	$T_3S_2E_1$	**85.37**
T_{12}	$T_3S_2E_2$	50.70
T_{13}	$T_4S_1E_1$	70.66
T_{14}	$T_4S_1E_2$	60.12
T_{15}	$T_4S_2E_1$	82.88
T_{16}	$T_4S_2E_2$	66.04
T_{17}	$T_5S_1E_1$	72.55
T_{18}	$T_5S_1E_2$	47.42
T_{19}	$T_5S_2E_1$	81.15
T_{20}	$T_5S_2E_2$	50.37
SEm		0.323
CD		0.924

Values are means of triplicates

SEm : standard error of the mean

4.1.2.5. Beta carotene content

Table 16. Beta carotene content of raw and ripe jackfruit types

Category	β carotene (µg/100g)
Jackfruit Types	
Muttom varikka	40.70
Then varikka	166.78
Sindoor	**253.86**
Chempikalom varikka	57.49
Local cv Koozha	55.71
SEm ±	0.022
CD	0.063
Stages	
Raw	100.51
Ripe	**129.30**
SEm ±	0.014
CD	0.040
Edible Portions	
Bulb	**187.65**
Seed	42.16
SEm ±	0.014
CD	0.040

Values are means of triplicates

SEm : standard error of the mean

Table 16 shows the β carotene contents of different types, stages of maturity and edible portion of jackfruit. The results reveal that the beta carotene content was the highest in Sindoor (253.86 µg) which was followed by Then varikka (166.78 µg). The lowest content was observed in Muttom varikka (40.70 µg). The beta carotene content recorded for Chempikalom varikka was 57.49 µg and Local cv Koozha was 55.71 µg. In the case of stages of maturity the ripe stages of jackfruit contained 129.30 µg and raw stage contained 100.51 µg. The edible portions of the jackfruit bulb contained 187.65 µg and the jackfruit seeds contained 42.16 µg.

Table 17. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their β carotene content

Parameters	β carotene (µg/100g)
Types X Stages	
T_1S_1	36.90
T_1S_2	44.49
T_2S_1	139.42
T_2S_2	194.14
T_3S_1	218.91
T_3S_2	**288.81**
T_4S_1	54.62
T_4S_2	60.36
T_5S_1	52.70
T_5S_2	58.71
SEm ±	0.031
CD	0.089
Types X Edible portion	
T_1E_1	48.09
T_1E_2	33.30
T_2E_1	289.41
T_2E_2	44.15
T_3E_1	**446.21**
T_3E_2	61.50
T_4E_1	86.75
T_4E_2	28.22
T_5E_1	67.81
T_5E_2	43.60
SEm ±	0.031
CD	0.089
Stages X Edible portion	
S_1E_1	162.84
S_1E_2	38.18
S_2E_1	**212.47**
S_2E_2	46.14
SEm ±	0.020
CD	0.056

Values are means of triplicates

SEm : standard error of the mean

Table 17 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages of maturity, ripe stage of Sindoor contained higher levels of betacarotene (288.81µg) followed by raw stage of Sindoor (218.91 µg). The lowest content was observed in raw stage of Muttom varikka (36.90 µg). The betacarotene content was recorded for ripe stage of Muttom varikka (44.49 µg), raw stage of Then varikka (139.42 µg), ripe stage of Then varikka (194.14 µg), raw stage of Chempikalom (54.62 µg), ripe stage of Chempikalom (60.36 µg), raw stage of Koozha (52.70 µg) and ripe stage of Koozha (58.71 µg).

In the case of types and edible portion, higher value was obtained by the bulbs of Sindoor (446.21 µg) and lowest value was observed in seeds of Chempikalom (28.22 µg). The values recorded for other types and edible portions were as follows, for bulbs of Muttom varikka (48.09 µg), seeds of Muttom varikka (33.30 µg), bulbs of Then varikka (289.41 µg), seeds of Then varikka (44.15 µg), seeds of Sindoor (61.50 µg), bulbs of Koozha (67.81 µg) and seeds of Koozha (43.60 µg).

The values obtained with respect to stages of maturity and edible portion showed that ripe stages of jackfruit bulbs contained higher content (212.47 µg) and lower content was obtained for raw seeds of jackfruit (38.18 µg). The betacarotene content recorded for raw bulbs was 162.84 µg and ripe seeds was 46.14 µg.

Table 18. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their β carotene content

Sl.No.	Types X Stages X Edible portion	β carotene (µg/100g)
T_1	$T_1S_1E_1$	44.58
T_2	$T_1S_1E_2$	29.22
T_3	$T_1S_2E_1$	51.60
T_4	$T_1S_2E_2$	37.38
T_5	$T_2S_1E_1$	235.22
T_6	$T_2S_1E_2$	43.63
T_7	$T_2S_2E_1$	343.60
T_8	$T_2S_2E_2$	44.67
T_9	$T_3S_1E_1$	389.21
T_{10}	$T_3S_1E_2$	48.60
T_{11}	$T_3S_2E_1$	**503.21**
T_{12}	$T_3S_2E_2$	74.40
T_{13}	$T_4S_1E_1$	82.40
T_{14}	$T_4S_1E_2$	26.83
T_{15}	$T_4S_2E_1$	91.10
T_{16}	$T_4S_2E_2$	29.62
T_{17}	$T_5S_1E_1$	62.81
T_{18}	$T_5S_1E_2$	42.60
T_{19}	$T_5S_2E_1$	72.81
T_{20}	$T_5S_2E_2$	44.60
SEm ±		0.044
CD		0.126

Values are means of triplicates

SEm : standard error of the mean

Table 18. shows the interaction effects of types, stages and edible portion. Here the highest β carotene content was obtained for Sindoor ripe flakes (503.21 µg) which was followed by Sindoor raw flakes (389.21 µg). The lowest content was observed in Chempikalom raw seeds (26.83 µg).

4.1.2.6. Vitamin C content

Table 19. Vitamin C content of raw and ripe jackfruit types

Category	Vitamin C (mg/100g)
Jackfruit Types	
Muttom varikka	19.14
Then varikka	20.54
Sindoor	**21.30**
Chempikalom varikka	20.68
Local cv Koozha	20.84
SEm ±	0.071
CD	0.203
Stages	
Raw	19.91
Ripe	**21.09**
SEm ±	0.045
CD	0.128
Edible Portions	
Bulb	20.35
Seed	**20.65**
SEm ±	0.045
CD	0.128

Values are means of triplicates

SEm : standard error of the mean

Table 19 reveals the Vitamin C content in different types, stages of maturity and edible portion of jackfruits. The result showed that the Vitamin C content was the highest in Sindoor (21.30 mg) which was followed by Local cv koozha (20.84 mg) and Chempikalom varikka (20.68 mg). The lowest content was observed in Muttom varikka (19.14 mg). In the case of stages of maturity the ripe stage of jackfruit reported 21.09 mg of Vitamin C and raw stage reported 19.91 mg. The edible portions of jackfruit bulbs contained 20.35mg and the jackfruit seeds reported 20.65mg.

Table 20.Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their vitamin C content

Parameters	Vitamin C (mg/100g)
Types X Stages	
T_1S_1	17.35
T_1S_2	20.93
T_2S_1	20.22
T_2S_2	20.87
T_3S_1	21.27
T_3S_2	21.33
T_4S_1	20.80
T_4S_2	20.56
T_5S_1	19.93
T_5S_2	**21.74**
SEm ±	0.100
CD	0.287
Types X Edible portion	
T_1E_1	18.35
T_1E_2	19.93
T_2E_1	21.13
T_2E_2	19.96
T_3E_1	**21.57**
T_3E_2	21.03
T_4E_1	20.23
T_4E_2	21.13
T_5E_1	20.47
T_5E_2	21.20
SEm ±	0.100
CD	0.287
Stages X Edible portion	
S_1E_1	19.51
S_1E_2	20.31
S_2E_1	**21.19**
S_2E_2	20.98
SEm ±	0.063
CD	0.181

Values are means of triplicates

SEm : standard error of the mean

Table 20 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion on Vitamin C content. In the case of types and stages of maturity, ripe stages of Local cv Koozha recorded the highest levels (21.74mg) followed by ripe stage of Sindoor (21.33 mg) and raw stage of Sindoor (21.27mg). The lowest content was observed in raw Muttom varikka (17.35 mg). The Vitamin C content recorded for ripe stage of Muttom varikka (20.93 mg), raw stage of Then varikka (20.22 mg), ripe stage of Then varikka (20.87 mg), raw stage of Chempikalom (20.80 mg), ripe stage of Chempikalom (20.56 mg) and raw stage of Koozha (19.93 mg).

With respect to types and edible portion, the higher values for Vitamin C was recorded for bulbs of Sindoor (21.57 mg) and lower value was obtained for bulbs of Muttom varikka (18.35 mg). The seeds of Muttom varikka recorded 19.93 mg, bulbs of Then varikka (21.13 mg), seeds of Then varikka (19.9 mg), seeds of Sindoor (21.03 mg), bulbs of Chempikalom (20.23 mg), seeds of Chempikalom (21.13 mg), bulbs of Koozha (20.47 mg) and seeds of Koozha (21.20 mg).

The values obtained with respect to stages and edible portion, it was observed that ripe bulbs of jackfruit contained higher Vitamin C (21.19mg) and the lowest value was obtained in the case of raw bulbs (19.51 mg). The Vitamin C content recorded for raw seeds was 20.31 mg and ripe seeds was 20.98 mg.

Table 21. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their vitamin C content

Sl.No.	Types X Stages X Edible portion	Vitamin C (mg/100g)
T_1	$T_1S_1E_1$	15.36
T_2	$T_1S_1E_2$	19.33
T_3	$T_1S_2E_1$	21.33
T_4	$T_1S_2E_2$	20.53
T_5	$T_2S_1E_1$	21.05
T_6	$T_2S_1E_2$	19.38
T_7	$T_2S_2E_1$	21.20
T_8	$T_2S_2E_2$	20.54
T_9	$T_3S_1E_1$	**21.49**
T_{10}	$T_3S_1E_2$	21.04
T_{11}	$T_3S_2E_1$	**21.66**
T_{12}	$T_3S_2E_2$	21.01
T_{13}	$T_4S_1E_1$	20.31
T_{14}	$T_4S_1E_2$	21.29
T_{15}	$T_4S_2E_1$	20.14
T_{16}	$T_4S_2E_2$	20.98
T_{17}	$T_5S_1E_1$	19.33
T_{18}	$T_5S_1E_2$	20.53
T_{19}	$T_5S_2E_1$	**21.62**
T_{20}	$T_5S_2E_2$	**21.86**
SEm $\pm$		0.142
CD		0.406

Values are means of triplicates
SEm : standard error of the mean

Table 21. shows the interaction effects of types, stages and edible portion (Three way interaction effect) on vitamin C content. Here the highest content was obtained for Local cv koozha ripe seeds (21.86 mg) which was on par with Sindoor ripe flakes (21.66 mg), Koozha ripe flakes (21.62 mg) and Sindoor raw flakes (21.49 mg). The lowest content was observed in Muttom varikka (15.36 mg).

4.1.2.7. Total mineral content

Table 22. Total Minerals contents in raw and ripe jackfruit types

Parameters	Total minerals (g/100g)
Effects of Jackfruit Types	
Muttom varikka	0.80
Then varikka	0.85
Sindoor	0.87
Chempikalom varikka	0.89
Local cv Koozha	**0.91**
SEm ±	0.002
CD	0.006
Effects of Stages	
Raw	0.86
Ripe	**0.87**
SEm ±	0.001
CD	0.004
Effects of Edible Portions	
Bulb	0.85
Seed	**0.88**
SEm ±	0.001
CD	0.004

Values are means of triplicates
SEm : standard error of the mean

Table 22 displays the total mineral contents in different types, stages of maturity and edible portion of jackfruit. The results reveal that Local cv Koozha had the highest total mineral content (0.91 g) which was followed by Chempikalom varikka (0.89 g), Sindoor (0.87 g), Then varikka (0.85 g) and Muttom varikka (0.80 g). In the case of stages of maturity both the ripe (0.87 g) and raw (0.86 g) stages were on par with each other. The total mineral content in edible portions showed that the seeds contained higher content of minerals (0.88 g) than bulbs (0.85 g).

Table 23 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages the highest value was recorded for ripe stage of Koozha (0.92 g), which was on par with ripe stage of Chempikalom (0.90 g) and raw stage of Koozha (0.89 g). The lowest value was obtained for raw stage of Muttom varikka (0.80 g) and ripe stage of Muttom varikka (0.80 g) which were on par with each other. The total mineral content reported for the raw stage of Then varikka was 0.85 g, ripe stage of Then varikka (0.86 g), raw stage of Sindoor (0.86 g), ripe stage of Sindoor (0.88 g) and raw stage of Chempikalom (0.88 g).

In the case of interaction between types and edible portion, the highest values were recorded for the seeds of Chempikalom varikka (0.92 g) which were on par with seeds of Local cv Koozha (0.91 g) followed by Koozha bulbs (0.90 g) and Sindoor seeds (0.90 g). The lowest value was obtained for Muttom varikka bulbs (0.79 g). The total mineral content reported for seeds of Muttom varikka was 0.82 g, bulbs of then varikka - 0.85 g, seeds of Then varikka - 0.86 g, bulbs of Sindoor - 0.84 g and seeds of Sindoor - 0.90 g.

With respect to stages and edible portion, jackfruit ripe seeds had higher value (0.89 g) and the lower value was obtained for jackfruit raw bulbs (0.84 g). The values reported for raw seeds were 0.88 g and ripe bulbs were 0.86 g.

Table 24. reveals the interaction effects of types, stages and edible portion. Here the highest value for total mineral content was obtained for Koozha ripe seeds (0.93 g) and Chempikalom ripe seeds (0.93 g), which was on par with Koozha raw seeds (0.92 g) and Chempikalom raw seeds (0.91 g). The lowest value was obtained for Muttom varikka raw flakes (0.78 g).

Table 23. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their total mineral content

Parameters	Total minerals (g/100g)
Types X Stages	
T_1S_1	0.80
T_1S_2	0.80
T_2S_1	0.85
T_2S_2	0.86
T_3S_1	0.86
T_3S_2	0.88
T_4S_1	0.88
T_4S_2	0.90
T_5S_1	0.89
T_5S_2	**0.92**
SEm ±	0.003
CD	0.009
Types X Edible portion	
T_1E_1	0.79
T_1E_2	0.82
T_2E_1	0.85
T_2E_2	0.86
T_3E_1	0.84
T_3E_2	0.90
T_4E_1	0.87
T_4E_2	**0.92**
T_5E_1	0.90
T_5E_2	0.91
SEm ±	0.003
CD	0.009
Stages X Edible portion	
S_1E_1	0.84
S_1E_2	0.88
S_2E_1	0.86
S_2E_2	**0.89**
SEm ±	0.002
CD	0.006

Values are means of triplicates

SEm : standard error of the mean

Table 24. Three way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their total mineral content

Sl.No.	Types X Stages X Edible portion	Total minerals (g/100g)
T_1	$T_1S_1E_1$	0.78
T_2	$T_1S_1E_2$	0.83
T_3	$T_1S_2E_1$	0.79
T_4	$T_1S_2E_2$	0.81
T_5	$T_2S_1E_1$	0.84
T_6	$T_2S_1E_2$	0.85
T_7	$T_2S_2E_1$	0.86
T_8	$T_2S_2E_2$	0.87
T_9	$T_3S_1E_1$	0.83
T_{10}	$T_3S_1E_2$	0.89
T_{11}	$T_3S_2E_1$	0.85
T_{12}	$T_3S_2E_2$	0.90
T_{13}	$T_4S_1E_1$	0.86
T_{14}	$T_4S_1E_2$	0.91
T_{15}	$T_4S_2E_1$	0.88
T_{16}	$T_4S_2E_2$	**0.93**
T_{17}	$T_5S_1E_1$	0.89
T_{18}	$T_5S_1E_2$	0.90
T_{19}	$T_5S_2E_1$	0.92
T_{20}	$T_5S_2E_2$	**0.93**
SEm $\pm$		0.004
CD		0.012

Values are means of triplicates

SEm : standard error of the mean

4.1.2.8. Calcium content

Table 25. Calcium content of raw and ripe jackfruit types

Parameters	Calcium (mg/100g)
Effects of Jackfruit Types	
Muttom varikka	69.76
Then varikka	82.68
Sindoor	79.44
Chempikalom varikka	70.19
Local cv Koozha	**110.01**
SEm ±	0.221
CD	0.632
Effects of Stages	
Raw	77.07
Ripe	**87.76**
SEm ±	0.140
CD	0.400
Effects of Edible Portions	
Bulb	**87.85**
Seed	76.98
SEm ±	0.140
CD	0.400

Values are means of triplicates
SEm : standard error of the mean

Table 25 depicts the calcium content of different types, stages of maturity and edible portions of jackfruit. The results show that Local cv koozha had the highest calcium content (110.01mg/100g). The lowest calcium content was obtained for Muttom varikka (69.76 mg/100g). Then varikka contained 82.68 mg, Sindoor contained 79.44mg and Chempikalom had 70.19 mg. All the five types had significantly different values. In the case of stages of maturity ripe stages contained significantly higher calcium (87.76 mg) than raw stage (77.07 mg). Calcium content with respect to edible portions revealed that jackfruit bulbs (87.85 mg) had higher content than seed (76.98 mg).

Table 26. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their calcium content

Parameters	Calcium (mg/100g)
Types X Stages	
T_1S_1	70.02
T_1S_2	69.50
T_2S_1	85.21
T_2S_2	80.15
T_3S_1	89.17
T_3S_2	69.71
T_4S_1	60.90
T_4S_2	79.48
T_5S_1	80.05
T_5S_2	**139.96**
SEm ±	0.313
CD	0.894
Types X Edible portion	
T_1E_1	85.04
T_1E_2	54.49
T_2E_1	80.21
T_2E_2	85.15
T_3E_1	64.68
T_3E_2	94.19
T_4E_1	99.65
T_4E_2	40.72
T_5E_1	109.69
T_5E_2	**110.33**
SEm ±	0.313
CD	0.894
Stages X Edible portion	
S_1E_1	85.95
S_1E_2	68.19
S_2E_1	**89.76**
S_2E_2	85.76
SEm ±	0.198
CD	0.565

Values are means of triplicates

SEm : standard error of the mean

Table 26 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion (Two way interaction). In the first case, highest calcium content was obtained for ripe stage of Local cv Koozha and the lowest calcium content was obtained for raw stage of Chempikalom varikka. In the case of interaction between types and edible portions higher values were observed in Koozha seed (110.33 mg) and the lowest values were observed in Chempikalom seed (40.72 mg). In the case of interaction between stages and edible portion, the highest calcium content was obtained for ripe bulbs (89.76 mg) and lowest content was observed in raw seeds (68.19 mg) of jackfruit.

Table 27. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their calcium content

Sl.No.	Types X Stages X Edible portion	Calcium (mg/100g)
T_1	$T_1S_1E_1$	90.03
T_2	$T_1S_1E_2$	50.00
T_3	$T_1S_2E_1$	80.04
T_4	$T_1S_2E_2$	58.97
T_5	$T_2S_1E_1$	80.29
T_6	$T_2S_1E_2$	90.14
T_7	$T_2S_2E_1$	80.14
T_8	$T_2S_2E_2$	80.17
T_9	$T_3S_1E_1$	79.67
T_{10}	$T_3S_1E_2$	98.67
T_{11}	$T_3S_2E_1$	49.70
T_{12}	$T_3S_2E_2$	89.72
T_{13}	$T_4S_1E_1$	99.68
T_{14}	$T_4S_1E_2$	22.11
T_{15}	$T_4S_2E_1$	99.63
T_{16}	$T_4S_2E_2$	59.34
T_{17}	$T_5S_1E_1$	80.07
T_{18}	$T_5S_1E_2$	80.04
T_{19}	$T_5S_2E_1$	139.30
T_{20}	$T_5S_2E_2$	**140.62**
SEm $\pm$		0.442
CD		1.264

Values are means of triplicates

SEm : standard error of the mean

Table 27. shows the interaction effects of types, stages and edible portion of jackfruit on their calcium content. Here the highest value was obtained for Local cv koozha ripe seeds (140.62 mg) and the lowest value was obtained for Chempikalom varikka raw seeds (22.11 mg).

4.1.2.9. Phosphurus content

Table 28. Phosphorus content in raw and ripe jackfruit types

Category	Phosphorus (mg/100g)
Jackfruit Types	
Muttom varikka	44.63
Then varikka	40.91
Sindoor	34.31
Chempikalom varikka	**47.36**
Local cv Koozha	29.16
SEm ±	0.148
CD	0.424
Stages	
Raw	**42.83**
Ripe	35.72
SEm ±	0.094
CD	0.268
Edible Portions	
Bulb	36.27
Seed	**42.28**
SEm ±	0.094
CD	0.268

Values are means of triplicates

SEm : standard error of the mean

Table 28 reveals the Phosphorus content in different types, stages of maturity and edible portion of jackfruit. The result shows that, phosphorus content was higher in Chempikalom varikka (47.36 mg) which was followed by Muttom varikka (44.63 mg). The lowest content was observed in Local cv koozha (29.16 mg). In the case of stages of maturity the raw stage of jackfruit contained 42.83 mg and ripe stage contained 35.72 mg. The edible portion of the jackfruit bulb contained 36.27 mg and the jackfruit seeds contained 42.28 mg.

Table 29 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages of maturity, raw stage of Chempikalom contained higher levels of phosphorus (58.95 mg). The lowest content was observed in ripe stage of koozha (25.22).

In the case of types and edible portion (Table 29), the higher values were obtained for seeds of Muttom varikka (55.52 mg) and lowest values were obtained for flakes of Koozha (23.86 mg). The values obtained for stages of maturity and edible portion showed that higher content was present in raw seeds (47.49 mg) and the lower amounts were present in ripe flakes (34.37 mg).

Table 30. reveals the interaction effect of types, stages and edible portion. Here the highest content was obtained for Muttom varikka ripe seeds (65 mg) and the lowest content was observed in Koozha ripe flakes (20.38 mg).

Table 29. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their phosphorus content

Parameters	Phosphorus (mg/100g)
Types X Stages	
T_1S_1	39.24
T_1S_2	50.02
T_2S_1	46.27
T_2S_2	35.54
T_3S_1	36.57
T_3S_2	32.06
T_4S_1	**58.95**
T_4S_2	35.76
T_5S_1	33.09
T_5S_2	25.22
SEm $\pm$	0.210
CD	0.600
Types X Edible portion	
T_1E_1	33.74
T_1E_2	**55.52**
T_2E_1	44.51
T_2E_2	37.31
T_3E_1	26.09
T_3E_2	42.54
T_4E_1	53.14
T_4E_2	41.58
T_5E_1	23.86
T_5E_2	34.46
SEm $\pm$	0.210
CD	0.600
Stages X Edible portion	
S_1E_1	38.17
S_1E_2	**47.49**
S_2E_1	34.37
S_2E_2	37.08
SEm $\pm$	0.133
CD	0.379

Values are means of triplicates

SEm : standard error of the mean

Table 30. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their phosphorus content

Sl.No.	Types X Stages X Edible portion	Phosphorus (mg/100g)
T_1	$T_1S_1E_1$	32.44
T_2	$T_1S_1E_2$	46.05
T_3	$T_1S_2E_1$	35.04
T_4	$T_1S_2E_2$	**65.00**
T_5	$T_2S_1E_1$	47.71
T_6	$T_2S_1E_2$	44.84
T_7	$T_2S_2E_1$	41.31
T_8	$T_2S_2E_2$	29.77
T_9	$T_3S_1E_1$	23.78
T_{10}	$T_3S_1E_2$	49.36
T_{11}	$T_3S_2E_1$	28.41
T_{12}	$T_3S_2E_2$	35.71
T_{13}	$T_4S_1E_1$	59.57
T_{14}	$T_4S_1E_2$	58.33
T_{15}	$T_4S_2E_1$	46.70
T_{16}	$T_4S_2E_2$	24.83
T_{17}	$T_5S_1E_1$	27.34
T_{18}	$T_5S_1E_2$	38.84
T_{19}	$T_5S_2E_1$	20.38
T_{20}	$T_5S_2E_2$	30.07
SEm ±		0.297
CD		0.848

Values are means of triplicates

SEm : standard error of the mean

4.1.2.10. Sodium content

Table 31. Sodium content in raw and ripe jackfruit types

Category	Sodium (mg/100g)
Jackfruit Types	
Muttom varikka	**8.18**
Then varikka	6.17
Sindoor	6.28
Chempikalom varikka	7.48
Local cv Koozha	**7.83**
SEm ±	0.186
CD	0.531
Stages	
Raw	**7.73**
Ripe	6.63
SEm ±	0.117
CD	0.336
Edible Portions	
Bulb	**7.63**
Seed	6.74
SEm ±	0.117
CD	0.336

Values are means of triplicates

SEm : standard error of the mean

Table 31 shows the sodium content in different types, stages of maturity and edible portion of jackfruit. The result shows that the sodium content was higher in Muttom varikka (8.18 mg) which was on par with Local cv koozha (7.83 mg). The lowest content was observed in Then varikka (6.17 mg). In the case of stages of maturity, raw stages of jackfruit contained 7.73 mg and ripe stage contained 6.63 mg. The edible portions of the jackfruit bulb contained 7.63 mg and the jackfruit seeds contained 6.74 mg.

Table 32. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their sodium content

Parameters	Sodium (mg/100g)
Types X Stages	
T_1S_1	8.35
T_1S_2	8.00
T_2S_1	4.80
T_2S_2	7.53
T_3S_1	5.00
T_3S_2	7.55
T_4S_1	**9.95**
T_4S_2	5.01
T_5S_1	**10.57**
T_5S_2	5.08
SEm $\pm$	0.263
CD	0.751
Types X Edible portion	
T_1E_1	8.03
T_1E_2	8.32
T_2E_1	7.50
T_2E_2	4.83
T_3E_1	5.03
T_3E_2	7.52
T_4E_1	7.47
T_4E_2	7.49
T_5E_1	**10.11**
T_5E_2	5.54
SEm $\pm$	0.263
CD	0.751
Stages X Edible portion	
S_1E_1	**9.12**
S_1E_2	6.34
S_2E_1	6.13
S_2E_2	7.14
SEm $\pm$	0.166
CD	0.475

Values are means of triplicates

SEm : standard error of the mean

Table 32 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages of maturity, raw stage of Local cv Koozha contained higher levels of sodium (10.57 mg) which was on par with raw stage of Chempikalom (9.95 mg). Lowest content was observed in raw stages of Then varikka (4.80 mg). The values reported in raw stage of Muttom varikka (8.35 mg), ripe stage of Muttom varikka (8.00 mg), ripe stage of Then varikka (7.53 mg), raw stage of Sindoor (5.00 mg), ripe stage of Sindoor (7.55 mg) and ripe stage of Chempikalom (5.01 mg).

In the case of types and edible portion, the higher values were recorded for bulbs of Local cv Koozha (10.11 mg) and lowest value was obtained for flakes of Sindoor (5.03 mg). The values recorded for bulbs of Muttom varikka (8.03 mg), seeds of Muttom varikka (8.32 mg), bulbs of Then varikka (7.50 mg), seeds of Then varikka (4.83 mg), seeds of Sindoor (7.52 mg), bulbs of Chempikalom (7.47 mg), seeds of Chempikalom (7.49 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in raw flakes (9.12 mg) and the lowest values were obtained for ripe flakes (6.13 mg).

Table 33 shows the interaction effects of types, stages and edible portion (Three way interaction effect). Here the highest content was obtained for Local cv koozha raw flakes (15.06 mg) and the lowest content was observed in Then varikka raw seeds (4.71 mg). The next highest value was reported in raw bulbs of Muttom varikka (10.70 mg) followed by ripe seeds of Muttom varikka (10.64 mg), ripe bulbs of Then varikka (10.11 mg) and ripe seeds of Sindoor (10.07 mg).

Table 33. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their sodium level

Sl.No.	Types X Stages X Edible portion	Sodium (mg/100g)
T_1	$T_1S_1E_1$	10.70
T_2	$T_1S_1E_2$	6.00
T_3	$T_1S_2E_1$	5.36
T_4	$T_1S_2E_2$	10.64
T_5	$T_2S_1E_1$	4.90
T_6	$T_2S_1E_2$	4.71
T_7	$T_2S_2E_1$	10.11
T_8	$T_2S_2E_2$	4.94
T_9	$T_3S_1E_1$	5.03
T_{10}	$T_3S_1E_2$	4.96
T_{11}	$T_3S_2E_1$	5.04
T_{12}	$T_3S_2E_2$	10.07
T_{13}	$T_4S_1E_1$	9.93
T_{14}	$T_4S_1E_2$	9.96
T_{15}	$T_4S_2E_1$	5.01
T_{16}	$T_4S_2E_2$	5.02
T_{17}	$T_5S_1E_1$	**15.06**
T_{18}	$T_5S_1E_2$	6.08
T_{19}	$T_5S_2E_1$	5.15
T_{20}	$T_5S_2E_2$	5.00
SEm $\pm$		0.371
CD		1.062

Values are means of triplicates

SEm : standard error of the mean

4.1.2.11. Potassium content

Table 34. Potassium content in raw and ripe jackfruit types

Category	Potassium (mg/100g)
Jackfruit Types	
Muttom varikka	374.08
Then varikka	390.00
Sindoor	388.33
Chempikalom varikka	**416.67**
Local cv Koozha	362.50
SEm ±	3.85
CD	11.02
Stages	
Raw	373.30
Ripe	**399.33**
SEm ±	2.44
CD	6.97
Edible Portions	
Bulb	353.30
Seed	**419.33**
SEm ±	2.44
CD	6.97

Values are means of triplicates

SEm : standard error of the mean

Table 34 depicts the Potassium content in different types, stages of maturity and edible portion of jackfruit. The result shows that potassium content was highest in Chempikalom varikka (416.67 mg) and the lowest content was observed in Local cv koozha (362.50 mg). In the case of stages of maturity the raw stage of jackfruit contained 373.30 mg and ripe stage contained 399.33 mg. The edible portions of the jackfruit bulb contained 353.30 mg and the jackfruit seeds contained 419.33 mg.

Table 35. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their potassium content

Parameters	Potassium (mg/100g)
Types X Stages	
T_1S_1	348.17
T_1S_2	400.00
T_2S_1	381.67
T_2S_2	398.33
T_3S_1	393.33
T_3S_2	383.33
T_4S_1	**421.67**
T_4S_2	**411.67**
T_5S_1	321.67
T_5S_2	403.33
SEm $\pm$	5.45
CD	15.59
Types X Edible portion	
T_1E_1	304.83
T_1E_2	**443.33**
T_2E_1	400.00
T_2E_2	380.00
T_3E_1	340.00
T_3E_2	**436.67**
T_4E_1	385.00
T_4E_2	**448.33**
T_5E_1	336.67
T_5E_2	388.33
SEm $\pm$	5.45
CD	15.59
Stages X Edible portion	
S_1E_1	335.27
S_1E_2	411.33
S_2E_1	371.33
S_2E_2	**427.33**
SEm $\pm$	3.45
CD	9.86

Values are means of triplicates

SEm : standard error of the mean

Table 35 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages of maturity, raw stage of Chempikalom contained higher level of potassium (421.67 mg) which was on par with ripe stage of Chempikalom (411.67 mg). The lowest content was observed in raw stage of Koozha (321.67 mg).

With respect to types and edible portion, the higher values were obtained for seeds of Chempikalom varikka (448.33 mg) which was on par with flakes of Muttom varikka (443.33 mg) and seeds of Sindoor (436.67 mg) and lower values were obtained for flakes of Muttom varikka (304.83 mg). The values recorded for bulbs of Then varikka (400.00 mg), seeds of Then varikka (380.00 mg), bulbs of Sindoor (340.00 mg), bulbs of Chempikalom (385.00 mg), bulbs of Koozha (336.67 mg) and seeds of Koozha (388.33 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in ripe seeds (427.33 mg) and the lower values were obtained for raw flakes (335.27 mg). The values reported in raw seeds (411.33 mg) and ripe bulbs (371.33 mg).

Table 36. reveals the interaction effects of types, stages and edible portion. Here the highest content was obtained for Muttom varikka ripe seeds (500.00 mg) which was on par with Chempikalom raw seeds (486.67 mg) and the lowest content was observed in Koozha raw flakes (286.67 mg).

Table 36. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their potassium content

Sl.No.	Types X Stages X Edible portion	Potassium (mg/100g)
T_1	$T_1S_1E_1$	309.67
T_2	$T_1S_1E_2$	386.67
T_3	$T_1S_2E_1$	300.00
T_4	$T_1S_2E_2$	**500.00**
T_5	$T_2S_1E_1$	406.67
T_6	$T_2S_1E_2$	356.67
T_7	$T_2S_2E_1$	393.33
T_8	$T_2S_2E_2$	403.33
T_9	$T_3S_1E_1$	316.67
T_{10}	$T_3S_1E_2$	470.00
T_{11}	$T_3S_2E_1$	363.33
T_{12}	$T_3S_2E_2$	403.33
T_{13}	$T_4S_1E_1$	356.67
T_{14}	$T_4S_1E_2$	**486.67**
T_{15}	$T_4S_2E_1$	413.33
T_{16}	$T_4S_2E_2$	410.00
T_{17}	$T_5S_1E_1$	286.67
T_{18}	$T_5S_1E_2$	356.67
T_{19}	$T_5S_2E_1$	386.67
T_{20}	$T_5S_2E_2$	420.00
SEm $\pm$		7.71
CD		22.04

Values are means of triplicates

SEm : standard error of the mean

4.1.2.12. Iron content

Table 37. Iron content in raw and ripe jackfruit types

Category	Iron (mg/100g)
Jackfruit Types	
Muttom varikka	0.97
Then varikka	**1.55**
Sindoor	**1.49**
Chempikalom varikka	1.37
Local cv Koozha	1.00
SEm ±	0.040
CD	0.115
Stages	
Raw	**1.34**
Ripe	1.21
SEm ±	0.025
CD	0.073
Edible Portions	
Bulb	1.11
Seed	**1.44**
SEm ±	0.025
CD	0.073

Values are means of triplicates

SEm : standard error of the mean

Table 37 shows the iron content in different types, stages of maturity and edible portion of jackfruit. The result shows that the iron content was higher in Then varikka (1.55 mg) which was on par with Sindoor (1.49 mg). The lowest content was observed in Muttom varikka (0.97 mg). In the case of stages of maturity the raw stage of jackfruit contained 1.34 mg and ripe stage contained 1.21 mg. Considering the edible portions of the jackfruit bulbs contained 1.1 mg and the jackfruit seeds contained 1.44 mg.

Table 38. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their iron content

Parameters	Iron (mg/100g)
Types X Stages	
T_1S_1	0.99
T_1S_2	0.95
T_2S_1	**1.58**
T_2S_2	**1.51**
T_3S_1	1.38
T_3S_2	**1.59**
T_4S_1	**1.56**
T_4S_2	1.18
T_5S_1	1.20
T_5S_2	0.81
SEm $\pm$	0.057
CD	0.163
Types X Edible portion	
T_1E_1	0.70
T_1E_2	1.23
T_2E_1	1.45
T_2E_2	**1.65**
T_3E_1	**1.50**
T_3E_2	1.47
T_4E_1	1.15
T_4E_2	**1.60**
T_5E_1	0.78
T_5E_2	1.23
SEm $\pm$	0.057
CD	0.163
Stages X Edible portion	
S_1E_1	1.11
S_1E_2	**1.57**
S_2E_1	1.12
S_2E_2	1.30
SEm $\pm$	0.036
CD	0.103

Values are means of triplicates

SEm : standard error of the mean

Table 38 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages of maturity, ripe stage of Sindoor reported the highest levels of iron (1.59 mg) which was on par with raw stage of Then varikka (1.58 mg), ripe stage of Then varikka (1.51 mg) and raw stage of Chempikalom (1.56 mg). The lowest content was observed in the ripe stages of koozha (0.81mg). The iron content was also recorded in raw stages of Muttom varikka (0.99 mg), ripe stages of Muttom varikka (0.95 mg), raw stages of Sindoor (1.38 mg), ripe stages of Chempikalom (1.18 mg), raw stages of Koozha (1.20 mg) and ripe stages of Koozha (0.81 mg).

In the case of types and edible portion, the higher values were obtained for seeds of Then varikka (1.65 mg) which were on par with seeds of Chempikalom (1.60 mg) and flakes of Sindoor (1.50 mg) and lowest values were obtained for flakes of Muttom varikka (0.70 mg). The iron content was also recorded in seeds of Muttom varikka (1.23 mg), bulbs of Then varikka (1.45 mg), seeds of Sindoor (1.47 mg), bulbs of Chempikalom (1.15 mg), bulbs of Koozha (0.78 mg) and seeds of Koozha (1.23 mg).

The values obtained for stages of maturity and edible portions revealed that higher content was observed in raw seeds (1.57 mg) and the lower value was obtained for raw flakes (1.11 mg). The ripe bulbs recorded 1.12 mg and ripe seeds recorded 1.30 mg.

Table 39. shows the interaction effects of types, stages and edible portion. Here the highest content was obtained for raw seeds of Chempikalom (1.87 mg) which was on par with ripe flakes of Sindoor (1.79 mg), ripe (1.64) and raw (1.65 mg) seeds of Then varikka. The lowest content was observed in Koozha ripe flakes (0.62 mg).

Table 39. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their iron content

Sl.No.	Types X Stages X Edible portion	Iron (mg/100g)
T_1	$T_1S_1E_1$	0.65
T_2	$T_1S_1E_2$	1.33
T_3	$T_1S_2E_1$	0.75
T_4	$T_1S_2E_2$	1.14
T_5	$T_2S_1E_1$	1.50
T_6	$T_2S_1E_2$	**1.65**
T_7	$T_2S_2E_1$	1.39
T_8	$T_2S_2E_2$	**1.64**
T_9	$T_3S_1E_1$	1.21
T_{10}	$T_3S_1E_2$	1.55
T_{11}	$T_3S_2E_1$	**1.79**
T_{12}	$T_3S_2E_2$	1.40
T_{13}	$T_4S_1E_1$	1.26
T_{14}	$T_4S_1E_2$	**1.87**
T_{15}	$T_4S_2E_1$	1.03
T_{16}	$T_4S_2E_2$	1.33
T_{17}	$T_5S_1E_1$	0.94
T_{18}	$T_5S_1E_2$	1.47
T_{19}	$T_5S_2E_1$	0.62
T_{20}	$T_5S_2E_2$	1.00
SEm $\pm$		0.080
CD		0.230

Values are means of triplicates

SEm : standard error of the mean

4.1.2.13. Magnesium content

Table 40. Magnesium content in raw and ripe jackfruit types

Category	Magnesium (mg/100g)
Jackfruit Types	
Muttom varikka	56.73
Then varikka	100.04
Sindoor	79.05
Chempikalom varikka	**107.80**
Local cv Koozha	85.75
SEm ±	1.09
CD	3.11
Stages	
Raw	84.74
Ripe	**87.01**
SEm ±	0.69
CD	1.97
Edible Portions	
Bulb	82.87
Seed	**88.88**
SEm ±	0.69
CD	1.97

Values are means of triplicates

SEm : standard error of the mean

Table 40 shows the magnesium content in different types, stages of maturity and edible portion of jackfruit. The result showed that the magnesium content was higher in Chempikalom varikka (107.80 mg) which was followed by Then varikka (100.04 mg). The lowest content was observed in Muttom varikka (56.73 mg). Considering the stages of maturity the raw stage of jackfruit contained 84.74 mg and ripe stage contained 87.01 mg. The edible portions of the jackfruit bulb contained 82.87 mg and the jackfruit seeds contained 88.88 mg.

Table 41. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their magnesium content

Parameters	Magnesium (mg/100g)
Types X Stages	
T_1S_1	62.99
T_1S_2	50.47
T_2S_1	86.18
T_2S_2	**113.89**
T_3S_1	78.05
T_3S_2	80.05
T_4S_1	109.29
T_4S_2	106.30
T_5S_1	87.19
T_5S_2	84.31
SEm $\pm$	1.54
CD	4.40
Types X Edible portion	
T_1E_1	59.36
T_1E_2	54.11
T_2E_1	98.53
T_2E_2	101.54
T_3E_1	57.07
T_3E_2	101.04
T_4E_1	102.90
T_4E_2	**112.69**
T_5E_1	96.47
T_5E_2	75.02
SEm $\pm$	1.54
CD	4.40
Stages X Edible portion	
S_1E_1	75.52
S_1E_2	**93.96**
S_2E_1	90.21
S_2E_2	83.80
SEm $\pm$	0.97
CD	2.78

Values are means of triplicates

SEm : standard error of the mean

Table 41 shows the interaction effects of types and stages of maturity, types and edible portion and finally stages of maturity and edible portion. In the case of types and stages of maturity, the ripe stage of Then varikka contained higher level of Magnesium (113.89 mg). The lowest content was observed in ripe stage of Muttom varikka (50.47 mg). The next highest magnesium content was recorded in raw (109.29 mg) and ripe stages (106.30 mg) of Chempikalom varikka followed by raw stages of Koozha (87.19 mg), raw stages of Then varikka (86.18 mg), ripe stages of Koozha (84.31 mg) and ripe stages of Sindoor (80.05 mg).

In the case of types and edible portion, the higher values were obtained for seeds of Chempikalom varikka (112.69 mg) and lowest values were obtained for bulbs of Sindoor (57.07 mg). The next highest values were found in bulbs of Chempikalom (102.90 mg) followed by seeds of Then varikka (101.54 mg), seeds of Sindoor (101.04 mg), bulbs of Then varikka (98.53 mg), bulbs of Koozha (96.47 mg) and seeds of Koozha (75.02 mg).

The values obtained for interaction effect of maturity and edible portion showed that the higher content was obtained in raw seeds (93.96 mg) and the lower values were obtained for raw bulbs (75.52 mg). The magnesium content recorded in ripe bulbs was 90.21 mg and ripe seeds was 83.80 mg.

Table 42. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Chempikalom raw seeds (140.78 mg) and the lowest content was observed in Muttom varikka ripe flakes (46.70 mg).

Table 42. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their magnesium content

Sl.No.	Types X Stages X Edible portion	Magnesium (mg/100g)
T_1	$T_1S_1E_1$	72.02
T_2	$T_1S_1E_2$	53.96
T_3	$T_1S_2E_1$	46.70
T_4	$T_1S_2E_2$	54.25
T_5	$T_2S_1E_1$	71.30
T_6	$T_2S_1E_2$	101.05
T_7	$T_2S_2E_1$	125.77
T_8	$T_2S_2E_2$	102.02
T_9	$T_3S_1E_1$	54.15
T_{10}	$T_3S_1E_2$	101.96
T_{11}	$T_3S_2E_1$	59.99
T_{12}	$T_3S_2E_2$	100.11
T_{13}	$T_4S_1E_1$	77.81
T_{14}	$T_4S_1E_2$	**140.78**
T_{15}	$T_4S_2E_1$	128.00
T_{16}	$T_4S_2E_2$	84.61
T_{17}	$T_5S_1E_1$	102.33
T_{18}	$T_5S_1E_2$	72.04
T_{19}	$T_5S_2E_1$	90.61
T_{20}	$T_5S_2E_2$	78.01
SEm $\pm$		2.18
CD		6.22

Values are means of triplicates

SEm : standard error of the mean

4.1.2.14. Manganese content

Table 43. Manganese content in raw and ripe jackfruit types

Category	Manganese (mg/100g)
Jackfruit Types	
Muttom varikka	0.91
Then varikka	1.06
Sindoor	0.86
Chempikalom varikka	**1.21**
Local cv Koozha	0.87
SEm ±	0.028
CD	0.079
Stages	
Raw	0.94
Ripe	**1.02**
SEm ±	0.018
CD	0.050
Edible Portions	
Bulb	**1.01**
Seed	0.95
SEm ±	0.018
CD	0.050

Values are means of triplicates
SEm : standard error of the mean

Table 43 displays the manganese content in different types, stages of maturity and edible portion of jackfruit. The result shows that the manganese content was higher in Chempikalom varikka (1.21mg) which was followed by Then varikka (1.06 mg). The lowest content was observed in Sindoor (0.86 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.94 mg and ripe stage contained 1.02 mg. With respect to edible portions of the jackfruit bulbs contained 1.01 mg and the jackfruit seeds contained 0.95 mg.

Table 44. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their manganese content

Parameters	Manganese (mg/100g)
Types X Stages	
T_1S_1	0.82
T_1S_2	1.00
T_2S_1	0.80
T_2S_2	1.31
T_3S_1	0.82
T_3S_2	0.91
T_4S_1	**1.51**
T_4S_2	0.91
T_5S_1	0.76
T_5S_2	0.98
SEm $\pm$	0.039
CD	0.112
Types X Edible portion	
T_1E_1	0.83
T_1E_2	1.00
T_2E_1	1.10
T_2E_2	1.01
T_3E_1	0.76
T_3E_2	0.96
T_4E_1	**1.39**
T_4E_2	1.03
T_5E_1	0.99
T_5E_2	0.75
SEm $\pm$	0.039
CD	0.112
Stages X Edible portion	
S_1E_1	0.88
S_1E_2	1.00
S_2E_1	**1.15**
S_2E_2	0.90
SEm $\pm$	0.025
CD	0.071

Values are means of triplicates

SEm : standard error of the mean

Table 44 shows the interaction effects of types and stages of maturity, types and edible portion followed by stages of maturity and edible portion. In the case of types and stages of maturity, raw stage of Chempikalom contained higher levels of manganese (1.51 mg). The lowest content was observed in raw stage of Koozha (0.76 mg). The manganese content in decreasing order as follows, ripe Then varikka (1.31 mg), ripe Muttom varikka (1.00 mg), ripe Koozha (0.98 mg), ripe Chempikalom (0.91 mg), ripe Sindoor (0.91 mg), raw Muttom varikka (0.82 mg) and raw Then varikka (0.80 mg).

In the case of types and edible portion, the higher values were obtained for bulbs of Chempikalom varikka (1.39 mg) and lowest values were obtained for seeds of Koozha (0.75 mg). The next highest value was reported in bulbs of Then varikka (1.10 mg) followed by seeds of Chempikalom (1.03 mg), seeds of Then varikka (1.01 mg), seeds of Muttom varikka (1.00 mg), bulbs of Koozha (0.99 mg), seeds of Sindoor (0.96 mg), bulbs of Muttom varikka (0.83 mg) and bulbs of Sindoor (0.76 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in ripe bulbs (1.15 mg) and the lowest values were obtained for raw bulbs (0.88 mg). The manganese content was also recorded in raw seeds of jackfruit (1.00 mg) and ripe seeds (0.90 mg).

Table 45 shows the interaction effects of types, stages and edible portion. Here the highest content was obtained for Chempikalom varikka raw bulbs (1.61 mg) and Then varikka ripe flakes (1.59 mg). The lowest content was observed in Then varikka raw flakes (0.61 mg).

Table 45. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their manganese content

Sl.No.	Types X Stages X Edible portion	Manganese (mg/100g)
T_1	$T_1S_1E_1$	0.68
T_2	$T_1S_1E_2$	0.96
T_3	$T_1S_2E_1$	0.97
T_4	$T_1S_2E_2$	1.03
T_5	$T_2S_1E_1$	0.61
T_6	$T_2S_1E_2$	0.99
T_7	$T_2S_2E_1$	**1.59**
T_8	$T_2S_2E_2$	1.04
T_9	$T_3S_1E_1$	0.65
T_{10}	$T_3S_1E_2$	0.99
T_{11}	$T_3S_2E_1$	0.87
T_{12}	$T_3S_2E_2$	0.94
T_{13}	$T_4S_1E_1$	**1.61**
T_{14}	$T_4S_1E_2$	1.41
T_{15}	$T_4S_2E_1$	1.17
T_{16}	$T_4S_2E_2$	0.66
T_{17}	$T_5S_1E_1$	0.85
T_{18}	$T_5S_1E_2$	0.67
T_{19}	$T_5S_2E_1$	1.13
T_{20}	$T_5S_2E_2$	0.82
SEm $\pm$		0.056
CD		0.159

Values are means of triplicates

SEm : standard error of the mean

4.1.2.15. Copper content

Table 46. Copper content in raw and ripe jackfruit types

Category	Copper (mg/100g)
Jackfruit Types	
Muttom varikka	0.12
Then varikka	**0.36**
Sindoor	**0.33**
Chempikalom varikka	0.16
Local cv Koozha	0.13
SEm ±	0.013
CD	0.038
Stages	
Raw	**0.21**
Ripe	**0.23**
SEm ±	0.008
CD	NS
Edible Portions	
Bulb	**0.22**
Seed	**0.22**
SEm ±	0.008
CD	NS

Values are means of triplicates
SEm : standard error of the mean

Table 46 shows the copper content in different types, stages of maturity and edible portion of jackfruit. The result shows that the copper content was higher in Then varikka (0.36 mg) which was on par with Sindoor (0.33 mg). The lowest content was observed in Muttom varikka (0.12 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.21 mg and ripe stage contained 0.23 mg and there was no significant difference. The edible portions of the jackfruit bulbs and the jackfruit seeds contained 0.22 mg.

Table 47 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion. In the case of types and stages of maturity, ripe stage of Then varikka contained higher levels of copper (0.40 mg). The lowest content was observed in ripe stage of Chempikalom (0.09 mg). The copper content was also recorded in ripe stages of Sindoor (0.38 mg), Then varikka (0.32 mg), raw stages of Sindoor (0.28 mg) and raw stages of Chempikalom (0.23 mg).

In the case of types and edible portion, the higher values were observed in seeds of Then varikka (0.37 mg), which was on par with bulbs of Then varikka (0.34 mg), seeds of Sindoor (0.33 mg) and bulbs of Sindoor (0.32 mg). The lowest values were obtained for seeds of Koozha (0.08 mg). The copper content was also recorded in bulbs of Chempikalom (0.14 mg), seeds of Chempikalom (0.17 mg), bulbs of Koozha (0.19 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in ripe bulbs (0.25 mg), which was on par with raw seeds (0.23 mg) and ripe seeds (0.21mg) of jackfruit.

Table 48 shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Then varikka ripe seeds (0.44 mg) and Sindoor ripe seeds (0.44 mg). The lowest content was observed in Koozha ripe seeds (0.06 mg).

Table 47. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their copper content

Parameters	Copper (mg/100g)
Types X Stages	
T_1S_1	0.12
T_1S_2	0.13
T_2S_1	0.32
T_2S_2	**0.40**
T_3S_1	0.28
T_3S_2	0.38
T_4S_1	0.23
T_4S_2	0.09
T_5S_1	0.11
T_5S_2	0.15
SEm $\pm$	0.019
CD	0.053
Types X Edible portion	
T_1E_1	0.10
T_1E_2	0.15
T_2E_1	0.34
T_2E_2	**0.37**
T_3E_1	0.32
T_3E_2	0.33
T_4E_1	0.14
T_4E_2	0.17
T_5E_1	0.19
T_5E_2	0.08
SEm $\pm$	0.019
CD	0.053
Stages X Edible portion	
S_1E_1	0.19
S_1E_2	0.23
S_2E_1	**0.25**
S_2E_2	0.21
SEm $\pm$	0.012
CD	0.034

Values are means of triplicates

SEm : standard error of the mean

Table 48. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their copper content

Sl.No.	Types X Stages X Edible portion	Copper (mg/100g)
T_1	$T_1S_1E_1$	0.08
T_2	$T_1S_1E_2$	0.15
T_3	$T_1S_2E_1$	0.11
T_4	$T_1S_2E_2$	0.14
T_5	$T_2S_1E_1$	0.33
T_6	$T_2S_1E_2$	0.31
T_7	$T_2S_2E_1$	0.35
T_8	$T_2S_2E_2$	**0.44**
T_9	$T_3S_1E_1$	0.21
T_{10}	$T_3S_1E_2$	0.35
T_{11}	$T_3S_2E_1$	**0.44**
T_{12}	$T_3S_2E_2$	0.32
T_{13}	$T_4S_1E_1$	0.21
T_{14}	$T_4S_1E_2$	0.25
T_{15}	$T_4S_2E_1$	0.08
T_{16}	$T_4S_2E_2$	0.09
T_{17}	$T_5S_1E_1$	0.13
T_{18}	$T_5S_1E_2$	0.11
T_{19}	$T_5S_2E_1$	0.25
T_{20}	$T_5S_2E_2$	0.06
SEm $\pm$		0.026
CD		0.075

Values are means of triplicates

SEm : standard error of the mean

4.1.2.16. Zinc content

Table 49. Zinc content in raw and ripe jackfruit types

Category	Zinc (mg/100g)
Jackfruit Types	
Muttom varikka	**0.80**
Then varikka	0.23
Sindoor	0.34
Chempikalom varikka	0.69
Local cv Koozha	0.44
SEm ±	0.004
CD	0.011
Stages	
Raw	**0.52**
Ripe	0.48
SEm ±	0.002
CD	0.007
Edible Portions	
Bulb	**0.51**
Seed	0.49
SEm ±	0.002
CD	0.007

Values are means of triplicates

SEm : standard error of the mean

Table 49 shows the zinc content in different types, stages of maturity and edible portion of jackfruit. The result shows that zinc content was higher in Muttom varikka (0.80 mg). The lowest content was observed in Then varikka (0.23 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.52 mg and ripe stage contained 0.48 mg. The edible portions of the jackfruit bulb contained 0.51 mg and the jackfruit seeds contained 0.49 mg.

Table 50. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their zinc content

Parameters	Zinc (mg/100g)
Types X Stages	
T_1S_1	0.80
T_1S_2	0.81
T_2S_1	0.25
T_2S_2	0.21
T_3S_1	0.34
T_3S_2	0.35
T_4S_1	0.54
T_4S_2	**0.84**
T_5S_1	0.69
T_5S_2	0.20
SEm ±	0.005
CD	0.015
Types X Edible portion	
T_1E_1	**0.84**
T_1E_2	0.76
T_2E_1	0.25
T_2E_2	0.21
T_3E_1	0.45
T_3E_2	0.24
T_4E_1	0.62
T_4E_2	0.76
T_5E_1	0.41
T_5E_2	0.48
SEm ±	0.005
CD	0.015
Stages X Edible portion	
S_1E_1	0.50
S_1E_2	**0.54**
S_2E_1	**0.53**
S_2E_2	0.43
SEm ±	0.003
CD	0.010

Values are means of triplicates

SEm : standard error of the mean

Table 50 shows the interaction effects of types and stages of maturity, types and edible portion followed by stages of maturity and edible portion. In the case of types and stages of maturity, ripe stage of Chempikalom recorded the highest levels of Zinc (0.84 mg). The lowest content was observed in ripe stage of koozha (0.20 mm).

In the case of types and edible portion, the higher values were obtained for bulbs of Muttom varikka (0.84 mg) and lower values were obtained for flakes of Then varikka (0.21 mg). The next highest zinc content was reported in seeds of Muttom varikka (0.76 mg) and seeds of Chempikalom varikka (0.76 mg) followed by bulbs of Chempikalom varikka (0.62 mg).

The values obtained or interaction of stages of maturity and edible portion showed that the higher content was obtained in raw seeds (0.54 mg), which was on par with ripe bulbs (0.53 mg) of jackfruit. The lowest values were obtained for ripe flakes (0.43 mg).

Table 51 shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Chempikalom ripe flakes (0.92 mg) and the lowest content was observed in Koozha ripe flakes and Then varikka ripe seeds (0.16 mg).

4.1.2.17. Selenium content

Selenium content was not detected in raw and ripe stages of both bulbs and seeds in the five types of jackfruits studied.

Table 51. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their zinc content

Sl.No.	Types X Stages X Edible portion	Zinc (mg/100g)
T_1	$T_1S_1E_1$	0.84
T_2	$T_1S_1E_2$	0.75
T_3	$T_1S_2E_1$	0.84
T_4	$T_1S_2E_2$	0.77
T_5	$T_2S_1E_1$	0.25
T_6	$T_2S_1E_2$	0.25
T_7	$T_2S_2E_1$	0.25
T_8	$T_2S_2E_2$	0.16
T_9	$T_3S_1E_1$	0.42
T_{10}	$T_3S_1E_2$	0.25
T_{11}	$T_3S_2E_1$	0.49
T_{12}	$T_3S_2E_2$	0.22
T_{13}	$T_4S_1E_1$	0.32
T_{14}	$T_4S_1E_2$	0.76
T_{15}	$T_4S_2E_1$	**0.92**
T_{16}	$T_4S_2E_2$	0.75
T_{17}	$T_5S_1E_1$	0.66
T_{18}	$T_5S_1E_2$	0.70
T_{19}	$T_5S_2E_1$	0.16
T_{20}	$T_5S_2E_2$	0.25
S.Em $\pm$		0.008
CD		0.022

Values are means of triplicates

SEm : standard error of the mean

4.1.3. Qualitative and Quantitative Screening of Bioactive compounds

The result of the qualitative analysis of bioactive compounds present in the jackfruit bulbs and seeds is presented in Table 52. The results revealed the presence of the bioactive compounds such as alkaloids, flavonoids, saponins, tannins and polyphenols. After the confirmation of presence of these bioactive compounds by preliminary qualitative tests, the fresh jackfruit samples were taken for quantitative estimation.

Table 52. Bioactive compound screening of jackfruit types

Treatments	Bioactive compounds				
	Alkaloids	Flavanoids	Saponins	Tannins	Polyphenols
$T_1S_1E_1$	++	++	++	++	++
$T_1S_1E_2$	++	++	++	++	++
$T_1S_2E_1$	++	++	++	++	++
$T_1S_2E_2$	++	++	++	++	++
$T_2S_1E_1$	++	++	++	++	++
$T_2S_1E_2$	++	++	++	++	++
$T_2S_2E_1$	++	++	++	++	++
$T_2S_2E_2$	++	++	++	++	++
$T_3S_1E_1$	++	++	++	++	++
$T_3S_1E_2$	++	++	++	++	++
$T_3S_2E_1$	++	++	++	++	++
$T_3S_2E_2$	++	++	++	++	++
$T_4S_1E_1$	++	++	++	++	++
$T_4S_1E_2$	++	++	++	++	++
$T_4S_2E_1$	++	++	++	++	++
$T_4S_2E_2$	++	++	++	++	++
$T_5S_1E_1$	++	++	++	++	++
$T_5S_1E_2$	++	++	++	++	++
$T_5S_2E_1$	++	++	++	++	++
$T_5S_2E_2$	++	++	++	++	++
$T_1S_1E_1$	++	++	++	++	++

++ Presence of Bioactive compounds

--Absence of Bioactive compounds

4.1.3.1. Alkaloid content

Table 53. Alkaloids content of raw and ripe jackfruit types

Category	Alkaloids (mg/100g)
Jackfruit Types	
Muttom varikka	**52.52**
Then varikka	7.68
Sindoor	25.61
Chempikalom varikka	41.90
Local cv Koozha	25.95
SEm ±	0.092
CD	0.264
Stages	
Raw	**33.89**
Ripe	27.57
SEm ±	0.058
CD	0.167
Edible Portions	
Bulb	29.59
Seed	**31.87**
SEm ±	0.058
CD	0.167

Values are means of triplicates

SEm : standard error of the mean

Table 53 depicts the level of Alkaloids in different types, stages of maturity and edible portion of jackfruit. The results show that the alkaloid content was higher in Muttom varikka (52.52 mg). The lowest content was observed in Then varikka (7.68 mg). In the case of stages of maturity the raw stages of jackfruit contained 33.89 mg and ripe stage contained 27.57 mg. The edible portions of the jackfruit bulb contained 29.59 mg and the jackfruit seeds contained 31.87 mg.

Table 54. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their alkaloid content

Parameters	Alkaloids (mg/100g)
Types X Stages	
T_1S_1	55.28
T_1S_2	49.77
T_2S_1	5.65
T_2S_2	9.72
T_3S_1	28.60
T_3S_2	22.62
T_4S_1	39.62
T_4S_2	44.19
T_5S_1	40.31
T_5S_2	11.59
SEm $\pm$	0.131
CD	0.374
Types X Edible portion	
T_1E_1	46.88
T_1E_2	58.17
T_2E_1	4.70
T_2E_2	10.66
T_3E_1	32.55
T_3E_2	18.67
T_4E_1	36.98
T_4E_2	46.82
T_5E_1	26.85
T_5E_2	25.05
SEm $\pm$	0.131
CD	0.374
Stages X Edible portion	
S_1E_1	36.15
S_1E_2	31.63
S_2E_1	23.03
S_2E_2	32.11
SEm $\pm$	0.083
CD	0.236

Values are means of triplicates

SEm : standard error of the mean

Table 54 shows the interaction effects of types and stages of maturity, types and edible portion and also stages of maturity and edible portion (Two way interaction). In the case of types and stages of maturity, raw stage of Muttom varikka contained higher level of alkaloid (55.28 mg). The lowest content was observed in raw stage of Then varikka (5.65 mg). The next highest value was reported in ripe stages of Muttom varikka (49.77 mg) followed by ripe stages of Chempikalom varikka (44.19 mg) and raw stages of Koozha (40.31 mg).

In the case of types and edible portion, the higher values were obtained for seeds of Muttom varikka (58.17 mg) and lowest values were obtained for flakes of Then varikka (4.70 mg). The alkaloid content in bulbs of Muttom varikka (46.88 mg), seeds of Chempikalom varikka (46.82 mg), bulbs of Chempikalom (36.98 mg), bulbs of Sindoor (32.55 mg), bulbs of Koozha (26.85 mg) and seeds of Koozha (25.05 mg) were also determined.

The values obtained for stages of maturity and edible portion showed that higher content was obtained in raw seeds (36.15 mg) and the lowest values were obtained for ripe flakes (23.03 mg). The values recorded in raw seeds (31.63 mg) and ripe seeds (32.11 mg).

Table 55. shows the interaction effects of types, stages and edible portion. Here the highest content was obtained for Muttom varikka ripe seeds (65.67 mg) and the lowest content was observed in Then varikka ripe flakes (2.20 mg).

Table 55. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their alkaloid content

Sl.No.	Types X Stages X Edible portion	Alkaloids (mg/100g)
T_1	$T_1S_1E_1$	59.90
T_2	$T_1S_1E_2$	50.67
T_3	$T_1S_2E_1$	33.87
T_4	$T_1S_2E_2$	65.67
T_5	$T_2S_1E_1$	7.21
T_6	$T_2S_1E_2$	4.09
T_7	$T_2S_2E_1$	2.20
T_8	$T_2S_2E_2$	17.23
T_9	$T_3S_1E_1$	35.07
T_{10}	$T_3S_1E_2$	22.13
T_{11}	$T_3S_2E_1$	30.03
T_{12}	$T_3S_2E_2$	15.20
T_{13}	$T_4S_1E_1$	39.00
T_{14}	$T_4S_1E_2$	40.23
T_{15}	$T_4S_2E_1$	34.97
T_{16}	$T_4S_2E_2$	53.40
T_{17}	$T_5S_1E_1$	39.60
T_{18}	$T_5S_1E_2$	41.02
T_{19}	$T_5S_2E_1$	14.10
T_{20}	$T_5S_2E_2$	9.07
SEm $\pm$		0.185
CD		0.528

Values are means of triplicates

SEm : standard error of the mean

4.1.4.2. Flavanoid content

Table 56. Flavanoid content in raw and ripe jackfruit types

Category	Flavanoids (mg/100g)
Jackfruit Types	
Muttom varikka	101.99
Then varikka	168.16
Sindoor	159.13
Chempikalom varikka	**304.26**
Local cv Koozha	255.24
SEm ±	0.132
CD	0.376
Stages	
Raw	182.93
Ripe	**212.58**
SEm ±	0.083
CD	0.238
Edible Portions	
Bulb	136.07
Seed	**259.44**
SEm ±	0.083
CD	0.238

Values are means of triplicates
SEm : standard error of the mean

Table 56 shows the level of flavanoids in different types, stages of maturity and edible portion of jackfruit. The results showed that the flavanoid content was higher in Chempikalom varikka (304.26 mg), the lowest content was observed in Muttom varikka (101.99 mg). In the case of stages of maturity the raw stage of jackfruit contained 182.93 mg and ripe stage contained 212.58 mg. The edible portions of the jackfruit bulbs contained 136.07 mg and the jackfruit seeds contained 259.44 mg.

Table 57. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their flavanoid content

Parameters	Flavanoids (mg/100g)
Types X Stages	
T_1S_1	104.23
T_1S_2	99.75
T_2S_1	145.97
T_2S_2	190.35
T_3S_1	151.48
T_3S_2	166.78
T_4S_1	**396.35**
T_4S_2	212.17
T_5S_1	116.62
T_5S_2	393.85
SEm $\pm$	0.186
CD	0.532
Types X Edible portion	
T_1E_1	73.98
T_1E_2	130.00
T_2E_1	179.82
T_2E_2	156.50
T_3E_1	116.40
T_3E_2	201.87
T_4E_1	86.10
T_4E_2	**522.42**
T_5E_1	224.05
T_5E_2	286.42
SEm $\pm$	0.186
CD	0.532
Stages X Edible portion	
S_1E_1	105.40
S_1E_2	**260.47**
S_2E_1	166.75
S_2E_2	258.41
SEm $\pm$	0.118
CD	0.336

Values are means of triplicates

SEm : standard error of the mean

Table 57 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion (Two way interaction). In the case of types and stages of maturity, raw stage of Chempikalom contained higher levels of flavanoids (396.35 mg), the lowest content was observed in ripe stage of Muttom varikka (99.75 mg). The next highest flavanoid content was recorded in ripe stages of Koozha (393.85 mg) followed by ripe stages of Chempikalom varikka (212.17 mg), ripe stages of Sindoor (166.78 mg).

In the case of types and edible portion, the highest values were reported in seeds of Chempikalom varikka (522.42 mg) and lowest values were obtained for bulbs of Muttom varikka (73.98 mg). The flavanoid content reported in seeds of Koozha (286.42 mg), bulbs of Koozha (224.05 mg), seeds of Sindoor (201.87 mg), bulbs of Then varikka (179.82 mg) and seeds of Then varikka (156.50 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in raw seeds (260.47 mg) and the lower values were obtained for raw flakes (105.40 mg). The flavanoid content reported in ripe stages of seeds (258.41 mg) and ripe bulbs (166.75 mg).

Table 58. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Chempikalom varikka raw seeds (687.67 mg) and the lowest content was observed in Chempikalom ripe flakes (67.17 mg).

Table 58. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their flavanoid content

Sl.No.	Types X Stages X Edible portion	Flavanoids (mg/100g)
T_1	$T_1S_1E_1$	77.14
T_2	$T_1S_1E_2$	131.33
T_3	$T_1S_2E_1$	70.83
T_4	$T_1S_2E_2$	128.67
T_5	$T_2S_1E_1$	123.60
T_6	$T_2S_1E_2$	168.33
T_7	$T_2S_2E_1$	236.03
T_8	$T_2S_2E_2$	144.67
T_9	$T_3S_1E_1$	105.13
T_{10}	$T_3S_1E_2$	197.83
T_{11}	$T_3S_2E_1$	127.67
T_{12}	$T_3S_2E_2$	205.90
T_{13}	$T_4S_1E_1$	105.03
T_{14}	$T_4S_1E_2$	**687.67**
T_{15}	$T_4S_2E_1$	67.17
T_{16}	$T_4S_2E_2$	357.17
T_{17}	$T_5S_1E_1$	116.08
T_{18}	$T_5S_1E_2$	117.17
T_{19}	$T_5S_2E_1$	332.03
T_{20}	$T_5S_2E_2$	455.67
SEm $\pm$		0.263
CD		0.752

Values are means of triplicates

SEm : standard error of the mean

4.1.4.3. Lycopene content

Table 59. Lycopene content of raw and ripe jackfruit types

Category	Lycopene (mg/100g)
Jackfruit Types	
Muttom varikka	**2.14**
Then varikka	0.77
Sindoor	1.68
Chempikalom varikka	1.85
Local cv Koozha	**2.10**
SEm ±	0.018
CD	0.051
Stages	
Raw	**1.69**
Ripe	**1.72**
SEm ±	0.011
CD	NS
Edible Portions	
Bulb	**1.77**
Seed	1.65
SEm ±	0.011
CD	0.032

Values are means of triplicates
SEm : standard error of the mean

Table 59 shows the level of lycopene in different types, stages of maturity and edible portion of jackfruit. The results show that the lycopene content was higher in Muttom varikka (2.14 mg) which was on par with Koozha (2.10 mg). The lowest content was observed in Then varikka (0.77 mg). In the case of stages of maturity the values were found to be on par. The edible portions of the jackfruit bulb contained 1.77 mg and the jackfruit seeds contained 1.65 mg.

Table 60. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their lycopene content

Parameters	Lycopene (mg/100g)
Types X Stages	
T_1S_1	2.05
T_1S_2	**2.22**
T_2S_1	0.81
T_2S_2	0.74
T_3S_1	1.79
T_3S_2	1.57
T_4S_1	1.63
T_4S_2	2.06
T_5S_1	**2.19**
T_5S_2	2.01
SEm $\pm$	0.025
CD	0.073
Types X Edible portion	
T_1E_1	**2.23**
T_1E_2	2.04
T_2E_1	0.55
T_2E_2	1.00
T_3E_1	**2.20**
T_3E_2	1.16
T_4E_1	1.72
T_4E_2	1.98
T_5E_1	**2.15**
T_5E_2	2.05
SEm $\pm$	0.025
CD	0.073
Stages X Edible portion	
S_1E_1	**1.78**
S_1E_2	1.61
S_2E_1	**1.76**
S_2E_2	1.68
SEm $\pm$	0.016
CD	0.046

Values are means of triplicates

SEm : standard error of the mean

Table 60 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion. In the case of types and stages of maturity, ripe stage of Muttom varikka (2.22 mg) contained higher level of lycopene which was on par with raw stage of koozha (2.19 mg). The lowest content was observed in ripe stage of Then varikka (0.74mg). the next highest content was reported in ripe stages of Chempikalom (2.06 mg) followed by raw stage of Muttom varikka (2.05 mg) and ripe stage of Koozha (2.01 mg).

In the case of types and edible portion, the higher values were obtained for bulbs of Muttom varikka (2.23 mg), which was on par with Sindoor flakes (2.20 mg) and Koozha bulbs (2.15 mg). Lower values were obtained for flakes of Then varikka (0.55 mg). The values reported in seeds of Muttom varikka (2.04 mg), seeds of Koozha (2.05 mg), seeds of Chempikalom (1.98 mg) and bulbs of Chempikalom (1.72 mg).

The values recorded for stages of maturity and edible portion showed that higher content was obtained in raw bulbs (1.78 mg), which was on par with ripe bulbs (1.76 mg). The lycopene content was reported in raw seeds of jackfruit was 1.61 mg and ripe seeds were 1.68 mg.

Table 61. showed the interaction effect of types, stages and edible portion. Here the highest content was obtained in Sindoor raw bulbs (2.53 mg) and the lowest content was observed in Then varikka ripe flakes (0.46 mg).

Table 61. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their lycopene content

Sl.No.	Types X Stages X Edible portion	Lycopene (mg/100g)
T_1	$T_1S_1E_1$	2.06
T_2	$T_1S_1E_2$	2.03
T_3	$T_1S_2E_1$	2.40
T_4	$T_1S_2E_2$	2.05
T_5	$T_2S_1E_1$	0.64
T_6	$T_2S_1E_2$	0.98
T_7	$T_2S_2E_1$	0.46
T_8	$T_2S_2E_2$	1.03
T_9	$T_3S_1E_1$	**2.53**
T_{10}	$T_3S_1E_2$	1.05
T_{11}	$T_3S_2E_1$	1.87
T_{12}	$T_3S_2E_2$	1.28
T_{13}	$T_4S_1E_1$	1.33
T_{14}	$T_4S_1E_2$	1.93
T_{15}	$T_4S_2E_1$	2.10
T_{16}	$T_4S_2E_2$	2.02
T_{17}	$T_5S_1E_1$	2.33
T_{18}	$T_5S_1E_2$	2.05
T_{19}	$T_5S_2E_1$	1.97
T_{20}	$T_5S_2E_2$	2.05
SEm $\pm$		0.036
CD		0.103

Values are means of triplicates

SEm : standard error of the mean

4.1.4.4. Saponin content

Table 62. Saponins content of raw and ripe jackfruit types

Category	Saponin (mg/100g)
Jackfruit Types	
Muttom varikka	136.37
Then varikka	174.92
Sindoor	**208.85**
Chempikalom varikka	109.67
Local cv Koozha	82.75
SEm ±	0.693
CD	1.980
Stages	
Raw	113.67
Ripe	**171.35**
SEm ±	0.438
CD	1.252
Edible Portions	
Bulb	**154.08**
Seed	130.94
SEm ±	0.438
CD	1.252

Values are means of triplicates
SEm : standard error of the mean

Table 62 shows the saponin content in different types, stages of maturity and edible portion of jackfruit. The results show that the saponin content was higher in Sindoor (208.85 mg).The lowest content was observed in Local cv koozha (82.75 mg). In the case of stages of maturity raw jackfruit contained 113.67 mg and ripe stages contained 171.35 mg. The edible portions of the jackfruit bulb contained 154.08 mg and the jackfruit seeds contained 130.94 mg.

Table 63. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their saponin content

Parameters	Saponin (mg/100g)
Types X Stages	
T_1S_1	85.33
T_1S_2	187.40
T_2S_1	118.50
T_2S_2	**231.33**
T_3S_1	206.00
T_3S_2	211.70
T_4S_1	87.50
T_4S_2	131.83
T_5S_1	71.00
T_5S_2	94.50
SEm $\pm$	0.980
CD	2.801
Types X Edible portion	
T_1E_1	125.22
T_1E_2	147.52
T_2E_1	219.17
T_2E_2	130.67
T_3E_1	188.00
T_3E_2	**229.70**
T_4E_1	127.00
T_4E_2	92.33
T_5E_1	111.00
T_5E_2	54.50
SEm $\pm$	0.980
CD	2.801
Stages X Edible portion	
S_1E_1	106.57
S_1E_2	120.77
S_2E_1	**201.59**
S_2E_2	141.12
SEm $\pm$	0.620
CD	1.771

Values are means of triplicates

SEm : standard error of the mean

Table 63 shows the interaction effects of types and stages of maturity, types and edible portion and also stages of maturity and edible portion (Two way interaction). In the case of types and stages of maturity, ripe stage of Then varikka contained higher level of saponins (231.33 mg). The lowest content was observed in raw stage of Koozha (71.00 mg). The next highest content was reported in ripe stages of Sindoor (211.70 mg) followed by raw stages of Sindoor (206.00 mg), ripe stages of Muttom varikka (187.40 mg), ripe stages of Chempikalom (131.83 mg) and raw stage of Then varikka (118.50).

In the case of types and edible portion, the higher values were obtained for seeds of Sindoor (229.70 mg) and lowest values were obtained for seeds of Koozha (54.50 mg). The next highest content was reported in bulbs of Then varikka (219.17 mg) followed by bulbs of Sindoor (188.00 mg), seeds of Muttom varikka (147.52 mg).

The values obtained for stages of maturity and edible portions revealed that higher content was obtained in ripe flakes (201.59 mg) and lower values were obtained for raw flakes (106.57 mg).

Table 64. shows the interaction of types, stages and edible portion. Here the highest content was obtained for Then varikka ripe bulbs (310.00 mg) and lowest content was observed in Koozha raw seeds (44.67 mg).

Table 64. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their saponin content

Sl.No.	Types X Stages X Edible portion	Saponin (mg/100g)
T_1	$T_1S_1E_1$	74.17
T_2	$T_1S_1E_2$	96.50
T_3	$T_1S_2E_1$	176.27
T_4	$T_1S_2E_2$	198.54
T_5	$T_2S_1E_1$	128.33
T_6	$T_2S_1E_2$	108.67
T_7	$T_2S_2E_1$	**310.00**
T_8	$T_2S_2E_2$	152.67
T_9	$T_3S_1E_1$	136.33
T_{10}	$T_3S_1E_2$	275.67
T_{11}	$T_3S_2E_1$	239.67
T_{12}	$T_3S_2E_2$	183.73
T_{13}	$T_4S_1E_1$	96.67
T_{14}	$T_4S_1E_2$	78.33
T_{15}	$T_4S_2E_1$	157.33
T_{16}	$T_4S_2E_2$	106.33
T_{17}	$T_5S_1E_1$	97.33
T_{18}	$T_5S_1E_2$	44.67
T_{19}	$T_5S_2E_1$	124.67
T_{20}	$T_5S_2E_2$	64.33
SEm $\pm$		1.385
CD		3.961

Values are means of triplicates

SEm : standard error of the mean

4.1.4.5. Tannin content

Table 65. Tannins content of raw and ripe jackfruit types

Category	Tannin (mg/100g)
Jackfruit Types	
Muttom varikka	20.63
Then varikka	81.93
Sindoor	**102.50**
Chempikalom varikka	46.17
Local cv Koozha	98.12
SEm ±	0.088
CD	0.251
Stages	
Raw	**88.29**
Ripe	51.45
SEm ±	0.055
CD	0.159
Edible Portions	
Bulb	**72.93**
Seed	66.81
SEm ±	0.055
CD	0.159

Values are means of triplicates

SEm : standard error of the mean

Table 65 shows the tannin content in different types, stages of maturity and edible portion of jackfruit. The result shows that the tannin content was higher in Sindoor (102.50 mg).The lowest content was observed in Muttom varikka (20.63 mg). In the case of stages of maturity the raw stage of jackfruit contained 88.29 mg and ripe stage contained 51.45 mg. The edible portions of the jackfruit bulb contained 72.93 mg and the jackfruit seeds contained 66.81 mg.

Table 66. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their tannin content

Parameters	Tannin (mg/100g)
Types X Stages	
T_1S_1	23.16
T_1S_2	18.09
T_2S_1	111.05
T_2S_2	52.81
T_3S_1	**125.00**
T_3S_2	80.00
T_4S_1	77.32
T_4S_2	15.02
T_5S_1	104.92
T_5S_2	91.32
SEm $\pm$	0.124
CD	0.355
Types X Edible portion	
T_1E_1	14.38
T_1E_2	26.88
T_2E_1	80.34
T_2E_2	83.52
T_3E_1	104.87
T_3E_2	100.13
T_4E_1	30.03
T_4E_2	62.31
T_5E_1	**135.03**
T_5E_2	61.20
SEm $\pm$	0.124
CD	0.355
Stages X Edible portion	
S_1E_1	**90.71**
S_1E_2	85.88
S_2E_1	55.15
S_2E_2	47.74
SEm $\pm$	0.078
CD	0.224

Values are means of triplicates

SEm : standard error of the mean

Table 66 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion. On considering types and stages of maturity, raw stage of Sindoor contained higher level of tannin (125.00 mg). The lowest content was observed in ripe stage of Chempikalom (15.02 mg). The level of tannin content in raw stages of Then varikka (111.05 mg), raw stage of Koozha (104.92 mg), ripe stage of Koozha (91.32 mg), ripe stage of Sindoor (80.00 mg), raw stage of Chempikalom (77.32 mg) and ripe stage of Then varikka (52.81 mg) were also determined.

In the case of types and edible portion, the highest values were obtained for bulbs of Koozha (135.03 mg) and lowest values were obtained for bulbs of Muttom varikka (14.38 mg). The level of tannin content in bulbs of Sindoor (104.87 mg), seeds of Sindoor (100.13 mg), seeds of Then varikka (83.52 mg), bulbs of Then varikka (80.34 mg) and seeds of Chempikalom (62.31 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in raw flakes (90.71 mg) and the lower values were obtained for ripe seeds (47.74 mg).

Table 67. shows the interaction effects of types, stages and edible portion. Here the highest content was obtained for Koozha raw flakes (174.73 mg) and the lowest content was observed in Muttom varikka raw bulbs (11.25 mg).

Table 67. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their tannin content

Sl.No.	Types X Stages X Edible portion	Tannin (mg/100g)
T_1	$T_1S_1E_1$	11.25
T_2	$T_1S_1E_2$	35.08
T_3	$T_1S_2E_1$	17.50
T_4	$T_1S_2E_2$	18.68
T_5	$T_2S_1E_1$	85.28
T_6	$T_2S_1E_2$	136.83
T_7	$T_2S_2E_1$	75.40
T_8	$T_2S_2E_2$	30.21
T_9	$T_3S_1E_1$	134.73
T_{10}	$T_3S_1E_2$	115.27
T_{11}	$T_3S_2E_1$	75.00
T_{12}	$T_3S_2E_2$	85.00
T_{13}	$T_4S_1E_1$	47.54
T_{14}	$T_4S_1E_2$	107.10
T_{15}	$T_4S_2E_1$	12.53
T_{16}	$T_4S_2E_2$	17.52
T_{17}	$T_5S_1E_1$	**174.73**
T_{18}	$T_5S_1E_2$	35.10
T_{19}	$T_5S_2E_1$	95.33
T_{20}	$T_5S_2E_2$	87.31
SEm $\pm$		0.175
CD		0.502

Values are means of triplicates

SEm : standard error of the mean

4.1.4.6. Polyphenol content

Table 68. Polyphenol content of raw and ripe jackfruit types

Category	Polyphenol (mg/100g)
Jackfruit Types	
Muttom varikka	1.04
Then varikka	3.13
Sindoor	**3.50**
Chempikalom varikka	3.03
Local cv Koozha	1.13
SEm ±	0.002
CD	0.007
Stages	
Raw	2.11
Ripe	**2.62**
SEm ±	0.002
CD	0.004
Edible Portions	
Bulb	**3.04**
Seed	1.69
SEm ±	0.002
CD	0.004

Values are means of triplicates

SEm : standard error of the mean

Table 68 shows the polyphenol content in different types, stages of maturity and edible portions of jackfruit. The results show that the polyphenol content was higher in Sindoor (3.50 mg). The lowest content was observed in Muttom varikka (1.04 mg). In the case of stages of maturity the raw stage of jackfruit contained 2.11 mg and ripe stage contained 2.62 mg. The edible portions of the jackfruit bulb contained 3.04 mg and the jackfruit seeds contained 1.69 mg.

Table 69. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their polyphenol content

Parameters	Polyphenol (mg/100g)
Types X Stages	
T_1S_1	0.92
T_1S_2	1.16
T_2S_1	2.88
T_2S_2	3.39
T_3S_1	3.12
T_3S_2	**3.87**
T_4S_1	2.60
T_4S_2	3.45
T_5S_1	1.04
T_5S_2	1.21
SEm $\pm$	0.004
CD	0.010
Types X Edible portion	
T_1E_1	0.57
T_1E_2	1.51
T_2E_1	4.71
T_2E_2	1.56
T_3E_1	**5.41**
T_3E_2	1.58
T_4E_1	3.82
T_4E_2	2.23
T_5E_1	0.69
T_5E_2	1.56
SEm $\pm$	0.004
CD	0.014
Stages X Edible portion	
S_1E_1	2.70
S_1E_2	1.52
S_2E_1	**3.38**
S_2E_2	1.85
SEm $\pm$	0.002
CD	0.006

Values are means of triplicates

SEm : standard error of the mean

Table 69 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion (Two way interaction). In the case of types and stages of maturity, ripe stage of Sindoor contained higher levels of polyphenols (3.87 mg). The lowest content was observed in raw stage of Muttom varikka (0.92 mg). The polyphenol content in ripe Chempikalom (3.45 mg), ripe Then varikka (3.39 mg), raw Sindoor (3.12) and raw Then varikka (2.88 mg)

In the case of types and edible portion, the higher values were obtained for bulbs of Sindoor (5.41 mg) and lowest values were obtained for bulbs of Muttom varikka (0.57 mg). The polyphenol content reported in bulbs of Then varikka (4.71 mg), bulbs of Chempikalom (3.82 mg), seeds of Chempikalom (2.23 mg), seeds of Sindoor (1.58 mg), seeds of Then varikka (1.56 mg), seeds of Koozha (1.56 mg), seeds of Muttom varikka (1.51 mg) and bulbs of Koozha (0.69 mg).

The values obtained for stages of maturity and edible portion showed that higher content was observed in ripe bulbs (3.38 mg) and the lowest values were obtained for raw seeds (1.52 mg). The polyphenol content in raw bulbs (2.70 mg) and ripe seeds (1.85 mg).

Table 70. showed the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Sindoor ripe bulbs (6.00 mg) and the lowest content was observed in Muttom varikka raw bulbs (0.53 mg).

Table 70. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their polyphenol content

Sl.No.	Types X Stages X Edible portion	Polyphenol (mg/100g)
T_1	$T_1S_1E_1$	0.53
T_2	$T_1S_1E_2$	1.31
T_3	$T_1S_2E_1$	0.61
T_4	$T_1S_2E_2$	1.71
T_5	$T_2S_1E_1$	4.31
T_6	$T_2S_1E_2$	1.45
T_7	$T_2S_2E_1$	5.11
T_8	$T_2S_2E_2$	1.67
T_9	$T_3S_1E_1$	4.83
T_{10}	$T_3S_1E_2$	1.42
T_{11}	$T_3S_2E_1$	**6.00**
T_{12}	$T_3S_2E_2$	1.75
T_{13}	$T_4S_1E_1$	3.21
T_{14}	$T_4S_1E_2$	2.00
T_{15}	$T_4S_2E_1$	4.43
T_{16}	$T_4S_2E_2$	2.46
T_{17}	$T_5S_1E_1$	0.63
T_{18}	$T_5S_1E_2$	1.45
T_{19}	$T_5S_2E_1$	0.75
T_{20}	$T_5S_2E_2$	1.67
SEm $\pm$		0.005
CD		0.014

Values are means of triplicates

SEm : standard error of the mean

4.1.4.7. Lectin content

Table 71. Lectin content of raw and ripe jackfruit types

Category	Lectin (mg/100g)
Jackfruit Types	
Muttom varikka	0.15
Then varikka	**1.40**
Sindoor	0.28
Chempikalom varikka	0.72
Local cv Koozha	0.18
SEm ±	0.003
CD	0.008
Stages	
Raw	0.54
Ripe	**0.56**
SEm ±	0.002
CD	0.005
Edible Portions	
Bulb	0.42
Seed	**0.67**
SEm ±	0.002
CD	0.005

Values are means of triplicates
SEm : standard error of the mean

Table 71 shows the lectin contents in different types, stages of maturity and edible portion of jackfruit. The results revealed that the lectin content was higher in Then varikka (1.40 mg), lowest content was observed in Muttom varikka (0.15 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.54 mg and ripe stage contained 0.56 mg. The edible portions of the jackfruit bulb contained 0.42 mg and the jackfruit seeds contained 0.67 mg.

Table 72. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their lectin content

Parameters	Lectin (mg/100g)
Types X Stages	
T_1S_1	0.13
T_1S_2	0.16
T_2S_1	**1.45**
T_2S_2	1.35
T_3S_1	0.27
T_3S_2	0.29
T_4S_1	0.66
T_4S_2	0.79
T_5S_1	0.17
T_5S_2	0.19
SEm $\pm$	0.004
CD	0.012
Types X Edible portion	
T_1E_1	0.07
T_1E_2	0.22
T_2E_1	1.17
T_2E_2	**1.63**
T_3E_1	0.24
T_3E_2	0.32
T_4E_1	0.58
T_4E_2	0.87
T_5E_1	0.05
T_5E_2	0.31
SEm $\pm$	0.004
CD	0.012
Stages X Edible portion	
S_1E_1	0.43
S_1E_2	0.65
S_2E_1	0.42
S_2E_2	**0.69**
SEm $\pm$	0.003
CD	0.007

Values are means of triplicates

SEm : standard error of the mean

Table 72 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion. In the case of types and stages of maturity, raw stage of Then varikka contained higher level of lectin (1.45 mg), the lowest content was observed in raw stage of Muttom varikka (0.13 mg). The lectin content reported in ripe stages of Then varikka (1.35 mg), ripe stage of Chempikalom (0.79 mg), raw stage of Chempikalom (0.66 mg), ripe stage of Sindoor (0.29 mg), raw stage of Sindoor (0.27 mg) and ripe stage of Koozha (0.19 mg).

In the case of types and edible portion, the higher values were obtained for seeds of Then varikka (1.63 mg) and lowest values were obtained for flakes of Koozha (0.05 mg). The level of lectin content in bulbs of Then varikka (1.17 mg), seeds of Chempikalom (0.87 mg), bulbs of Chempikalom (0.58 mg) and seeds of Sindoor (0.32 mg).

The values obtained for stages of maturity and edible portion showed that the higher content was obtained in ripe seeds (0.69 mg) and the lowest values were obtained for ripe flakes (0.42 mg) which were on par with raw bulbs (0.43 mg).

Table 73. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Then varikka ripe seeds (1.66 mg) and the lowest content was observed in Koozha raw flakes (0.04 mg).

Table 73. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their lectin content

Sl.No.	Types X Stages X Edible portion	Lectin (mg/100g)
T_1	$T_1S_1E_1$	0.06
T_2	$T_1S_1E_2$	0.21
T_3	$T_1S_2E_1$	0.08
T_4	$T_1S_2E_2$	0.24
T_5	$T_2S_1E_1$	1.30
T_6	$T_2S_1E_2$	1.61
T_7	$T_2S_2E_1$	1.05
T_8	$T_2S_2E_2$	**1.66**
T_9	$T_3S_1E_1$	0.24
T_{10}	$T_3S_1E_2$	0.31
T_{11}	$T_3S_2E_1$	0.25
T_{12}	$T_3S_2E_2$	0.33
T_{13}	$T_4S_1E_1$	0.51
T_{14}	$T_4S_1E_2$	0.81
T_{15}	$T_4S_2E_1$	0.65
T_{16}	$T_4S_2E_2$	0.93
T_{17}	$T_5S_1E_1$	0.04
T_{18}	$T_5S_1E_2$	0.30
T_{19}	$T_5S_2E_1$	0.07
T_{20}	$T_5S_2E_2$	0.32
SEm $\pm$		0.006
CD		0.017

Values are means of triplicates

SEm : standard error of the mean

4.1.4.8. Lignin content

Table 74. Lignin content of raw and ripe jackfruit types

Category	Lignin (mg/100g)
Jackfruit Types	
Muttom varikka	6.59
Then varikka	**9.56**
Sindoor	5.07
Chempikalom varikka	2.86
Local cv Koozha	4.91
SEm ±	0.002
CD	0.006
Stages	
Raw	**6.47**
Ripe	5.12
SEm ±	0.001
CD	0.004
Edible Portions	
Bulb	5.35
Seed	**6.25**
SEm ±	0.001
CD	0.004

Values are means of triplicates
SEm : standard error of the mean

Table 74 shows the lignin content in different types, stages of maturity and edible portions of jackfruit. The results show that the lignin content was higher in Then varikka (9.56 mg). The lowest content was observed in Chempikalom varikka (2.86 mg). In the case of stages of maturity the raw stages of jackfruit contained 6.47 mg and ripe stage contained 5.12 mg. The edible portions of the jackfruit bulb contained 5.35 mg and the jackfruit seeds contained 6.25 mg.

Table 75. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their level of lignin content

Parameters	Lignin (mg/100g)
Types X Stages	
T_1S_1	7.29
T_1S_2	5.88
T_2S_1	**11.13**
T_2S_2	7.99
T_3S_1	5.49
T_3S_2	4.65
T_4S_1	2.92
T_4S_2	2.81
T_5S_1	5.54
T_5S_2	4.28
SEm $\pm$	0.003
CD	0.009
Types X Edible portion	
T_1E_1	6.65
T_1E_2	6.52
T_2E_1	7.68
T_2E_2	**11.44**
T_3E_1	3.87
T_3E_2	6.26
T_4E_1	3.02
T_4E_2	2.70
T_5E_1	5.50
T_5E_2	4.32
SEm $\pm$	0.003
CD	0.009
Stages X Edible portion	
S_1E_1	5.65
S_1E_2	**7.30**
S_2E_1	5.04
S_2E_2	5.20
SEm $\pm$	0.002
CD	0.006

Values are means of triplicates

SEm : standard error of the mean

Table 75 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion (Two way interaction). In the case of types and stages of maturity, raw stage of Then varikka contained higher level of lignin (11.13 mg), lower content was observed in ripe Chempikalom (2.81 mg). The lignin content in ripe stages of Then varikka (7.99 mg), raw stages of Muttom varikka (7.29 mg), ripe stages of Muttom varikka (5.88 mg), raw stages of Koozha (5.54 mg), raw stages of Sindoor (5.49 mg), ripe stages of Sindoor (4.65 mg), ripe stages of Koozha (4.28 mg) and raw stages of Chempikalom (2.92 mg).

In the case of types and edible portion, the higher value was obtained for seeds of Then varikka (11.44 mg) and lower values were obtained for seeds of Chempikalom (2.70 mg). The lignin content reported in bulbs of Then varikka (7.68 mg), bulbs of Muttom varikka (6.65 mg), seeds of Muttom varikka (6.52 mg), seeds of Sindoor (6.26 mg), bulbs of Koozha (5.50 mg) and seeds of Koozha (4.32 mg).

The values obtained for stages of maturity and edible portions reveal that the higher content was obtained in raw seeds (7.30 mg) and lower values were obtained for ripe bulbs (5.04 mg). The lignin content reported in raw stages of jackfruit bulbs (5.65 mg) and ripe stages of seeds (5.20 mg).

Table 76. shows the interaction effects of types, stages and edible portion. Here the highest content was obtained for Then varikka raw seeds (14.07 mg) and the lowest content was observed in Chempikalom ripe seeds (2.66 mg).

Table 76. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their lignin content

Sl.No.	Types X Stages X Edible portion	Lignin (mg/100g)
T_1	$T_1S_1E_1$	6.77
T_2	$T_1S_1E_2$	7.81
T_3	$T_1S_2E_1$	6.54
T_4	$T_1S_2E_2$	5.22
T_5	$T_2S_1E_1$	8.18
T_6	$T_2S_1E_2$	**14.07**
T_7	$T_2S_2E_1$	7.18
T_8	$T_2S_2E_2$	8.82
T_9	$T_3S_1E_1$	4.54
T_{10}	$T_3S_1E_2$	6.45
T_{11}	$T_3S_2E_1$	3.21
T_{12}	$T_3S_2E_2$	6.08
T_{13}	$T_4S_1E_1$	3.09
T_{14}	$T_4S_1E_2$	2.75
T_{15}	$T_4S_2E_1$	2.96
T_{16}	$T_4S_2E_2$	2.66
T_{17}	$T_5S_1E_1$	5.68
T_{18}	$T_5S_1E_2$	5.41
T_{19}	$T_5S_2E_1$	5.33
T_{20}	$T_5S_2E_2$	3.23
SEm $\pm$		0.005
CD		0.013

Values are means of triplicates

SEm : standard error of the mean

4.1.4.9. Trypsin inhibitors

Table 77. Trypsin inhibitors content of raw and ripe jackfruit types

Category	Trypsin inhibitors (mg/100g)
Jackfruit Types	
Muttom varikka	2.75
Then varikka	**22.50**
Sindoor	**22.83**
Chempikalom varikka	13.17
Local cv Koozha	18.50
SEm ±	0.162
CD	0.464
Stages	
Raw	**16.97**
Ripe	14.93
SEm ±	0.103
CD	0.294
Edible Portions	
Bulb	14.83
Seed	**17.07**
SEm ±	0.103
CD	0.294

Values are means of triplicates
SEm : standard error of the mean

Table 77 shows the content of trypsin inhibitors in different types, stages of maturity and edible portion of jackfruit. The results show that the trypsin inhibitor content was higher in Sindoor (22.83 mg), which was on par with Then varikka (22.50 mg).The lowest content was observed in Muttom varikka (2.75 mg). In the case of stages of maturity the raw jackfruit contained 16.97 mg and ripe stage contained 14.93 mg. The edible portions of the jackfruit bulb contained 14.83 mg and the jackfruit seeds contained 17.07 mg.

Table 78. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their level of trypsin inhibitors

Parameters	Trypsin inhibitors (mg/100g)
Types X Stages	
T_1S_1	2.50
T_1S_2	3.00
T_2S_1	**27.67**
T_2S_2	17.33
T_3S_1	22.67
T_3S_2	23.00
T_4S_1	12.00
T_4S_2	14.33
T_5S_1	20.00
T_5S_2	17.00
SEm $\pm$	0.230
CD	0.657
Types X Edible portion	
T_1E_1	3.50
T_1E_2	2.00
T_2E_1	**26.50**
T_2E_2	18.50
T_3E_1	21.33
T_3E_2	24.33
T_4E_1	9.83
T_4E_2	16.50
T_5E_1	13.00
T_5E_2	24.00
SEm $\pm$	0.230
CD	0.657
Stages X Edible portion	
S_1E_1	16.67
S_1E_2	**17.27**
S_2E_1	13.00
S_2E_2	16.87
SEm $\pm$	0.145
CD	0.415

Values are means of triplicates

SEm : standard error of the mean

Table 78 shows the interaction effects of types and stages of maturity, types and edible portion and stages of maturity and edible portion. In the case of types and stages of maturity, raw stage of Then varikka contained higher level of of trypsin inhibitors (27.67 mg), lowest content was observed in raw stage of Muttom varikka (2.50 mg). The level of trypsin inhibitors were also studied in ripe stages of Muttom varikka (3.00 mg), ripe stages of Then varikka (17.33 mg), raw stages of Sindoor (22.67 mg), ripe stages of Sindoor (23.00 mg), raw stages of Chempikalom (12.00 mg), ripe stages of Chempikalom (14.33 mg), raw stages of Koozha (20.00 mg) and ripe stages of Koozha (17.00 mg).

In the case of types and edible portion, the higher values were obtained for bulbs of Then varikka (26.50 mg) and lowest values were obtained for seeds of Muttom varikka (2.00 mg). The level of trypsin inhibitors in bulbs of Muttom varikka (3.50 mg), seeds of Then varikka (18.50 mg), bulbs of Sindoor (21.33 mg), seeds of Sindoor (24.33 mg), bulbs of Chempikalom (9.83 mg), seeds of Chempikalom (16.50 mg), bulbs of Koozha (13.00 mg) and seeds of Koozha (24.00 mg).

The values obtained for stages of maturity and edible portions show that higher content was obtained in raw seeds (17.27 mg), which was on par with ripe seeds (16.87 mg). The lowest values were obtained for ripe bulbs (13.00 mg).

Table 79. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest content was obtained for Then varikka raw bulbs (30.67 mg) and the lowest content was observed in Muttom varikka raw seeds (1.67 mg).

Table 79. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their level of trypsin inhibitors

Sl.No.	Types X Stages X Edible portion	Trypsin inhibitors (mg/100g)
T_1	$T_1S_1E_1$	3.33
T_2	$T_1S_1E_2$	1.67
T_3	$T_1S_2E_1$	3.67
T_4	$T_1S_2E_2$	2.33
T_5	$T_2S_1E_1$	**30.67**
T_6	$T_2S_1E_2$	24.67
T_7	$T_2S_2E_1$	22.33
T_8	$T_2S_2E_2$	12.33
T_9	$T_3S_1E_1$	22.33
T_{10}	$T_3S_1E_2$	23.00
T_{11}	$T_3S_2E_1$	20.33
T_{12}	$T_3S_2E_2$	25.67
T_{13}	$T_4S_1E_1$	8.33
T_{14}	$T_4S_1E_2$	15.67
T_{15}	$T_4S_2E_1$	11.33
T_{16}	$T_4S_2E_2$	17.33
T_{17}	$T_5S_1E_1$	18.67
T_{18}	$T_5S_1E_2$	21.33
T_{19}	$T_5S_2E_1$	7.33
T_{20}	$T_5S_2E_2$	26.67
SEm $\pm$		0.325
CD		0.929

Values are means of triplicates

SEm : standard error of the mean

4.1.4.2. Oligosaccharide Content (Raffinose)

Table 80. Oligosaccharide content and Retention time of raw and ripe jackfruit types

Sl.No.	Types X Stages X Edible portion	Retention Time	Area (AU)	Amount ($\mu g\ g^{-1}$)
T_1	$T_1S_1E_1$	0.40	6573.8	1.11
T_2	$T_1S_1E_2$	0.41	3974.2	0.61
T_3	$T_1S_2E_1$	0.40	7224.8	1.01
T_4	$T_1S_2E_2$	0.41	4322.6	0.66
T_5	$T_2S_1E_1$	0.40	6413.5	1.00
T_6	$T_2S_1E_2$	0.41	3778.3	0.58
T_7	$T_2S_2E_1$	0.40	6523.5	0.98
T_8	$T_2S_2E_2$	0.41	4036.5	0.62
T_9	$T_3S_1E_1$	0.41	7223.7	1.12
T_{10}	$T_3S_1E_2$	0.41	4838.5	0.74
T_{11}	$T_3S_2E_1$	0.41	7313.3	1.11
T_{12}	$T_3S_2E_2$	0.41	4939.4	0.76
T_{13}	$T_4S_1E_1$	0.40	7313.6	1.13
T_{14}	$T_4S_1E_2$	0.41	4256.7	0.65
T_{15}	$T_4S_2E_1$	0.40	7323.8	1.12
T_{16}	$T_4S_2E_2$	0.41	4132.2	0.64
T_{17}	$T_5S_1E_1$	0.40	6173.3	0.97
T_{18}	$T_5S_1E_2$	0.41	3691.6	0.57
T_{19}	$T_5S_2E_1$	0.40	6284.5	0.95
T_{20}	$T_5S_2E_2$	0.41	4266.7	0.65

Values are means of triplicates
SEm : standard error of the mean

The quantity of raffinose content in raw and ripe stages of both bulbs and seeds of jackfruit was identified through HPTLC assay and the data is tabulated in Table 80. In HPTLC analysis, the retention factor recorded by all the samples were 0.40 and 0.41 minutes. Raffinose content was higher in raw Chempikalom bulbs (1.13µg) and the lowest content was observed in Local cv koozha seeds (0.57µg).

Table 81. Oligosaccharide (Raffinose) contents in raw and ripe jackfruit types

Parameters	Raffinose (µg g^{-1})
Effects of Jackfruit Types	
Muttom varikka	0.85
Then varikka	0.79
Sindoor	**0.93**
Chempikalom varikka	0.88
Local cv Koozha	0.78
SEm ±	0.001
CD	0.002
Effects of Stages	
Raw	**0.85**
Ripe	**0.85**
SEm ±	0.00
CD	0.001
Effects of Edible Portions	
Bulb	**1.05**
Seed	0.65
SEm ±	0.00
CD	0.001

Values are means of triplicates
SEm : standard error of the mean

Table 81 shows the Oligosaccharide (Raffinose) contents in different types, stages of maturity and edible portion of jackfruit. The results show that Sindoor had the highest raffinose content (0.93µg/µl). The lowest raffinose content was observed in Local cv koozha (0.78 µg/µl). Considering the stages of maturity, both the raw and ripe stage contained 0.85 µg/µl. There was significant difference between the two stages. Raffinose content in edible portions showed that bulb of jackfruits (1.05 µg/µl) had higher content than seeds (0.65 µg/µl).

Table 82. Two way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their Raffinose content

Parameters	Raffinose (µg g^{-1})
Types X Stages	
T_1S_1	0.86
T_1S_2	0.83
T_2S_1	0.79
T_2S_2	0.80
T_3S_1	**0.93**
T_3S_2	**0.93**
T_4S_1	0.89
T_4S_2	0.88
T_5S_1	0.77
T_5S_2	0.80
SEm ±	0.001
CD	0.002
Types X Edible portion	
T_1E_1	1.06
T_1E_2	0.63
T_2E_1	0.99
T_2E_2	0.60
T_3E_1	1.11
T_3E_2	0.75
T_4E_1	**1.12**
T_4E_2	0.64
T_5E_1	0.96
T_5E_2	0.61
SEm ±	0.001
CD	0.002
Stages X Edible portion	
S_1E_1	**1.07**
S_1E_2	0.63
S_2E_1	1.03
S_2E_2	0.67
SEm ±	0.00
CD	0.001

Values are means of triplicates

SEm : standard error of the mean

Table 82 shows the interaction effects of types and stages, types and edible portion and stages and edible portion (Two way interaction). With respect to types and stages highest raffinose content was obtained for both raw and ripe stage of Sindoor (0.93 $\mu g\ g^{-1}$) and the lowest raffinose content was obtained for raw stage of Koozha (0.77 $\mu g\ g^{-1}$). In the case of interaction between types and edible portion the highest value obtained for Chempikalom varikka bulbs (1.12 $\mu g\ g^{-1}$) and the lowest value was obtained for Then varikka seeed (0.60 $\mu g\ g^{-1}$). In the case of interaction between stages and edible portion, the highest raffinose content was obtained for raw bulbs (1.07 $\mu g\ g^{-1}$) and the lowest value was obtained for raw seeds (0.63 $\mu g\ g^{-1}$).

Table 83. shows the three way interaction effects of types, stages and edible portion. Here in the highest value was obtained for Chempikalom raw bulbs (1.13 $\mu g/g^{-1}$), the lowest values were obtained for Local cv koozha raw seeds (0.57 $\mu g/g^{-1}$).

Table 83. Three way Interaction effects of Types, Stages and Edible portion of jackfruit on their Raffinose content

Sl.No.	Types X Stages X Edible portion	Raffinose (µg g^{-1})
T_1	$T_1S_1E_1$	1.11
T_2	$T_1S_1E_2$	0.61
T_3	$T_1S_2E_1$	1.01
T_4	$T_1S_2E_2$	0.66
T_5	$T_2S_1E_1$	1.00
T_6	$T_2S_1E_2$	0.58
T_7	$T_2S_2E_1$	0.98
T_8	$T_2S_2E_2$	0.62
T_9	$T_3S_1E_1$	1.12
T_{10}	$T_3S_1E_2$	0.74
T_{11}	$T_3S_2E_1$	1.11
T_{12}	$T_3S_2E_2$	0.76
T_{13}	$T_4S_1E_1$	**1.13**
T_{14}	$T_4S_1E_2$	0.65
T_{15}	$T_4S_2E_1$	1.12
T_{16}	$T_4S_2E_2$	0.64
T_{17}	$T_5S_1E_1$	0.97
T_{18}	$T_5S_1E_2$	0.57
T_{19}	$T_5S_2E_1$	0.95
T_{20}	$T_5S_2E_2$	0.65
SEm ±		0.001
CD		0.003

Values are means of triplicates

SEm : standard error of the mean

4.1.5. Antioxidant activity

Antioxidants can inhibit the propagation of free-radical reactions and protect the human body from diseases. Free-radicals and other reactive oxygen species (ROS), such as superoxide anion, hydroxyl radical, and hydrogen peroxide are an entire class of highly reactive molecules derived from the normal metabolism of oxygen or from exogenous factors and agents. ROS's125 are reported to be a causative agent of various diseases such as arthritis, asthma, dementia, mongolism, carcinoma and Parkinson's disease (Perry et al., 2000).

4.1.5.1. Total antioxidant activity

Table 84. Total antioxidant activity of raw and ripe jackfruit types

Category	IC_{50} Values (µg/ml)
Jackfruit Types	
Muttom varikka	35.15
Then varikka	35.39
Sindoor	40.90
Chempikalom varikka	35.47
Local cv Koozha	**33.53**
SEm ±	0.010
CD	0.028
Stages	
Raw	**35.82**
Ripe	36.36
SEm ±	0.006
CD	0.018
Edible Portions	
Bulb	37.20
Seed	**34.98**
SEm ±	0.006
CD	0.018

Values are means of triplicates

SEm : standard error of the mean

Table 84 shows the antioxidant activity of different types, stages of maturity and edible portion of jackfruit. The results show that the antioxidant activity expressed as IC_{50} values ranged from 33.53µg/ml to 40.90 µg/ml in five types of jackfruit types. The highest antioxidant capacity was observed in Local cv koozha (33.53 µg/ml) and least antioxidant capacity was observed in Sindoor (40.90 µg/ml). In the case of stages of maturity, the raw stage of jackfruit had IC_{50} value of 35.82 µg/ml and ripe stage of jackfruits had IC_{50} value of 36.36 µg/ml. In the case of edible portions it was observed that the antioxidant activity was higher in seeds (34.98µg/ml) than jackfruit bulb (37.20 µg/ml).

Table 85 shows the interaction effects of Types and Stages of maturity, Types and Edible portion and Stages of maturity and Edible portion (Two way interaction). In the case of types and stages of maturity, raw stage of Koozha (32.99µg/ml) had higher antioxidant activity and lower antioxidant activity was observed in raw (40.91 µg/ml) and ripe (40.89µg/ml) stage of Sindoor. Considering the activity of types and edible portion, it was observed that the higher antioxidant activity was observed in seeds of Koozha (30.89 µg/ml) and lower antioxidant activity was observed in bulbs of Sindoor (41.69 µg/ml). The stages and edible portion showed that the raw seeds (34.79µg/ml) had higher antioxidant activity and the lowest antioxidant activity was observed in ripe bulbs (37.55 µg/ml).

Table 86. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the highest antioxidant activity was observed in raw seeds of Koozha (30.35µg/ml) and lowest antioxidant activity was observed in raw bulbs of Sindoor (41.75µg/ml).

Table 85. Two way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their total antioxidant activity

Parameters	IC_{50} Values (µg/ml)
Types X Stages	
T_1S_1	34.76
T_1S_2	35.55
T_2S_1	35.13
T_2S_2	35.65
T_3S_1	40.91
T_3S_2	40.89
T_4S_1	35.29
T_4S_2	35.66
T_5S_1	**32.99**
T_5S_2	34.07
SEm ±	0.014
CD	0.040
Types X Edible portion	
T_1E_1	35.67
T_1E_2	34.64
T_2E_1	36.16
T_2E_2	34.62
T_3E_1	41.69
T_3E_2	40.11
T_4E_1	36.30
T_4E_2	34.65
T_5E_1	36.17
T_5E_2	**30.89**
SEm ±	0.014
CD	0.040
Stages X Edible portion	
S_1E_1	36.84
S_1E_2	**34.79**
S_2E_1	37.55
S_2E_2	35.17
SEm ±	0.009
CD	0.025

Values are means of triplicates

SEm : standard error of the mean

Table 86. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their total antioxidant activity

Sl.No.	Types X Stages X Edible portion	Mean Value
T_1	$T_1S_1E_1$	35.01
T_2	$T_1S_1E_2$	34.51
T_3	$T_1S_2E_1$	36.32
T_4	$T_1S_2E_2$	34.77
T_5	$T_2S_1E_1$	35.75
T_6	$T_2S_1E_2$	34.51
T_7	$T_2S_2E_1$	36.57
T_8	$T_2S_2E_2$	34.72
T_9	$T_3S_1E_1$	41.75
T_{10}	$T_3S_1E_2$	40.06
T_{11}	$T_3S_2E_1$	41.62
T_{12}	$T_3S_2E_2$	40.17
T_{13}	$T_4S_1E_1$	36.07
T_{14}	$T_4S_1E_2$	34.51
T_{15}	$T_4S_2E_1$	36.53
T_{16}	$T_4S_2E_2$	34.78
T_{17}	$T_5S_1E_1$	35.63
T_{18}	$T_5S_1E_2$	**30.35**
T_{19}	$T_5S_2E_1$	36.72
T_{20}	$T_5S_2E_2$	31.42
SEm $\pm$		0.020
CD		0.057

Values are means of triplicates

SEm : standard error of the mean

4.1.5.2. DPPH radical scavenging activity

Table 87. DPPH radical scavenging activity in raw and ripe jackfruit types

Parameters	IC_{50} Values (µg/ml)
Effects of Jackfruit Types	
Muttom varikka	37.31
Then varikka	25.58
Sindoor	24.51
Chempikalom varikka	**20.06**
Local cv Koozha	24.35
SEm ±	0.075
CD	0.214
Effects of Stages	
Raw	30.77
Ripe	**21.95**
SEm ±	0.047
CD	0.135
Effects of Edible Portions	
Bulb	26.92
Seed	**25.81**
SEm ±	0.047
CD	0.135

Values are means of triplicates
SEm : standard error of the mean

Free radicals produced due to oxidative stress and exposure to radiation causes damage to the biomolecules. The DPPH antioxidant assay is based on the ability of DPPH, a stable free radical, to decolorize in the presence of antioxidants. The DPPH radical contains an odd electron that is responsible for the absorbance at 540 nm and also for the visible deep purple colour. When DPPH accepts an electron donated by an antioxidant compound, the DPPH is decolorized, which can be quantitatively measured from the changes in absorbance.

Table 87 shows the level of DPPH radical scavenging activity in different types, stages of maturity and edible portion of jackfruit. The findings reveal that Chempikalom varikka had the highest DPPH activity with an IC_{50} value of 20.06 µg/ml, followed by Local cv koozha (24.35 µg/ml), the lowest DPPH radical scavenging activity was found in Muttom varikka (37.31 µg/ml). The DPPH activity was higher in ripe stage (21.95 µg/ml) of jackfruit than raw stage (30.77 µg/ml). The edible portions of the jackfruit showed that, jackfruit seed had the highest DPPH activity with an IC_{50} value of 25.81 µg/ml, followed by bulbs (26.92 µg/ml).

Table 88 shows the interaction effects of types and stages, types and edible portion and stages and edible portion (Two way interaction). From these findings it was revealed that ripe stage of Chempikalom varikka had the higher DPPH radical scavenging activity (4.46µg/ml) and lowest DPPH radical scavenging activity was observed in ripe stage of Koozha with an IC_{50} value of 41.35 µg/ml. With respect to types and edible portion, the higher DPPH radical scavenging activity was observed in Chempikalom seed (18.56 µg/ml) and lower activity was observed in Muttom varikka bulbs (37.32 µg/ml) and Muttom varikka seeds (37.30 µg/ml). The stages and edible portion showed that ripe bulbs had highest DPPH radical scavenging with IC_{50} value of 21.47 µg/ml and the least activity was observed in raw bulbs of jackfruit (32.36 µg/ml).

Table 89. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the data reveals that the higher DPPH radical scavenging activity was observed in Chempikalom ripe seeds (2.31 µg/ml) and the lower activity was observed in Muttom varikka ripe seeds (43.50 µg/ml) which was on par with raw bulbs of Then varikka (43.67 µg/ml).

Table 88. Two way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit on their DPPH radical scavenging activity

Parameters	IC_{50} Values (µg/ml)
Types X Stages	
T_1S_1	33.77
T_1S_2	40.85
T_2S_1	39.67
T_2S_2	11.50
T_3S_1	37.41
T_3S_2	11.62
T_4S_1	35.66
T_4S_2	**4.46**
T_5S_1	7.36
T_5S_2	41.35
SEm ±	0.106
CD	0.302
Types X Edible portion	
T_1E_1	37.32
T_1E_2	37.30
T_2E_1	26.78
T_2E_2	24.39
T_3E_1	25.87
T_3E_2	23.16
T_4E_1	21.56
T_4E_2	**18.56**
T_5E_1	23.07
T_5E_2	25.63
SEm ±	0.106
CD	0.302
Stages X Edible portion	
S_1E_1	32.36
S_1E_2	29.18
S_2E_1	**21.47**
S_2E_2	22.44
SEm ±	0.067
CD	0.191

Values are means of triplicates

SEm : standard error of the mean

Table 89. Three way interaction effects of Types, Stages and Edible portion of jackfruit for their DPPH radical scavenging activity

Sl.No.	Types X Stages X Edible portion	IC_{50} Values (µg/ml)
T_1	$T_1S_1E_1$	36.43
T_2	$T_1S_1E_2$	31.11
T_3	$T_1S_2E_1$	38.20
T_4	$T_1S_2E_2$	43.50
T_5	$T_2S_1E_1$	43.67
T_6	$T_2S_1E_2$	35.67
T_7	$T_2S_2E_1$	9.89
T_8	$T_2S_2E_2$	13.11
T_9	$T_3S_1E_1$	39.41
T_{10}	$T_3S_1E_2$	35.41
T_{11}	$T_3S_2E_1$	12.33
T_{12}	$T_3S_2E_2$	10.91
T_{13}	$T_4S_1E_1$	36.51
T_{14}	$T_4S_1E_2$	34.82
T_{15}	$T_4S_2E_1$	6.61
T_{16}	$T_4S_2E_2$	**2.31**
T_{17}	$T_5S_1E_1$	5.81
T_{18}	$T_5S_1E_2$	8.90
T_{19}	$T_5S_2E_1$	40.33
T_{20}	$T_5S_2E_2$	42.36
SEm ±		0.150
CD		0.428

Values are means of triplicates

SEm : standard error of the mean

4.1.5.3. Hydroxyl radical scavenging activity

Table 90. Hydroxyl radical scavenging activity of raw and ripe jackfruit types

Parameters	IC_{50} Values (µg/ml)
Effects of Jackfruit Types	
Muttom varikka	33.13
Then varikka	35.61
Sindoor	35.02
Chempikalom varikka	35.21
Local cv Koozha	33.40
SEm ±	0.006
CD	0.017
Effects of Stages	
Raw	34.35
Ripe	34.60
SEm ±	0.004
CD	0.011
Effects of Edible Portions	
Bulb	35.82
Seed	33.13
SEm ±	0.004
CD	0.011

Values are means of triplicates
SEm : standard error of the mean

Table 90. shows the hydroxyl radical scavenging activity in different types, stages of maturity and edible portion of jackfruit. The findings reveal that Muttom varikka had the highest hydroxyl radical scavenging activity with an IC_{50} value of 33.13 µg/ml. The lowest DPPH radical scavenging activity was found in Then varikka (35.61 µg/ml). The hydroxyl radical scavenging activity was higher in raw stage (34.35 µg/ml) of jackfruit than ripe stage (34.60 µg/ml). Considering the activity of edible portions of the jackfruit, jackfruit seeds had higher activity with an IC_{50} value of 33.13 µg/ml and lower activity was observed in jackfruit bulbs with IC_{50} value of 35.82 µg/ml.

Table 91. Two way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit for their hydroxyl radical scavenging activity

Parameters	IC_{50} Values (µg/ml)
Types X Stages	
T_1S_1	33.79
T_1S_2	**32.47**
T_2S_1	35.41
T_2S_2	35.82
T_3S_1	34.59
T_3S_2	35.45
T_4S_1	35.09
T_4S_2	35.34
T_5S_1	32.87
T_5S_2	33.93
SEm ±	0.008
CD	0.024
Types X Edible portion	
T_1E_1	34.14
T_1E_2	32.12
T_2E_1	36.84
T_2E_2	34.39
T_3E_1	36.10
T_3E_2	33.94
T_4E_1	36.19
T_4E_2	34.24
T_5E_1	35.83
T_5E_2	**30.97**
SEm ±	0.008
CD	0.024
Stages X Edible portion	
S_1E_1	35.62
S_1E_2	**33.08**
S_2E_1	36.02
S_2E_2	33.18
SEm ±	0.005
CD	0.015

Values are means of triplicates

SEm : standard error of the mean

Table 91 shows the interaction effects of types and stages, types and edible portion and stages and edible portion (Two way interaction). From these findings it was revealed that ripe stage of Muttom varikka had higher hydroxyl radical scavenging activity (32.47 µg/ml) and lowest hydroxyl radical scavenging activity was observed in ripe stage of Then varikka with an IC_{50} 35.82 µg/ml. In the case of types and edible portion, the maximum hydroxyl radical scavenging activity was observed in Koozha seed (30.97 µg/ml) and minimum activity was observed in Then varikka bulbs (36.84 µg/ml). Analysing the interaction of stages and edible portions, it was seen that raw seeds had higher hydroxyl radical scavenging with IC_{50} value of 33.08 µg/ml and the lower activity was observed in ripe bulbs of jackfruit (36.02 µg/ml).

Table 92. shows the interaction effects of types, stages and edible portion (Three way interaction). Here the data reveals that the higher hydroxyl radical scavenging activity was observed in Koozha raw seeds (30.42 µg/ml) and lower activity was observed in Then varikka ripe bulbs (36.92 µg/ml).

Table 92. Three way interaction effects of Types, Stages of maturity and Edible portion of jackfruit for their hydroxyl radical scavenging activity

Sl.No.	Types X Stages X Edible portion	IC_{50} Values (µg/ml)
T_1	$T_1S_1E_1$	34.43
T_2	$T_1S_1E_2$	33.15
T_3	$T_1S_2E_1$	33.85
T_4	$T_1S_2E_2$	31.09
T_5	$T_2S_1E_1$	36.76
T_6	$T_2S_1E_2$	34.06
T_7	$T_2S_2E_1$	36.92
T_8	$T_2S_2E_2$	34.72
T_9	$T_3S_1E_1$	35.46
T_{10}	$T_3S_1E_2$	33.73
T_{11}	$T_3S_2E_1$	36.75
T_{12}	$T_3S_2E_2$	34.15
T_{13}	$T_4S_1E_1$	36.13
T_{14}	$T_4S_1E_2$	34.05
T_{15}	$T_4S_2E_1$	36.25
T_{16}	$T_4S_2E_2$	34.43
T_{17}	$T_5S_1E_1$	35.32
T_{18}	$T_5S_1E_2$	**30.42**
T_{19}	$T_5S_2E_1$	36.34
T_{20}	$T_5S_2E_2$	31.52
SEm $\pm$		0.012
CD		0.034

Values are means of triplicates

SEm : standard error of the mean

4.1.5.4. Superoxide radical scavenging activity

Table 93. Super oxide radical scavenging activity of raw and ripe jackfruit types

Parameters	IC_{50} Values (µg/ml)
Effects of Jackfruit Types	
Muttom varikka	5.56
Then varikka	6.05
Sindoor	5.36
Chempikalom varikka	5.97
Local cv Koozha	**5.25**
SEm ±	0.005
CD	0.013
Effects of Stages	
Raw	**5.57**
Ripe	5.70
SEm ±	0.003
CD	0.008
Effects of Edible Portions	
Bulb	5.99
Seed	**5.29**
SEm ±	0.003
CD	0.008

Values are means of triplicates
SEm : standard error of the mean

Table 93. shows the superoxide radical scavenging activity in different types, stages of maturity and edible portion of jackfruit. The findings reveal that Local cv koozha had the highest superoxide radical scavenging activity with an IC_{50} value of 5.25 µg/ml. The lowest superoxide radical scavenging activity was found in Then varikka (6.05 µg/ml). The superoxide radical scavenging activity was higher in raw stage (5.57µg/ml) of jackfruit than ripe stage (5.70 µg/ml). The edible portions of the jackfruit showed that, jackfruit seeds had the higher activity with IC_{50} value of 5.29 µg/ml and lower activity was observed in jackfruit bulbs with IC_{50} value of 5.99 µg/ml.

Table 94. Two way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit for their super oxide radical scavenging activity

Parameters	IC_{50} Values (µg/ml)
Types X Stages	
T_1S_1	5.49
T_1S_2	5.63
T_2S_1	6.04
T_2S_2	6.05
T_3S_1	5.33
T_3S_2	5.40
T_4S_1	5.93
T_4S_2	6.01
T_5S_1	**5.09**
T_5S_2	5.42
SEm ±	0.006
CD	0.018
Types X Edible portion	
T_1E_1	5.86
T_1E_2	5.26
T_2E_1	6.26
T_2E_2	5.84
T_3E_1	5.63
T_3E_2	5.10
T_4E_1	6.38
T_4E_2	5.56
T_5E_1	5.82
T_5E_2	**4.68**
SEm ±	0.006
CD	0.018
Stages X Edible portion	
S_1E_1	5.98
S_1E_2	**5.17**
S_2E_1	6.00
S_2E_2	5.40
SEm ±	0.004
CD	0.012

Values are means of triplicates

SEm : standard error of the mean

Table 94 shows the interaction effects of Types and Stages, Types and Edible portion and Stages and Edible portion. From these findings it is observed that raw stage of koozha had higher superoxide radical scavenging activity (5.09 µg/ml) and lowest superoxide radical scavenging activity was observed in ripe stage of Then varikka with an IC_{50} 6.05 µg/ml. In the case of types and edible portion, the highest superoxide radical scavenging activity was observed in Koozha seeds (4.68 µg/ml) and least activity was observed in Chempikalom varikka bulbs (6.38µg/ml). The interaction of stages and edible portions revealed that raw seeds had higher superoxide radical scavenging with IC_{50} value of 5.17 µg/ml and the minimum activity was observed in ripe bulbs of jackfruit (6.00 µg/ml).

Table 95. shows the interaction effects of types, stages and edible portion. Here the data reveals that the highest superoxide radical scavenging activity was observed in Koozha raw seeds (4.34 µg/ml) and the minimum activity was observed in Chempikalom varikka ripe bulbs (6.44 µg/ml).

To conclude the first part of the experiment, the results showed that nutrient wise, raw seeds of Chempikalom and ripe bulbs of Sindoor scored higher than the rest of treatments while with respect to antioxidant activity, ripe seeds of Koozha were better than other treatments.The profiling of nutrients and bioactive compounds in the first part of the experiment is an eye opener on specific features of the common jackfruit types that can be exploited according to varying needs.

Table 95. Three way Interaction effects of Types, Stages of maturity and Edible portion of jackfruit for their super oxide radical scavenging activity

Sl.No.	Types X Stages X Edible portion	IC_{50} Values (µg/ml)
T_1	$T_1S_1E_1$	5.85
T_2	$T_1S_1E_2$	5.12
T_3	$T_1S_2E_1$	5.87
T_4	$T_1S_2E_2$	5.39
T_5	$T_2S_1E_1$	6.27
T_6	$T_2S_1E_2$	5.82
T_7	$T_2S_2E_1$	6.25
T_8	$T_2S_2E_2$	5.85
T_9	$T_3S_1E_1$	5.61
T_{10}	$T_3S_1E_2$	5.04
T_{11}	$T_3S_2E_1$	5.64
T_{12}	$T_3S_2E_2$	5.16
T_{13}	$T_4S_1E_1$	6.32
T_{14}	$T_4S_1E_2$	5.53
T_{15}	$T_4S_2E_1$	6.44
T_{16}	$T_4S_2E_2$	5.58
T_{17}	$T_5S_1E_1$	5.83
T_{18}	$T_5S_1E_2$	**4.34**
T_{19}	$T_5S_2E_1$	5.81
T_{20}	$T_5S_2E_2$	5.02
SEm ±		0.009
CD		0.026

Values are means of triplicates

SEm : standard error of the mean

4.2. ANALYSIS OF MEASURES FOR REDUCING ANTINUTRIENTS IN RAW JACKFRUIT

Oligosaccharides present in jackfruit bulb flour and seed flour of both enzyme and yeast treated samples were analysed by HPTLC analytical tools and the results are presented in Table 96 & 97.

4.2.1. Treatment with enzyme α galactosidase

The enzyme α galactosidase was premixed with the dry flour of jackfruit seed and jackfruit bulb separately in the ratio 1:100. The moisture level was made to vary from 25 – 200% (dough to batter stage). The hydrolysis was carried out for 90 minutes in both jackfruit bulb and seed flours and breakdown of oligosaccharides was evaluated.

4.2.1.1 Reduction of oligosaccharide (Raffinose) content in bulb flour

The oligosaccharide (Raffinose) content in pre treated and treated jackfruit bulb flour (JFBF) treated with enzyme at different moisture levels differed customarily in the HPTLC assays. In HPTLC analysis, the retention factor of standared Raffinose was 0.58 minutes. The distance that each component of a mixture travels can be quantified using retention factors (Rf). The retention factor of a particular material is the ratio of the distance the spot moved above the origin to the distance the solvent front moved above the origin. Retention factor recorded by jackfruit bulb flour (control) and bulb flour with enzyme treated at varying moisture levels were 0.58, 0.58, 0.58, 0.58, 0.58, 0.57, 0.57, 0.57, 0.57 at 25%, 50%, 75%, 100%, 125%, 150%, 175%, 200% respectively.

These values were compared to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 0.97in control (without treatment); while the amount in treated samples were in M_1 (25%) - 0.89, M_2 (50 %) - 0.85, M_3 (75 %) - 0.80, M_4 (100 %) - 0.71, M_5 (125 %) - 0.74, M_6 (150 %) - 0.83, M_7 (175 %) - 0.75, M_8 (200 %) - 0.82μg g^{-1} respectively. The level of Raffinose after treatment was seen to decrease with increase in moisture content (25-100%). Thereafter the

variation was not uniform (125%, 150%, 175%, 200%). However it may be noted that the level of oligosaccharides decreased in comparison to control (0.97 μg g^{-1}), which indicates the typical effect of enzyme on breakdown of oligosaccharides.

4.2.1.2 Reduction of oligosaccharide (Raffinose) content in seed flour

The oligosaccharide (Raffinose) content in pre treated and treated jackfruit seed flour (JFSF) treated with enzyme at different moisture levels differed in HPTLC assay and the data is tabulated in Table 97. In the HPTLC analysis, the retention factor of standard Raffinose was 0.61 minutes. Retention factor recorded by pretreated (0.61 minutes) and treated jackfruit seed flour was compared to that of the standard Raffinose. Raffinose content in plain jackfruit bulb flour was 1.16 and 0.83, 0.68, 0.63, 0.56, 0.50, 0.58, 0.74 and 1.08 μg g^{-1} at 25%, 50%, 75%, 100%, 125%, 150%, 175%, 200% dilutions respectively. The level of Raffinose content in seed flour after treatment was seen to decrease with increase in moisture content (25-100%). Here the raffinose content was seen to reduce up to 125% of moisture. Thereafter the variation was not uniform (150%, 175%, 200%). However it may be noted that the level of oligosaccharides decreased in comparison to control (1.16 μg g^{-1}), which indicates the asymptotic effect of enzyme on breakdown of oligosaccharides.

Table 96. Quantification of Oligosaccharide (Raffinose) in jackfruit bulb flour at different moisture levels and enzyme treatment

Treatments (%)	Retention Factor	Area (AU)	Amount ($\mu g/g^{-1}$)
Standard	0.58	6319.7	-
M_0 (control)	0.58	6178.0	0.97
M_1 25	0.58	5677.3	0.89
M_2 50	0.58	5394.8	0.85
M_3 75	0.58	5117.0	0.80
M_4 100	0.58	4500.9	0.71
M_5 125	0.57	4734.9	0.74
M_6 150	0.57	5307.7	0.83
M_7 175	0.57	4795.3	0.75
M_8 200	0.57	5185.9	0.82

Table 97. Quantification of Oligosaccharide (Raffinose) in jackfruit seed flour at different moisture levels and enzyme treatment

Treatments (%)	Retention Factor	Area (AU)	Amount ($\mu g\ g^{-1}$)
Standard	0.61	5102.6	-
M_0 (control)	0.61	5963.0	1.16
M_1 25	0.61	4265.2	0.83
M_2 50	0.61	3510.5	0.68
M_3 75	0.61	3253.0	0.63
M_4 100	0.61	2866.2	0.56
M_5 125	0.61	2595.2	0.50
M_6 150	0.61	2986.6	0.58
M_7 175	0.61	3824.3	0.74
M_8 200	0.61	5557.7	1.08

Table 98. One way interaction effect of moisture levels and edible portion on raffinose content of jackfruit flours

Treatments	Raffinose (μg g^{-1})
Moisture level	
M_0	1.07
M_1	0.86
M_2	0.76
M_3	0.71
M_4	0.63
M_5	0.62
M_6	0.70
M_7	0.74
M_8	0.95
SEm ±	0.001
CD	0.004
Edible portion	
E_1	0.82
E_2	0.75
SEm ±	0.001
CD	0.002

Values are means of triplicates
SEm : standard error of the mean

Table 98 shows the effect of varying moisture levels and edible portion on raffinose content. From this table it is observed that the raffinose content was higher in control samples of jackfruit bulb flour and seed flour (1.07 μg/g^{-1}). The lowest raffinose content was observed in treatment M_5 (125% moisture level). With respect to edible portion, E_1 (Bulb flour) contained 0.82 μg $g^{-1}$and E_2 (Seed flour) contained 0.75 μg g^{-1}.

Table 99. Two way interaction effect of moisture level and edible portion on raffinose content

Treatments	Raffinose (µg g^{-1})
M_0E_1	0.97
M_0E_2	1.16
M_1E_1	0.89
M_1E_2	0.83
M_2E_1	0.85
M_2E_2	0.68
M_3E_1	0.80
M_3E_2	0.63
M_4E_1	0.71
M_4E_2	0.56
M_5E_1	0.74
M_5E_2	0.50
M_6E_1	0.83
M_6E_2	0.58
M_7E_1	0.75
M_7E_2	0.74
M_8E_1	0.82
M_8E_2	1.08
SEm ±	0.002
CD	0.005

Values are means of triplicates
SEm : standard error of the mean

Table 99 shows the two way interaction effect of varying moisture level and edible portion on raffinose content. Here it is observed that M_0E_2 (Control seed flour) contained highest level of raffinose content (1.16 µg g^{-1}), the lowest raffinose content was observed in M_5E_2 (125% moisture level of seed flour), which contained 0.50 µg g^{-1}.

4.2.2. Treatment with *Saccharomyces cerevisiae*

To reduce the level of oligosaccharides, flours were made into batter and subjected to fermentation with *Saccharomyces cerevisiae* @ 5gms/kg for 6 hrs and 8 hrs and 12 hrs respectively (Krishnaja, 2014).

4.2.2.1 Reduction of oligosaccharide (Raffinose) content in bulb flour

The oligosaccharide (Raffinose) content in treated with *Saccharomyces cerevisiae* and untreated jackfruit bulb flour at different fermentation times differed in the HPTLC assay and the data is tabulated in Table 100. In HPTLC analysis, the retention factor of standared Raffinose was 0.79. Retention factor recorded by untreated jackfruit bulb flour was 0.79, bulb flour with 6 hrs fermentation was 0.79, 8 hrs fermentation - 0.79 and 12 hrs - 0.80 respectively, which were comparable to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 0.75 $\mu g\ g^{-1}$, 0.63 $\mu g\ g^{-1}$, 0.58 $\mu g\ g^{-1}$and 0.74 $\mu g\ g^{-1}$ in F_1, F_2, F_3 treatments respectively. In the case of jackfruit bulb flours 8 hours fermentation was found to contain the least oligosaccharides.

Table 100. Quantification of Oligosaccharide (Raffinose) content in jackfruit bulb flours with different duration of fermentation

Treatments	Retention Factor	Area (AU)	Amount ($\mu g/g^{-1}$)
Standard	0.79	4974.03	-
F_0 (control)	0.79	6295.57	0.75
F_1 6 hrs	0.79	5222.87	0.63
F_2 8 hrs	0.79	6192.57	0.58
F_3 12 hrs	0.80	8612.57	0.74

4.2.2.2 Reduction of oligosaccharide (Raffinose) content in seed flour

The oligosaccharide (Raffinose) content in treated with *Saccharomyces cerevisiae* and untreated jackfruit seed flour at different durations of fermentation as observed in HPTLC assay are tabulated in Table 101. In HPTLC analysis, the retention factor of standared Raffinose was 0.57. Retention factor recorded in both untreated and treated jackfruit seed flours were compared to that of the standard Raffinose. Raffinose content in jackfruit seed flour was 1.28 $\mu g\ g^{-1}$, 0.42 $\mu g\ g^{-1}$, 0.31 $\mu g\ g^{-1}$and 0.62 $\mu g\ g^{-1}$ in F_1, F_2, F_3 treatments respectively. Raffinose content was found to reduce in these three treatments and F_1 ie; 6 hours fermentation was selected as the best treatment.

Table 101. Quantification of Oligosaccharide (Raffinose) content in jackfruit seed flour with different duration of fermentation

Treatments	Retention Factor	Area (AU)	Amount ($\mu g\ g^{-1}$)
Standard	0.57	4999.8	-
F_0 (control)	0.57	6413.5	1.28
F_1 6 hrs	0.57	2107.8	0.42
F_2 8 hrs	0.57	1596.2	0.31
F_3 12 hrs	0.57	3100.1	0.62

Table 102. One way interaction effect of fermentation time and edible portions of jackfruit on raffinose content

Treatments	Raffinose (µg g^{-1})
Fermentation time	
F_0	**1.02**
F_1	0.52
F_2	0.45
F_3	0.68
SEm ±	0.003
CD	0.010
Edible portion	
E_1	**0.68**
E_2	**0.66**
SEm ±	0.002
CD	0.007

Values are means of triplicates
SEm : standard error of the mean

Table 102 shows the effect of fermentation time and edible portions. Here it was revealed that F_0 (control) contained 1.02 µg g^{-1} and the raffinose content was reduced in treatment F_2 (8 hrs fermentation) to 0.45 µg g^{-1}. With respect to edible portions it was observed that E_1 (Bulb flour) contained 0.68 µg g^{-1} and E_2 (Seed flour) contained 0.66 µg g^{-1}.

Table 103. Two way interaction effect of fermentation time and edible portions on raffinose content

Treatments	Raffinose (µg g^{-1})
F_0E_1	0.75
F_0E_2	**1.28**
F_1E_1	0.62
F_1E_2	0.42
F_2E_1	0.58
F_2E_2	0.31
F_3E_1	0.74
F_3E_2	0.62
SEm ±	0.004
CD	0.014

Values are means of triplicates
SEm : standard error of the mean

Table 103 shows the two way interaction effect of varying fermentation time and edible portions. The results revealed that F_0E_1 (Bulb flour control) contained 0.75 µg g^{-1} and F_0E_2 (Seed flour control) contained 1.28 µg g^{-1}. The lowest raffinose content was observed in F_2E_2 – seed flour fermented for 8 hour (0.31 µg g^{-1}) followed by F_1E_2 – seed flour fermented for 6 hour (0.42 µg g^{-1}), F_2E_1 – bulb flour fermented for 8 hour (0.58 µg g^{-1}).

4.2.3. Antinutrient levels of selected enzyme treated flour

Table 104 shows the antinutritional levels of untreated and enzyme treated flour. From this table it is observed that antinutrients such as oligosaccharides, tannins, phytates and trypsin inhibitors were reduced after enzyme treating. From this result it was observed that oligosaccharide content in bulb flour was reduced from 0.97 - 0.71µg and seed flour from 1.16 - 0.50µg.Tannin content in the bulb flour was 23.34 mg, which was reduced upto 8.80mg and from seed flour 36.52 mg to 11.87 mg. Phytates and trypsin inhibitors are the other two major antinutrients present in jackfruit. The level of phytates present in untreated bulb flour was 12.63 mg which was reduced upto 8.56mg and the seed flour contained

15.68 mg, which was reduced to 10.33mg. The level of trypsin inhibitors in untreated bulb flour was 38.22 mg to 18.83mg and from seed flour 42.35 to 23.50mg.

Table 104. Antinutritional levels of untreated and enzyme treated flour

Parameters	Untreated Flours		Enzyme Treated Flours	
	Bulb Flour	Seed Flour	Bulb Flour (M_4)	Seed Flour (M_5)
Oligosaccharides (µg)	0.97	1.16	0.71	0.50
Tannins (mg)	23.34	36.52	8.80	11.87
Phytates (mg)	12.63	15.68	8.56	10.33
Trypsin inhibitors (mg)	38.22	42.35	18.83	23.50

4.2.4. Antinutrient levels of selected yeast treated flour

Table 105 shows the antinutritional levels of pretreated and yeast treated flour. Yeast fermented bulb flour and seed flour showed reduction in the antinutrient contents from raw flour. In the case of bulb flour, tannin content was reduced from 23.34 mg to 10.32 mg, phytates from 12.63mg to 7.04 mg, trypsin inhibitors from 38.22mg to 18.50mg. Fermented foods plays an important role in conferring the required stability, safety and sensory properties to the product (Stanton et al., 2005). Fermentation helps in degradation of antinutritional factors and increases mineral bioavailability, protein digestibility of tannin rich cereals, and degradation of flatulence causing oligosaccharides.

From this table it was observed that antinutrients such as oligosaccharides, tannins, phytates and trypsin inhibitors were reduced in both enzyme treated and yeast fermented flours. From these two treatments fermentation process was selected as the best treatment because of its ease of processing.

Table 105. Antinutritional levels of untreated and yeast treated flour

Parameters	Untreated Flours (F_0)		Yeast Treated Flours (F_2)	
	Bulb Flour	Seed Flour	Bulb Flour	Seed Flour
Oligosaccharides ($\mu g\ g^{-1}$)	0.75	1.28	0.58	0.31
Tannins (mg)	23.34	36.52	7.45	10.32
Phytates (mg)	12.63	15.68	7.04	9.33
Trypsin inhibitors (mg)	38.22	42.35	16.83	18.50

4.2.5. Storage studies

Storage studies are essential parameters to be assessed, since they determine the suitability of a particular ingredient for product development. Among the two types of treatments studied, based on the reduction of oligosaccharide content, ease of fermentation, economy and availability of raw materials, treatment with *Saccharomyces cerevisiae* (yeast) for 8 hours was selected as the best treatment for both jackfruit seed and bulb flour.

For the storage study, cleaned jackfruit bulbs and seeds were cut into thin slices. They were then blanched and dried below 50^0 C in the electric drier for 6-7 hours. Proper care was given to avoid the cross contamination from other foreign particles. Properly dried bulbs and seeds were powdered and sieved properly and stored in ambient condition. The stored powder was then examined for moisture content, peroxide value and microbial growth initially and up to a period of six months.

4.2.5.1. Moisture levels of treated flour

Moisture content is one of the important properties of food materials to be considered. Knowledge of the moisture content is often necessary to predict the behaviour of foods during processing. For estimating the moisture content, the

selected best treatment was packed in PP covers, sealed air tight and stored at ambient conditions. The moisture content was recorded periodically up to 6 months and the data is shown in Table 106. Compared to enzyme treated flours, moisture level was lower in yeast fermented flours. During the initial storage period, the moisture content obtained for bulb flour was 7.63 per cent and seed flour was 7.41 per cent and it was seen to increase after each month of storage period.

Table 106. Moisture level of selected treated flour (%)

Period of study	Enzyme treated Bulb flour	Enzyme treated Seed flour	Yeast fermented Bulb flour	Yeast fermented Seed flour
Initial	8.55	7.52	7.63	7.41
Ist Month	8.59	7.61	7.70	7.53
IInd Month	8.71	7.68	7.92	7.74
IIIrd Month	8.93	7.95	8.21	7.92
IVth Month	8.98	8.12	8.36	8.15
Vth Month	9.13	8.16	8.39	8.21
VIth Month	9.17	8.23	8.47	8.28

4.2.5.2. Microbial load of the selected treated bulb flour and seed flour

It was evident from the tables (107&108) that during six months of storage period bacterial colonies were observed from the Vth month and VIth month ($2x10^7$ cfu g^{-1}). Simultaneosly, fungi were detected from the IInd month onwards in enzyme treated bulb flour (1.5×10^3 cfu g^{-1}) and IIIrd month onwards in yeast treated jackfruit bulb flour ($3x10^3$ cfu g^{-1}) and seed flour (2×10^3 cfu g^{-1}). Even though bacteria and fungi were detected, they were present within the permissible limit. However after fourth month the level of fungal colonies were above the permissible limits (4×10^4 cfu g^{-1}). No coliforms could be detected in both enzyme treated and yeast fermented flours.

Table 107. Microbial load of the selected enzyme treated bulb and seed flours

Storage Period	Bacteria (cfu x 10^7 g^{-1})		Fungi (cfu x 10^3 g^{-1})		Coliforms (cfu x 10^7 g^{-1})	
	Bulb flour	Seed Flour	Bulb flour	Seed Flour	Bulb flour	Seed Flour
Initial	ND	ND	ND	ND	ND	ND
Ist Month	ND	ND	ND	ND	ND	ND
IInd Month	ND	ND	1.5	ND	ND	ND
IIIrd Month	ND	ND	3.0	2.0	ND	ND
IVth Month	ND	ND	3.0	3.0	ND	ND
Vth Month	2.0	2.0	5.0	5.0	ND	ND
VIth Month	3.0	2.0	5.0	5.0	ND	ND

Table 108. Microbial load of the selected fermented bulb flour and seed flour

Storage Period	Bacteria (cfu x 10^7 g^{-1})		Fungi (cfu x 10^3 g^{-1})		Coliforms (cfu x 10^7 g^{-1})	
	Bulb flour	Seed Flour	Bulb flour	Seed Flour	Bulb flour	Seed Flour
Initial	ND	ND	ND	ND	ND	ND
Ist Month	ND	ND	ND	ND	ND	ND
IInd Month	ND	ND	ND	ND	ND	ND
IIIrd Month	ND	ND	3.0	2.0	ND	ND
IVth Month	ND	ND	3.0	3.0	ND	ND
Vth Month	2.0	2.0	4.0	4.0	ND	ND
VIth Month	2.0	2.0	4.0	4.0	ND	ND

4.2.5.3. Peroxide value (mEq/Kg^{-1}) of selected treatments

Peroxide value gives an indication about the extent of peroxidation having taken place in stored food materials. The peroxide value was recorded for a period of six months. The peroxide content was not observed for both enzyme treated and yeast fermented bulb flour and seed flour for the first three months of the study. The above table indicates that the enzyme treated bulb flour reported peroxide contents from the IVth Month (0.24 mEq Kg^{-1}), which rise on the Vth Month (0.26 mEq Kg^{-1}) and VIth Month(0.27 mEq Kg^{-1}). In the case of enzyme treated seed flour, the peroxide content was observed from Vth Month (0.19 mEq Kg^{-1}) and VIth Month(0.21 mEq Kg^{-1}).

Table 109. Peroxide value (mEq Kg^{-1}) of selected best treatments

Period of study	Enzyme treated Bulb flour	Enzyme treated Seed flour	Yeast fermented Bulb flour	Yeast fermented Seed flour
Initial	0	0	0	0
Ist Month	0	0	0	0
IInd Month	0	0	0	0
IIIrd Month	0	0	0	0
IVth Month	0.24	0	0.21	0.20
Vth Month	0.26	0.19	0.23	021
VIth Month	0.27	0.21	0.24	0.23

In the case of yeast fermented bulb flour, peroxide formation was observed from the IVth month (0.21 mEq Kg^{-1}), which rise in the Vth month (0.23 mEq Kg^{-1}) and VIth month(0.24 mEq Kg^{-1}) and in the case of seed flour, peroxide content was observed in the IVth month (0.20 mEq Kg^{-1}),which increased in the Vth month (0.21 mEq Kg^{-1}) and VIth month (0.23 mEq Kg^{-1}). However it could be noted that the peroxide contents in all the samples were within the permitted limits. This shows that both the enzyme treated and yeast fermented bulb flour and seed flour

can be stored for a period of six months without any discriminate changes, thereby enhancing their market values.

To conclude the second part of the experiment, the results show that the level of Raffinose after treatment (enzyme) with bulb flour and seed flour was seen to decrease with increase in moisture content (25-100%). Thereafter the content slightly staggered and then reduced (125%, 150%, 175%, 200%). However the level of oligosaccharides decreased in comparison to levels in control (0.97 μg g^{-1}). When flours were to be made into batter and subjected to fermentation with *Saccharomyces cerevisiae,* raffinose content in jackfruit bulb flour and seed flour reduced after 6, 8 and 12 hours of fermentation. Considering the reduction of raffinose content and sensory evaluation of the treated flour, eight hour fermentation (F_2) was selected as the best treatment.

4.3. Development of raw jackfruit based textured vegetable protein

A meat analogue or textured vegetable protein was standardized from the jackfruit bulb flour, jackfruit seed flour and gluten and subjected to quality analysis.

4.3.1. Cooking characteristics

Cooking not only affects sensory qualities but also leads to changes in physical and chemical properties of food. The chunks formed from the eleven treatments were subjected to cooking procedures and analysed for their cooking characters. From these procedures the best treatment was identified.

4.3.1. a. *Appearance*

Appearance is the criteria for the desirability of any food product. Cooked TVP was evaluated for overall visual quality (OVQ), by the sensory panel. On evaluation of OVQ scores, the treatment P_7 got highest score (93.50), which was on par with P_8 (86.50), P_{10} (86.50) and P_{11} (82.10). The lowest score was obtained by P_4 (11.35) followed by P_5 (15.75). The scores obtained for other treatments were 47.75, 39.70, 42.30, and 35.55 for P_1, P_2, P_3 and P_6 (Table 110).

Table 110. Overall Visual Quality (OVQ) of cooked TVP

Sl.No.	Treatment	G	JFBF	JFSF	OVQ Scores
1	P_1	50	20	30	47.75^{c}
2	P_2	50	30	20	39.70^{cd}
3	P_3	50	10	40	42.30^{c}
4	P_4	50	25	25	11.35^{e}
5	P_5	50	-	50	15.75^{e}
6	P_6	50	50	-	35.55^{cd}
7	P_7	70	20	10	93.50^{a}
8	P_8	70	10	20	86.50^{ab}
9	P_9	70	15	15	69.50^{b}
10	P_{10}	70	-	30	86.50^{ab}
11	P_{11}	70	30	-	82.10^{ab}
CD (0.05)					18.31

(Results are expressed as mean values of ten replicates)

4.3.1.b. *Cooking Time*

Cooking time is the time taken for the white core to disappear when the sample is boiled in water (Chen et al., 2002). Products which need less energy to cook have great demand, hence cooking time of the developed products were determined. Statistical interpretation showed (Table 111.) that there was significant difference in cooking time among the treatments. Cooking time of the different treatments ranged from 7.33 min to 15.0 min. The results further revealed that among the treatments P_7 took the least time (7.33 min) for cooking. The second treatment which took less time for cooking was P_8 and P_9 (7.66 min) and it was seen to be par with P_{10} (8.33 min) and P_{11} (8.66 min). More time was taken for cooking P_4 (15.0 min), which was followed by P_1 (14.66 min) and P_2 (14.33 min). P_5 took 11.0 min for cooking which was on par with P_6 (10.33 min) and P_3 (10.33 min).

Table 111. Cooking characteristics of TVP

Sl.No.	Treatment	G	JFBF	JFSF	Cooking Time (Min)	Cooked Weight (g)
1	P_1	50	20	30	14.66	29.93
2	P_2	50	30	20	14.33	26.16
3	P_3	50	10	40	10.33	29.93
4	P_4	50	25	25	15.00	41.23
5	P_5	50	-	50	11.00	29.73
6	P_6	50	50	-	10.33	29.63
7	P_7	70	20	10	7.33	24.96
8	P_8	70	10	20	7.66	23.43
9	P_9	70	15	15	7.66	23.56
10	P_{10}	70	-	30	8.33	23.33
11	P_{11}	70	30	-	8.66	24.93
CD (0.05)					1.021	0.347

(Results are expressed as mean values of three replicates)

4.3.1.c. *Cooked Weight*

Cooked weight is an indicator of the extent of absorption of moisture by a food after complete cooking. It was determined by assessing the increase in weight of raw material (10 g) after complete cooking. Cooked weight of TVP was calculated as the increase in weight of raw TVP after cooking. The data revealed that highest increase of weight was obtained for P_4 (41.23g) and the lowest weight was obtained for P_{10} (23.33 g), which was on par with P_8 (23.43 g) and P_9 (23.56 g). The next highest score was obtained by P_3 (29.93) and P_1 (29.93) which were on par with P_5 (29.73) and P_6 (29.63). The scores obtained for P_2, P_7, P_{11} were 26.16, 24.96, 24.93 respectively. Table 111. indicates that all the treatments were significantly different.

4.3.2. Sensory evaluation of TVP

Sensory evaluation is a scientific discipline that analyses and measures human responses to the composition and nature of foods and drink with respect to appearance, touch, odour, texture and taste. Food sensory analysis is the use of the human senses to objectively analyse foods – for properties such as taste, flavour and texture. It is used in assessing the quality of products, troubleshooting problems and new product development (Munishamanna, 2012). Sensory evaluation does not just deal with likes and dislikes, but the process scientifically elicits, measures, analyses and interprets psychological and physiological responses to physical stimuli produced by a food product. All the eleven treatments were cooked and evaluated by ten panel members for favour of standardizing.

Standardization plays a key role in product development, which facilitates the growth of food industries. A standardized recipe is one that has been tried, adopted and retried several times for use by a given food service and which has been found to produce the same acceptable results and yield, each time when the exact procedures are used with the same type of equipment and the same quantity and quality of ingredients. One of the foremost purpose of standardization is to

Table 112. Sensory evaluation of textured vegetable protein (TVP)

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	69.60	47.70	42.85	60.25	58.50	41.90
T_2	60.80	51.55	45.00	60.25	58.50	36.30
T_3	47.40	43.70	51.85	39.40	40.05	59.40
T_4	15.15	35.90	46.35	25.50	24.45	35.10
T_5	22.80	39.85	46.75	28.20	34.40	55.90
T_6	35.10	55.30	71.05	35.80	40.05	63.50
T_7	99.60	91.75	83.40	101.70	100.15	92.40
T_8	88.40	78.60	63.40	91.30	93.35	72.30
T_9	79.40	67.05	54.00	75.50	69.55	55.90
T_{10}	51.00	51.50	51.45	52.40	50.00	49.50
T_{11}	41.25	47.60	54.40	41.60	41.50	48.30
(CV 0.05%)	18.31					

(Values indicated are mean rank values of ten members)

facilitate the smooth movement of materials and products through all stages of production in any industrial activity, starting from the raw material to the finished products, then to the dealer and finally to the retailers and consumers (Akanbi et al., 2011).

Appearance is the one of the important criteria for the desirability of any food product. From Table 112, it is observed that T_7 scored the highest (99.60) among all the eleven treatments for appearance. Treatment T_7 was immediately followed by T_8 with a score of 88.40. The lowest score was obtained for T_4 (15.15). The values obtained for other treatments were 79.40, 69.60, 60.80, 51.00, 47.40, 41.25, 35.10 and 22.80 for T_9, T_1, T_2, T_{10}, T_3, T_{11}, T_6, T_5 respectively. From this table it was observed that T_7 and T_8 were on par.

Colour is another important visual attribute that has been used to judge the overall quality of products. If the colour is unattractive, a potential consumer may not be impressed by any other attributes. The highest score was secured by T_7 (91.75) followed by T_8 (78.60), T_9 (67.05), T_6 (55.30), T_2 (51.55), T_{10} (51.50), T_1 (47.70), T_{11} (47.60), T_3 (43.70), T_5 (39.85) and T_4 (35.90). It was observed that T_7 and T_8 were on par and other treatments were significantly different from each other.

Taste is one of the major attributes which determines the acceptability of a food. Taste is the sensation produced when a substance in the mouth reacts chemically with receptors of taste buds. The highest score was obtained by T_7 (100.15) followed by T_8 (93.35), T_9 (69.55), T_1 (58.50), T_2 (58.50), T_{10} (50.00), T_{11} (41.50), T_3 (40.05), T_6 (40.05), T_5 (34.40) and the lowest score was obtained by T_4 (24.45). From this table it is observed that T_7 and T_8 were on par and significantly different from other treatments.

Odour preference is generated by stimulation of sensory cells by specific volatile compounds present in foods. The highest score was obtained by T_7 (83.40) followed by T_6 (71.05), T_8 (63.40), T_{11} (54.40), T_9 (54.00), T_3 (51.85), T_{10} (51.45), T_5 (46.75), T_4 (46.35), T_2 (45.00) and the lowest score was obtained by

T_1 (42.85). The treatments T_6, T_7 and T_8 were on par and other treatments were significantly different from these three.

Texture contributes to the physical property of food stuffs as apprehended by the eye, skin and muscle senses located in the mouth. In the case of TVP, texture is an important parameter that is to be considered. The highest score was obtained by T_7 (101.70) which was followed by T_8 (91.30), T_9 (75.50), T_1 (60.25), T_2 (60.25), T_{10} (52.40), T_{11} (41.60), T_3 (39.40), T_6 (35.80), T_5 (28.20) and the lowest score was obtained by T_4 (25.50). The treatments T_7, T_8 and T_9 were on par and other treatments were significantly different from these. Based on the sensory attributes such as appearance, colour, flavour, texture and taste (overall acceptability) the highest score was obtained for T_7 which was followed by T_8. The lowest score was obtained by treatment T_4 (35.10). Thus T_7 was identified as the best treatment.

4.3.3. Quality analysis of TVP

The functional, nutritional, chemical composition and shelf stability of the finalized product were ascertained using standard procedures.

4.3.3.1. Functional quality analysis of TVP

Functional properties describe how ingredients behave during preparation and cooking, how they affect the finished food product in terms of how it looks, tastes, and feels. The functional qualities help in the quality assessment and acceptability of any product. Functional qualities such as yield, appearance, rehydration ratio and water absorption index were studied.

4.3.3.1.a. *Yield of TVP*

Estimation of yield percent in food processing will be useful in determining cost of product. The yield per cent of the TVP was calculated on dry weight basis. Drying removes moisture, as a result the product shrinks and decreases in size and weight, thus requiring less space for storage. Mostly foods

Table 113. Functional quality analysis of TVP

Sl.No.	Treatment	G	JFBF	JFSF	Yield	Rehydration Ratio	Water Absorption Index
1	P_1	50	20	30	0.670	0.417	111.33
2	P_2	50	30	20	0.670	0.413	120.00
3	P_3	50	10	40	0.770	0.413	121.66
4	P_4	50	25	25	0.746	0.416	131.33
5	P_5	50	-	50	0.723	0.416	140.66
6	P_6	50	50	-	0.693	0.415	138.33
7	P_7	70	20	10	0.750	0.423	104.33
8	P_8	70	10	20	0.723	0.423	109.33
9	P_9	70	15	15	0.650	0.456	105.33
10	P_{10}	70	-	30	0.670	0.456	126.33
11	P_{11}	70	30	-	0.683	0.456	123.66
CD (0.05)					0.010	0.008	1.068

lose volume or weight as they are processed. Yield of dried products are directly related to how much water is contained in the original product. Yield ratio of the different combinations were analysed and the results are presented in the Table 113. Yield ratio of different treatments ranged from 0.650 - 0.770 per cent. Results further reveal that P_3 having G: JFBF: JFSF in the ratio of 50:10:40 had the highest value (0.770). The lowest value was obtained by P_9 (0.650). Yield ratio obtained for other treatments were 0.670, 0.670, 0.746, 0.723, 0.693, 0.750, 0.723, 0.670 and 0.683 for P_1, P_2, P_4, P_5, P_6, P_7, P_8, P_{10}, P_{11} respectively.

4.3.3.1.b. *Texture*

Texture analysis is the mechanical testing of food products in order to measure their physical properties. Problematic textural issues occurring during storage or transportation can be overcome by texture analysis. It may also prove to be an effective means of comparison with competitive products, or where claim substantiation is necessary to take a technical proactive stance in market. In this context texture analysis can serve as an effective tool for assessment (Lambo *et al.*, 2005). Crispness, hardness, toughness, and firmness are the textural properties that are generally on the same property spectrum. Cohesiveness is the tendancy of a product to cohere or stick together. Texture profile analysis showed that the crispness value obtained for TVP was 2.22 and Soyachunks was 0.42. Hardness value obtained for TVP was 1.32 and chunks was 1.02. Values for stringiness is an important attribute for which TVP had 22.20 and soya chunks had 17.04.

4.3.3.1.c. *Rehydration Ratio*

Rehydration is an essential parameter to analyze dried products. A high value of rehydration ratio means the dried product has a good quality because the pores allow water to renter the cells (Noomhorm, 2007). Rehydration is a process which is aimed at restoring the properties of a raw material when the dried material comes in contact with water (An *et al.*, 2013). Rehydration ratio was highest for the treatments P_9, P_{10}, P_{11} (0.456) followed by P_7 and P_8 (0.423). Treatments P_2 and P_3 (0.413) had the least rehydration ratio. The rehydration ratio

obtained for other treatments were 0.417, 0.416, 0.416, 0.415 for P_1, P_4, P_5, P_6 respectively.

Table 114. Textural properties of Textured vegetable protein (TVP)

Textural Properties	Control (Soya chunks)	TVP
Crispness	0.42	2.22
Hardness (N)	1.02	1.32
Toughness	1.08	1.22
Firmness	1.08	1.34
Work of penetration	2.05	1.51
Rupture strength	1.08	1.22
Work of cutting	2.05	1.51
Cohesiveness	0.02	0.02
Stringiness (s)	17.04	22.20
Crunchiness	0.80	0.42
CD (0.05)	1.12	0.60

4.3.3.1.d. *Water Absorption Index (WAI)*

Water absorption index, an indicator of the ability of flour to absorb water, depends on the availability of hydrophilic groups which binds to water molecules and on the gel forming capacity of macromolecules. Nevertheless highest WAI denotes the excellent binding capacity of ingredients. Water absorption is the increase in weight of dried products after cooking in boiling water according to their cooking time (Purwandari *et al.*, 2014). Water absorption index of the treatments are represented in the Table 113. The values ranged from 104.33 - 140.66 per cent. Water absorption of TVP was found to be higher in P_5 (140.66) treatment which contained more amount of seed flour. The treatment P_6 (138.33) was on par with P_5 which contained more amount of bulb flour. In these treatments it was seen that the increase in concentration of both bulb flour and seed flour increased water absorption.

4.3.3.2. Nutrient content and chemical composition of TVP

In recent years, there have been significant changes in the preference of consumers for exotic foods that are healthier and have higher nutritional quality. Traditional foods more or less satisfy these parameters adequately. New food products should thus be developed based on these principles. Individual food manufacturers must respond rapidly to these changes in order to remain competitive within the food industry. Table 115 shows the nutrient composition of finalized TVP. The nutrients analyzed were carbohydrates, total protein, fat, calories, fiber and total minerals. The carbohydrate content of the finalized TVP was 34.97 g/ 100g, total protein content 61.50g/100 g, fat 14.40g/100g, calories 440.26 Kcal, fiber 4.20g/100g and total minerals 2.4g/100g.

Table 115. Nutrient Composition of finalized TVP

Nutrient/ chemical composition	Content in TVP (100g)
Total Protein (g)	61.50
Carbohydrates (g)	34.97
Fats (g)	14.40
Calories (K cal)	440.26
Fiber (g)	4.20
Total minerals (g)	2.40

4.3.4. Storage studies

The shelf life of a food is the time period within which the food is safe to consume and has an acceptable quality to consumers. Shelf stability of a product depends upon many factors like the raw materials used and chemical composition of the product. Shelf life study of the finalized TVP was conducted for three consecutive months. At intervals of one month, the finalized TVP were analysed for moisture content and microbial growth.

4.3.4.1 Moisture level of the TVP

Moisture content is one of the most commonly measured properties of food materials. Knowledge of the moisture content is often necessary to predict the behaviour of foods during processing. The moisture content of the developed jackfruit based TVP in PP covers was analysed. The evaluation of TVP was conducted periodically for three months and the data is shown in Table 116. Initial moisture content of TVP was 7.41 per cent. At the end of first month TVP showed little increase (7.65) in moisture content. At the end of second month of storage moisture content of TVP was 8.72. The moisture content increased further by the end of third month. However the levels were within permitted limits of safety.

Table 116. Moisture level of the finalized TVP

Sl.No.	Storage Period	TVP
1.	Initial	7.41
2.	Ist Month	7.65
3.	IInd Month	8.72
4.	IIIrd Month	8.89
CD (0.05)		0.033

4.3.4.2 Assessment of Microbial profile of the TVP

Assessment of microbial profile is an important factor, which help to determine the quality and safety of the product. Microbial contamination of the TVP developed in the study was assessed to determine the keeping quality of the products. There are a lot of chances of contamination through various means including conditions of storage of the products. It is evident from Table 117, that during the three months of storage period, bacterial colonies were found to appear in the third month of storage (1.0×10^7) in developed TVP, while fungal colonies

were observed from the second (1.5×10^3) month. Even though bacteria and fungi were detected, it was in negligible levels and within the permissible limits. No colifrms could be detected in the product.

Table 117. Microbial Profile of the finalized TVP

Sl.No.	Storage Period	Bacteria (cfu x 10^7 g^{-1})	Fungi (cfu x 10^3 g^{-1})	Coliforms (cfu x 10^7 g^{-1})
1.	Initial	ND	ND	ND
2.	Ist Month	ND	ND	ND
3.	IInd Month	ND	1.5	ND
4.	IIIrd Month	1.0	3.0	ND

The demand for convenience foods among the literate consumers is on the rise around the globe. It has been argued that convenience is a barrier to achieving proper nutrition using adequate servings. In order to incorporate the fruit based nutritional benefits, it has become important to develop newer and novel foods that could reach the consumers' acceptance. With this background an attempt was visualized to develop jackfruit based textured vegetable protein (TVP) to make jackfruit more popular among the health conscious people. The physico chemical and textural qualities of the developed product were on par with soyachunks available in the market. Processed TVP showed good storage stability up to three months. The third part of the study concluded with a positive note on scope of commercializing this jackfruit based protein concentrate. The product is both novel and healthy, raising its scope for scaling up. To sell the product in the market the total cost of the product was calculated by assessing fixed cost and variable cost. The cost of the developed product was Rs. 24.09 (Fixed cost Rs. 21.9 and variable cost Rs. 2.19).

Discussion

5. DISCUSSION

The results obtained from the present study entitled ''Profiling bioactive compounds and nutrients in jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein'' are discussed in this chapter under the following heads:

5.1. Nutrient content, chemical composition of the selected types and the antioxidant activity of jackfruit

5.2. Analysis of measures for reducing antinutrients in raw jackfruit

5.3. Development of raw jackfruit based textured vegetable protein

5.1. NUTRIENT CONTENT, CHEMICAL COMPOSITION OF THE SELECTED TYPES AND THE ANTIOXIDANT ACTIVITY OF JACKFRUIT

Jackfruit is locally called kathal and has gained the position as the national fruit of Bangladesh because of its popularity and various other outstanding features.

Jackfruit is a multiple fruit, consisting of edible (pulp and seed) and non edible (rind and rachis) portions. Tender green fruit is used as a vegetable. The juicy pulp of the ripe fruit is eaten fresh as dessert. Seeds are normally discarded or streamed and eaten as a snack, or used in some local dishes. The seeds are eaten cooked, roasted, or fried. Jams, beverages, candies, preserves, and dehydrated forms are other industrial uses for the jackfruit (Naik, 1949).

This fruit can also provide protein and carbohydrates for the body, which will result in more strength for the individual. The proximate composition of two varieties of jackfruit seeds were studied, and considerable biochemical difference between the two varieties was reported by Kumar *et al.* (1988). Jackfruit provides

approximately 2 MJ of energy per kilogram of wet weight of ripe perianth (Ahmed *et al.*, 1986).

5.1.1. Proximate Composition, Vitamins and Minerals

For the purpose of nutrient and chemical profiling, four varikka types namely Muttom varikka, Then varikka, Sindoor and Chembikalom varikka and a Local cv Koozha types were selected. Both the ripe and raw stages of seeds and bulbs were analysed separately (Ripa *et al.*, 2009).

In proximate analysis carbohydrate, protein, fat, fiber and moisture were analyzed. The nutrient compositions of jack fruit were comparable to those of most common fruits (Pourmorad *et al.*, 2006; Goswami *et al.*, 2011).. Jackfruit seed was found to be richer in carbohydrate, crude protein, fat, fiber, ash and in all the minerals studied than the pulp, while the pulp was richer in vitamins A, C, E, and the B vitamins (B1, B2, B3, folic acid). The ripe bulbs are rich in sugar (21 to 30%), low in starch content (0.7 to 5.0%) and contain a fair amount of carotenoids (34 to 800 µg/100 g) and vitamins C (Jagadeesh *et al.*, 2007; Faria *et al.*, 2009).

Anneahira (2010) stated that the jackfruit – in particular the seeds are known to contain a lot of carbohydrates, proteins and minerals (calcium and phosphorus). In the present study, the results reveal that Chempikalom varikka had the highest carbohydrate content (34.69g/100g) which was significantly higher from others. The lowest carbohydrate content was seen in Then varikka (11.06g/100g) followed by Muttom varikka (15.36). Sindoor contained 21.11g/100g which was on par with Local cv Koozha 21.24g. In the case of stages of maturity, ripe jackfruit (22.63g/100g) contained significantly higher carbohydrate than raw stage of jackfruit (18.76g/100g), both these values were significantly different too. Carbohydrate content in edible portions showed that jackfruit bulbs had higher content (21.00g/100g) than jackfruit seed (20.39g/100g). The carbohydrate content of the various edible portions were also significantly different.

In the current study, the highest protein content was obtained for Local cv Koozha ripe seeds (6.25g/100g) and the lowest value was obtained in Muttom varikka raw bulbs (1.12g/100g) followed by Muttom varikka ripe bulbs (1.27g/100g). The protein content obtained for Sindoor raw seeds was 4.80g which was on par with Koozha raw bulb (4.76g) and Chempikalom ripe seeds (4.75g). Bobbio *et al.* (1978) reported the protein content in the jack fruit seeds as 12.3 per cent. Tulyathan *et al.* (2002) have reported the jack fruit seeds contained 11.17 per cent. Berry and Kalra (1988) reported that in jack fruit seeds the protein content was 6.6 per cent. Begum *et al.* (1989) reported that in jack fruit seeds protein content was 13.6 g. In the present study the protein content values were higher. Jack fruit seed flour had high protein content (14.66 g). Thus, jack fruit seed flour can be substituted in the place of corn flour in common recipes to improve their protein content. Sirisha *et al.* (2014) reported that The total protein content was estimated in five varieties of Artocarpus seed extract. It was reported to be more in *A.hircitus* with 40.3±1.2 mg/gm of extract followed by *A.heterophyllus* with 37.3± 1 and *A. integer* with 37.3±0.9 mg/gm and was low in *A. integrifolia* (33.6±1.2) and *A. incisus* with 33.3±0.8 mg/gm of extract.

Fibers are less digestible, but fiber rich foods can modulate the digestive processes and thereby improve absorption in the human body (McCleary, 1999). In the present study, the highest fibre content was obtained for Local cv Koozha raw bulbs (2.38g) which was followed by Koozha ripe bulbs (2.09g) and the lowest value was obtained for Sindoor ripe seeds (1.05g). The ripe stage of Chempikalom bulbs contained 1.93g which was on par with raw stage of Sindoor bulbs (1.88g). Berry and Kalra (1998) reported that the fiber content of the jack fruit seed was 1.5 per cent. Kumari and Grewal (2007) in a study reported that diets lacking in fibre may be the cause of various lifestyle disorders including gastrointestinal and cardiovascular diseases.

Water is elixir of life, playing a critical role in the physical and chemical functions of our bodies. Measuring the amount of water contained in certain materials can be very difficult due to the complexity of the water molecules and

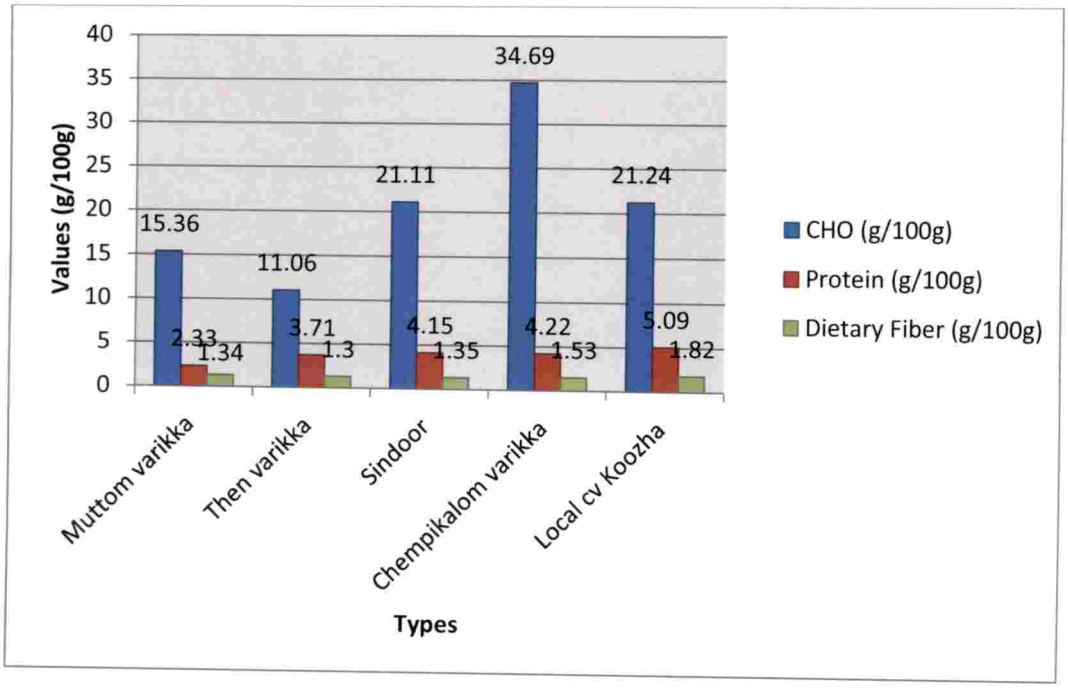


Figure 4. Proximate composition of selected jackfruit types

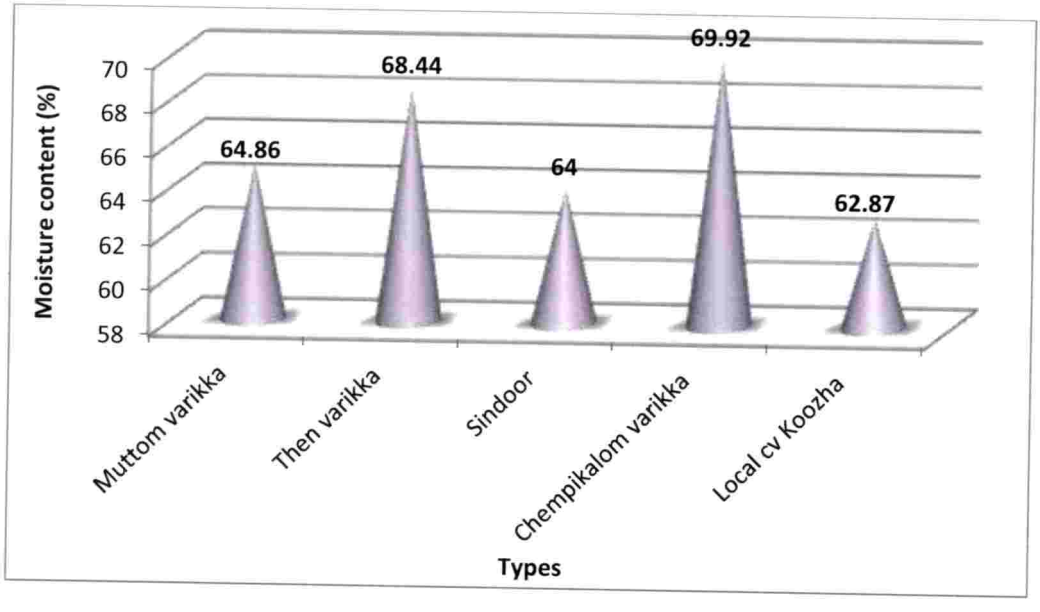


Figure 5. Moisture level of selected jackfruit types

its strong intermolecular bonding capabilities. In most cases measurement of water is better defined as the measurement of moisture content. In the present study, the highest moisture content was observed in Sindoor ripe bulbs (85.37%) and Then varikka ripe bulbs (85.01%). The lowest value was observed in Local cv Koozha raw seeds (47.42%). The next highest moisture content was observed in Chempikalom ripe bulbs (82.88%) which was followed by Muttom varikka ripe bulbs (81.42%) and Local cv Koozha ripe flakes (81.15%). Berry and Kalra (1988) reported that the moisture content in the seeds was 31.6 per cent and in the jack fruit seed starch it was 13 per cent. Bobbio *et al.* (1978) have reported that the 13 per cent moisture content in the jack fruit seed starch. Okudu (2015) reported that the moisture content of the pulp (89.5g/100g) was significantly ($p<0.05$) higher than that of the seed (10.3g/100g) but the crude protein, crude fat, crude fiber, ash and carbohydrate of the seed (16.3, 5.3, 4.3, 5.3, 58.4g/100g) were however significantly higher ($p<0.05$) than that of pulp (3.3, 0.76, 1.1, 1.1, 4.3g/100g).

Nutritional studies have demonstrated potential benefits of jackfruit seeds. Moisture content and dry matter analysis is very important because it directly affects its nutritional content, its stability and storage. Proximal values of jackfruit seeds were found to be rich in proteins (11.85 ± 0.45g) and carbohydrates (26.20 ± 0.56). Moisture content (61.8 ± 0.09) was also very high, crude fat (1 ± 0.006) and ash content (0.15 ± 0.01) were found to be very low (Gupta *et al.*, 2011).

In the present study, the results revealed that the beta carotene content was higher in Sindoor (253.86 µg) which was followed by Then varikka (166.78 µg). In the case of stages of maturity the ripe stages of jackfruit contained 129.30 µg and raw stage contained 100.51 µg. The edible portions of the jackfruit bulb contained 187.65 µg and the jackfruit seeds contained 42.16 µg. Analysing the interaction effects of types, stages and edible portion, the highest content was obtained for Sindoor ripe flakes (503.21 µg) which was followed by Sindoor raw flakes (389.21 µg). The lowest content was observed in Chempikalom raw seeds (26.83 µg). The IOM (Institute of Medicine, 2001) states that consuming 3 - 6 mg

of beta-carotene daily (equivalent to 833 IU to 1,667 IU vitamin A) will maintain blood levels of beta-carotene in the range associated with a lower risk of chronic diseases. In a study conducted by Jahan *et al.* (2011), it was reported that the highest amount of beta carotene was found in jackfruit, 4401.82µg (4.40mg) and lowest amount was found in blackberry, 1112.38 µg (1.11mg).

In the present study, the Vitamin C content was higher in Sindoor (21.30 mg) which was followed by Local cv koozha (20.84 mg) and Chempikalom varikka (20.68 mg). The lowest content was observed in Muttom varikka (19.14 mg). In the case of stages of maturity the ripe stage of jackfruit contained 21.09 mg of Vitamin C and raw stage contained 19.91 mg. The edible portions of the jackfruit bulb contained 20.35mg and the jackfruit seeds contained 20.65mg. The interaction effects of types, stages and edible portion (Three way interaction effect) revealed that the highest content was obtained for Local cv koozha ripe seeds (21.86 mg) which was on par with Sindoor ripe flakes (21.66 mg), Koozha ripe flakes (21.62 mg) and Sindoor raw flakes (21.49 mg). Thomas *et al.* (1992) observed that vitamin C has the ability to donate electrons in a number of enzymatic and non enzymatic reactions and Smirhoff (2000) reported that Vitamin C is a powerful water soluble antioxidant scavenger of ROS. Athar *et al.* (2008) opinioned that vitamin C has synergistic action with other antioxidants and has a potential role in minimizing the damage caused by oxidative process. Tanjung *et al.* (2014) reported that jackfruits contained 0.440± 0.012mg/100mg vitamin C and then betacarotene content was 0.192± 0.021mg/100ml. Okudu (2015) in a study reported that the vitamins A and C content of the jackfruit pulp (294.8µg/100g and 27.6mg/100g respectively) were significantly ($p<0.05$) higher than those of the seed (145µg/100g and 12.9mg/100g respectively).

Ash content represents the total mineral content in that food materials. Ash value equal to or more than 0.50 per cent is an appreciable level of mineral content (Adeleke and Odedeji, 2010). In the present study, the highest total mineral content was obtained for Koozha ripe seeds (0.93mg) and Chempikalom ripe seeds (0.93mg), which was on par with Koozha raw seeds (0.92mg) and

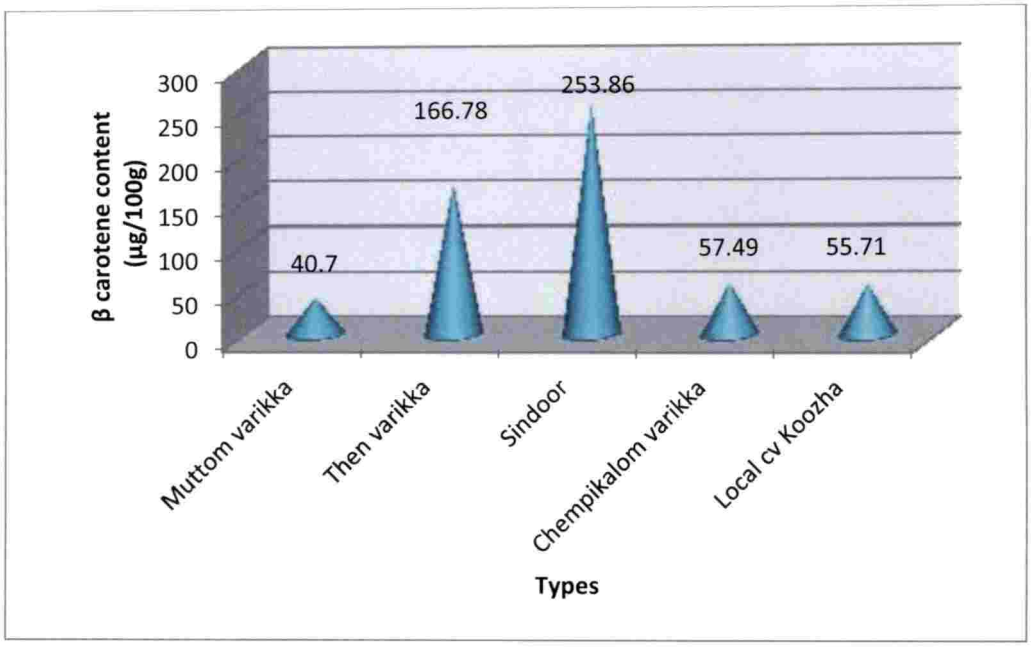


Figure 6. β carotene content in selected jackfruit types

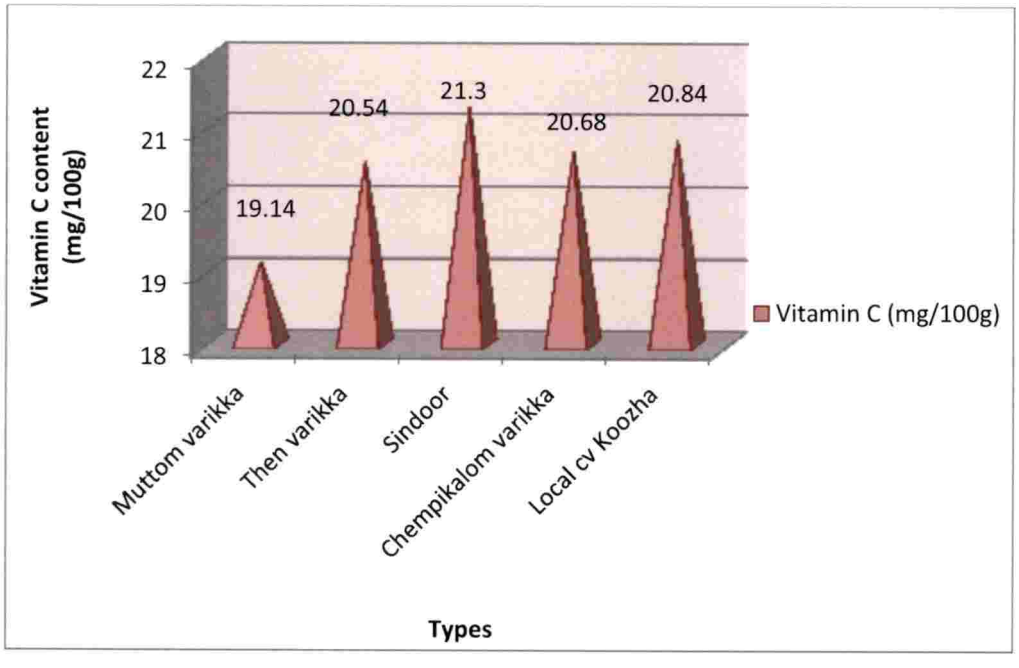


Figure 7. Vitamin C content in selected jackfruit types

Chempikalom raw seeds (0.91mg). The highest calcium content was obtained for Local cv Koozha ripe seeds (140.62 mg) and the lowest value was obtained for Chempikalom vari*kka* raw seeds (22.11 mg). The highest phosphorus content was obtained for Muttom varikka ripe seeds (65 mg) and the lowest content was observed in Koozha ripe flakes (20.38 mg). The highest sodium content was obtained for Local cv Koozha raw flakes (15.06 mg) and the lowest content was observed in Then varikka raw seeds (4.71 mg). The calcium and magnesium content of the pulp were found to be 19.3 and 29.6mg/100g respectively while those of the seeds were 40.6 and 53.8mg/100g respectively (Okudu, 2015).

The pulp of ripe fruit is eaten fresh and used in fruit salads as it possesses high nutrient value, Every 100 g of ripe fruit pulp contained carbohydrate (18.9 g), protein (1.9 g), fat (0.1 g), moisture (77%), fiber (1.1 g), total mineral matter (0.8 g), calcium (20 mg), phosphorus (30 mg), iron (500 mg), vitamin A (540 I.U), thiamin (30 mg) and caloric value of 84 calories (Bose, 1985; Samaddar, 1985). The seeds were found to be good sources of mineral elements. A study conducted by Ajayi (2008) revealed that potassium was the predominant mineral element with 2470.00 ppm and 1680.00 ppm in *Artocarpus heterophyllus* and *Treculia africana*, respectively followed by sodium, magnesium and calcium. They also contained reasonable quantity of iron, particularly in *Artocarpus heterophyllus* (148.50 ppm).

Kumar *et al.* (1998) reported the proximate composition of the jack fruit seeds of 'Kathari' and 'Bharat' varieties of jack fruit and suggested that they are good sources of carbohydrates (26.83-28.01 %), protein (6.25-6.75 %) and minerals (1.16-1.27 %). Fractionation of nitrogen revealed that non-protein nitrogen formed 5.6 per cent and 7.00 per cent of the total nitrogen in 'Kathari' and 'Bharat Baramasi' seeds, respectively. Globulin – nitrogen formed the major portion of total nitrogen in both the varieties. The moisture content of the jack fruit seed was found to be 64.5 per cent and the level of carbohydrates was 25.8 g, energy -135 Kcal, proteins - 6.6 g, total minerals - 1.2 g, iron - 1.5 mg, calcium - 50 mg, phosphrous - 97 mg, fibre - 1.5 mg (per 100 g of edible portion)

(Praveenasri *et al.*, 2006). Gupta *et al.* (2011) reported the mineral composition of jackfruit seed as K - 786.6±1.23mg, Ca - 29.47±0.51mg, Na - 28.39±0.36mg, Ba - 0.275±0.32mg, Zn - 2.280±0.12mg, Ar - 0.047±0.38 mg, Sn- 0.031±0.05 mg, Cr - 0.018±0.02mg and Cd - 0.010±0.002mg.

Banerjee and Datta (2015) analysed the nutritive value of fresh jackfruit seeds and reported that the moisture level was 64.5 per cent, protein- 6.6g, fat - 0.4g, minerals – 1.2g, fibre- 1.2g, carbohydrate – 25.8g, energy – 133 Kcal and calcium -50mg. Tejpal and Amrita (2016) reported that the moisture content of the *Artocarpus heterophyllus* was found to be 76.2 – 85.2 per cent and the level of carbohydrate was 23.5g energy - 95 Kcal, dietary fibre - 1.5g, protein - 1.72g, calcium - 34mg, iron - 0.60mg, magnesium - 37mg, manganese - 0.197mg, phosphorus - 36mg, potassium - 303mg, sodium - 3.3mg and zinc - 0.42mg.

5.1.2. Bioactive compounds

Bioactive compounds such as carotenoids, phenolic compounds, flavanoids, phytosterols, organosulphur compounds and nondigestible carbohydrates have significant health potentials and have the ability for therapeutic roles (Rodriguez *et al.*, 2006). Mungole *et al.* (2010) opinioned that phytochemical screening aids in identifying and quantifying valuable compounds having therapeutic importance.

Shahidi (2010) reported that bioactive compounds have the ability to prevent and reduce incidence of chronic diseases, which in turn could lead to cost savings as health. The jackfruits contain different compounds especially phenolic compounds, flavonoids, stilbenoids, arylbenzofurons, carotenoids, volatile acids, sterols and tannins which varies depending upon the variety (Jagtap and Bapat, 2010; Baliga *et al.*, 2011).

Alkaloids are phytochemicals which are reported to possess analgesic, antispasmodic, antibacterial, cytotoxic, antiplasmodial, hallucinogenic and antineoplastic activity (Nyarko and Addy, 1990; Jagetia and Baliga, 2006; Patel *et*

al., 2012). In the present study, the alkaloid contents in different types, stages of maturity and edible portions of jackfruit show that the alkaoid content was higher in Muttom varikka (52.52 mg), the lowest content was observed in Then varikka (7.68 mg). In the case of stages of maturity the raw stage of jackfruit contained 33.89 mg and ripe stage contained 27.57 mg. The edible portions of the jackfruit bulb contained 29.59 mg and the jackfruit seeds contained 31.87 mg. The interaction effects of types, stages and edible portion revealed that the highest content was obtained for Muttom varikka ripe seeds (65.67 mg) and the lowest content was observed in Then varikka ripe flakes (2.20 mg).

Sirisha *et al.* (2014) in another study reported that alkaloid content was high in *A.heterophyllus* (1.25±0.03) followed by *A.integrifolia* (1.23±0.03), *A.hircitus* (1.16±0.02), *A.incisus* (0.44±0.03) and *A. integer* (0.34±0.3) µg of boldine equivalents g-1 of extract. Okudu (2015) reported that the oxalate, phytate, alkaloid, saponin, flavonoid content of the seeds were 129,109, 164, 78,139mg/100g while those of pulp were 41, 18, 33, 17, 23mg/100g.

Flavonoids are phenolic compounds known to possess strong antioxidant properties. They are reported to have anti cancer, antiviral, anti-inflammatory activities also (Havsteen, 2002).

In the present study, the level of flavanoids in different types, stages of maturity and edible portions of jackfruit showed that the flavanoid content was higher in Chempikalom varikka (304.26 mg).The lowest content was observed in Muttom varikka (101.99 mg). In the case of stages of maturity the raw stage of jackfruit contained 182.93 mg and ripe stage contained 212.58 mg. The edible portions of the jackfruit bulb contained 136.07 mg and the jackfruit seeds contained 259.44 mg. The interaction effects of types, stages and edible portion shows that the highest content was obtained for Chempikalom varikka raw seeds (687.67 mg) and the lowest content was observed in Chempikalom ripe flakes (67.17 mg).

Sirisha and Rao, (2014) screened flavonoid content of Artocarpus seed oils at 100 mg/ml and reported *A.integer* with 7.25±0.02, *A.inciscus* with 6.92±0.03, *A.hircitus* with 5.3±0.03, *A.integrifolia* with 4.44±0.03 and low content in *A.heterophyllus* with 3.63±0.01 µg quercetin equivalents g-1. Sirisha *et al.* (2014) in another study reported higher flavonoid content in *A.integer* 2.62±0.02 followed by *A.hircitus* 1.82±0.02, *A.incisus* 1.64±0.02, *A.integrifolia* 1.12±0.02 and *A.heterophyllus* 0.72±0.02 µg of quercetin (C5H10O7) equivalents g-1 of extract. The alkaloid content in jackfruit seeds was found to be 1.16± 0.09g/100g.

In the present study, the level of lycopene contents in different types, stages of maturity and edible portion of jackfruit reveal that the lycopene content was higher in Muttom varikka (2.14 mg) which was on par with Koozha (2.10 mg). In the case of stages of maturity the raw stage of jackfruit contained 1.69 mg and ripe stage contained 1.72 mg and there was no significant difference between them. The edible portions of the jackfruit bulb contained 1.77 mg and the jackfruit seeds contained 1.65 mg. Table 62. showed the interaction effect of types, stages and edible portion. Here the highest content was obtained in Sindoor raw bulbs (2.53 mg) and the lowest content was observed in Then varikka ripe flakes (0.46 mg). Tanjung *et al.* (2014) reported that the lycopene content in jackfruit was 0.072± 0.001 mg/100ml.

Saponins are chemically triterpenes and steroidal saponins, both of which are worthy to impart astringency and bitter taste at high concentrations (Chikwendu, 2005). In the past, saponins were considered as antinutrients (Shanthakumari *et al.*, 2008) but now, considerable interest has been put forward on exploiting saponin rich plant sources owing to its hypocholesterolemic, haemolytic (Nyarko and Addy, 1990), anti inflammatory and anti carcinogenic properties (Vinha and Soares, 2012).

In the present study, the saponin content in different types, stages of maturity and edible portions of jackfruit revealed that the saponin content was

higher in Sindoor (208.85 mg), the lowest content was observed in Local cv Koozha (82.75 mg). In the case of stages of maturity raw jackfruit contained 113.67 mg and ripe stages contained 171.35 mg. The interaction of types, stages and edible portion showed that the highest content was obtained for Then varikka ripe bulbs (310.00 mg) and lowest content was observed in Koozha raw seeds (44.67 mg). High amount of saponins (6.32± 0.098g/100g) were found in jackfruit seeds (Gupta *et al.*, 2011). Saponin is known for its medicinal uses, including antispasmodic activity and toxicity to cancer cells.

Tannins revealed potential antiviral (Okaka *et al.*, 1992), antibacterial (Pourmorad *et al.*, 2006) and antiparasitic properties (Ragone, 2006). In the present study, the tannin content in different types, stages of maturity and edible portion of jackfruit show that the tannin content was higher in Sindoor (102.50 mg). In the case of stages of maturity the raw stages of jackfruit contained 88.29 mg and ripe stages contained 51.45 mg. The edible portions of the jackfruit bulb contained 72.93 mg and the jackfruit seeds contained 66.81 mg. The interaction effects of types, stages and edible portion revealed that the highest content was obtained for Koozha raw flakes (174.73 mg) and the lowest content was observed in Muttom varikka raw bulbs (11.25 mg).

It is believed that tannins isolated from the stem bark of Myracrodruon urundeuva may have neuroprotective functions capable of reversing 6-hydroxydopamine-induced toxicity (Matuschek *et al.*, 2001). Sirisha *et al.* (2014) reported that the tannin content was higher in *A.incisus* 3.36±0.03 followed by *A.integer* 1.19±0.02, *A.hircitus* 1.04±0.03, *A.integrifolia* 0.83±0.03 and *A.heterophyllus* 0.62±0.02 µg of tannic acid equivalents g -1 of extract. In another study the estimated tannin content of seed oils were; *A.integer* 2.2±0.02, *A.integrifolia* 1.53±0.02, *A.heterophyllus* 0.78±0.05, *A.hircitus* 0.73±0.02 and *A.inciscus* 0.67±0.02 µg/gram of extract (Sirisha and Rao, 2014).

Kolodziej and Kiderlen (2005) have reported a strong relationship between phenolic content and antioxidant activity in selected fruits and vegetables. The

Folin-Ciocalteu method for the determination of the total phenolic and tannin content showed that Jackfruit seeds presented the highest amounts of phenolics (406.14 mg GAE/100g) and tannins (198.38 mg GAE/100g) reported by Nair *et al.* (2012).

In the present study, polyphenol content was higher in Sindoor (3.50 mg). The lowest content was observed in Muttom varikka (1.04 mg). In the case of stages of maturity the raw stage of jackfruit contained 2.11 mg and ripe stage contained 2.62 mg. The edible portions of the jackfruit bulb contained 3.04 mg and the jackfruit seeds contained 1.69 mg. In the case of interaction effects of types, stages and edible portion, the highest content was obtained for Sindoor ripe bulbs (6.00 mg) and the lowest content was observed in Muttom varikka raw bulbs (0.53 mg).

Barberan and Espin (2001) reported that the phenolic content of plants are influenced by a number of intrinsic (genus, species, cultivar) and extrinsic (agronomic, environmental, handling and storage) factors. The seeds of jackfruit showed higher amounts of total phenolic content (27.7 mg GAE g^{-1}) than the edible portions (Soong and Barlow, 2004). Bakar *et al.* (2009) reported that jackfruit pulp contained lower amounts of total phenolics (0.46 mg GAE g^{-1}) as compared to *A. odoratissimus* flesh (4.39 mg GAE g^{-1}). Gupta *et al.* (2011) reported the phytochemical content of jackfruit seeds with high quantity of saponins (6.32±0.098 g/100 g). Saponins have been known for their medicinal uses, including antispasmodic activity, and toxicity to cancer cells. Some alkaloids function as spasmolytic, anti-cholinergic and anesthetic agents. The alkaloid content in jackfruit seeds were found to be 1.16±0.09 g/100 g. Polyphenolics are known to function as antioxidants through a number of mechanisms including radical scavenging by H-donation, prevention of chain initiation by donating electrons or by binding of transition metal ion catalysts.

The applications of lectins ranges from identification of microorganisms, cell surface biology studies to Cancer research and they serve as probes for the characterization and isolation of simple and complex sugars (Hardy, 2000).

In the present study, the lectin contents in different types, stages of maturity and edible portion of jackfruit revealed that the lectin content was higher in Then varikka (1.40 mg), lowest content was observed in Muttom varikka (0.15 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.54 mg and ripe stage contained 0.56 mg. The edible portions of the jackfruit bulb contained 0.42 mg and the jackfruit seeds contained 0.67 mg. The interaction effects of types, stages and edible portion revealed that the highest content was obtained for Then varikka ripe seeds (1.66 mg) and the lowest content was observed in Koozha raw flakes (0.04 mg). The occurrence of lectin, termed as Jacalin, in the seeds of jackfruit was reported for first time by Chatterjee *et al.* (1979).

Lignin is not digestible at all by the bacterial enzymes in the colon and it also lowers the digestibility of the other fiber components. In the present study, the lignin content was higher in Then varikka (9.56 mg). In the case of stages of maturity the raw stage of jackfruit contained 6.47 mg and ripe stage contained 5.12 mg. The edible portions of the jackfruit bulb contained 5.35 mg and the jackfruit seeds contained 6.25 mg. The interaction effects of types, stages and edible portion showed that the highest content was obtained for Then varikka raw seeds (14.07 mg) and the lowest content was observed in Chempikalom ripe seeds (2.66 mg). Ververis *et al.* (2007) reported in a study that lignin percentage in algal biomass is 1.52 ± 0.2, orange peel is 2.10 ± 0.3 and lemon peel is 1.73 ± 0.2.

Studies have proved that the nutritional and phytochemical composition among jackfruits vary depending on the cultivar as well as region (Azad, 2000; Haq, 2006; Baliga *et al.*, 2011). Chrips *et al.* (2008) also reported that protein and carbohydrate concentration also varied in seeds across India where some varities contained 6.8 per cent of protein content in seeds. The artocarpus species

contained a diversity of compounds especially phenolic compounds, flavanoids, carotenoids, sterols and tannins which varies depending on the variety (Chandrika *et al.*, 2004; Hakim *et al.*, 2006; Jagtap and Bapat, 2010).

5.1.3. Antinutrients

Anti-nutritional factors are naturally occurring compounds that are classified under a broad group of secondary metabolites. They can be the compounds that are present in human or animal foods which cause anti-nutritional effects and anti-physiological effects such as impaired reproductive function or reduced immunocompetence or substances which reduce feed intake in animals (Zakarial *et al.*, 2011). It has been revealed that anti-nutritional factors are also known as anti-nutrients which are toxic substances that can be found in most foods and are able to restrict the nutrient availability to the body (Mohan *et al.*, 2012). They include proteinase inhibitors, lectins, phytates, polyphenols etc (Lopez Amoros *et al.*, 2006; Lin and Lai, 2006). Most of food antinutrients have an impact on the digestive system, like the inhibition of digestive enzymes (e.g. protease inhibitors), impairment of hydrolytic functions and transport at the enterocyte sites, formation of insoluble complexes which cannot be adsorbed, decrease of bioavailability of some nutrients (phytates, polyphenols) and the increase of the production of gases in the colon (α-galactosides) (Xu and Chang, 2009). Anti-nutritional factors are naturally-occurring compounds that exert anti-nutritional and anti-physiological effects and limit the nutrient availability to living organism (Rajan *et al.*, 2012).

According to Soetan and Oyewole (2009), antinutritional factors are compounds which reduce the nutrient utilization and food intake of plants or plant products used as human foods or animal feeds and they play a vital role in determining the use of plants for humans and animals. Soudy *et al.* (2010) reported that factors such as nutrient content, digestibility, presence or absence of antinutrients, toxic factors etc need to be considered while using a crop as a food. In the current study, the antinutrients such as trypsin inhibitors and

oligosaccharides present in the raw and ripe stages of both bulbs and seeds of selected jackfruit types were ascertained.

5.1.3.1. Trypsin inhibitors

Praveenasri *et al.* (2006) and Munishamanna *et al.* (2007) reported that the jack fruit seeds contain powerful trypsin inhibitors. In the present study, the trypsin inhibitor content was higher in Sindoor (22.83 mg), which was on par with Then varikka (22.50 mg).The lowest content was observed in Muttom varikka (2.75 mg). In the case of stages of maturity the raw jackfruit contained 16.97 mg and ripe stage contained 14.93 mg. The edible portions of the jackfruit bulb contained 14.83 mg and the jackfruit seeds contained 17.07 mg. The interaction effects of types, stages and edible portion shows that the highest content was obtained for Then varikka raw bulbs (30.67 mg) and the lowest content was observed in Muttom varikka raw seeds (1.67 mg). Kiran and Padmaja (2003) had obtained 10-20 per cent reduction of trypsin inhibitor activity on oven dried sweet potato slices.

5.1.3.2. Oligosaccharides (Raffinose)

In recent years, oligosaccharides and their derivatives have become useful for health applications in various fields because of their specific biological activities. In the food industries, several oligosaccharides have received increasing attention as key components for functional foods and nutraceutical products. Prebiotics are non-digestible oligosaccharides which have been shown to have properties that can modulate gastrointestinal problems and improve general health and well being (Gurtas *et al.*, 2001). Wichienchot *et al.* (2010) reported that the major carbohydrates of white and red-flesh pitayas (dragon fruit) were glucose, fructose and some oligosaccharides (total concentrations of 86.2 and 89.6 g/kg, respectively). The benefits of prebiotic oligosaccharides include relief from constipation, reduced risk of colon cancer, inhibition of pathogens in gastrointestinal tract, increased mineral absorption, immune modulation, short

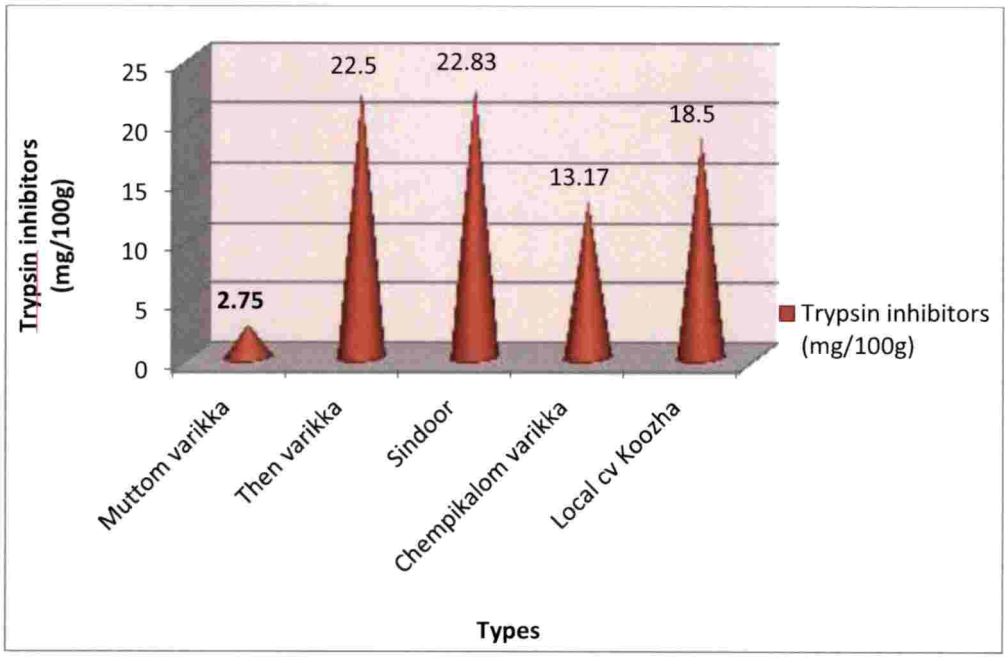


Figure 8. Trypsin inhibitors in selected jackfruit types

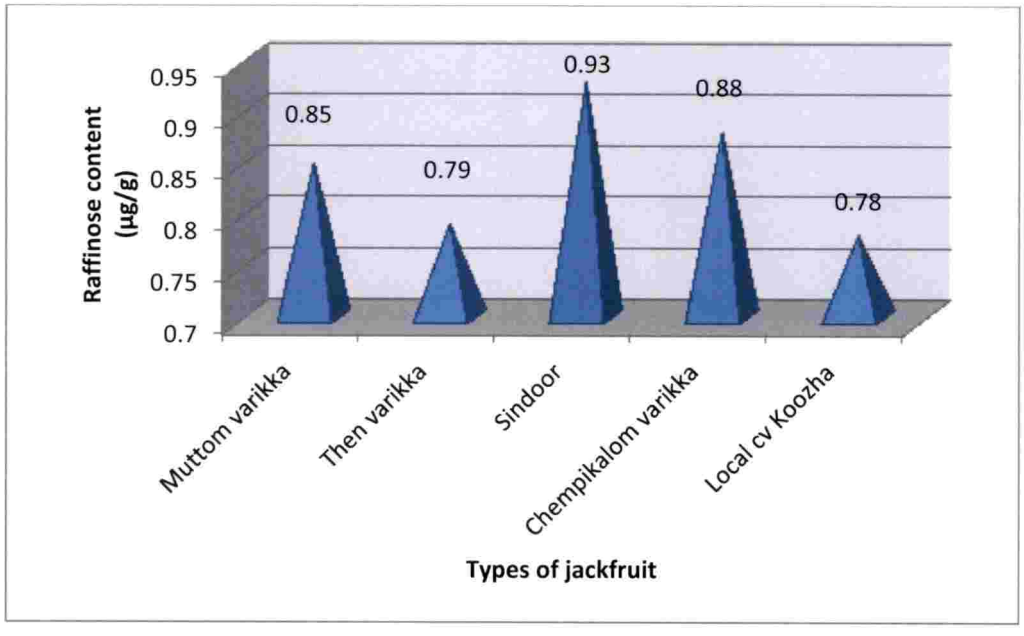


Figure 9. Raffinose Content in selected jackfruit types

chain fatty acid and vitamin production, reduced blood cholesterol and lipids alongwith improved microbial balance in the gut.

In the present study, Sindoor had the highest raffinose content (0.93µg/µl), the lowest raffinose content was observed in Local cv Koozha (0.78 µg/µl). Considering the stages of maturity, both the raw and ripe stage contained 0.85 µg/µl. There was significant difference between the two stages. Raffinose content in edible portions showed that bulb of jackfruits (1.05 µg/µl) had higher content than seeds (0.65 µg/µl). The three way interaction effects of types, stages and edible portion revealed that the highest value was obtained for Chempikalom raw bulbs (1.13 $\mu g/g^{-1}$), the lowest values were obtained for Local cv Koozha raw seeds (0.57 $\mu g/g^{-1}$).

5.1.4. Antioxidant activity

The role of dietary antioxidants in human health and disease is undeniable and sufficient evidence exists to broadly recommend that an increased intake of fruits and vegetables may contribute significantly to good health (Beard and Ryan, 2011).

The search for natural antioxidants derived from plants, has been on the increase in the recent past (Shanmugapriya *et al.*, 2011; Sylvie *et al.*, 2014). Antioxidants have been found to minimise the negative effects of free radicals in the body. Free radicals are usually produced, as by-products of the cell's metabolic activities (De Beer *et al.*, 2002). These radicals cause oxidative stress, when there is a major imbalance between them and the antioxidants defence system. This results in damage to DNA, proteins and lipids through oxidative stress (Lobo *et al.*, 2010). Chronic diseases such as heart diseases, diabetes mellitus, cancer and neurodegenerative diseases, are also mediated by mechanisms that involve the action of free radicals (Abu Bakar *et al.*, 2015). These diseases are among the major causes of death worldwide (WHO, 2007).

The jackfruit also contains useful antioxidant compounds (Ko *et al.*, 1998). The prenylflavones, isolated from *Artocarpus heterophyllus* was found to serve as powerful antioxidants against lipid peroxidation (Ko *et al.*, 1998). Carotenoids are known to have protective effect against oxidation which can contribute to antioxidant activity (Mezadri *et al.*, 2008). Hosu *et al.* (2014) reported that bioactive compounds such as flavonoids, anthocyanins and tannins could have contributed to the antioxidant activity. Antioxidant activity can be determined by several methods. Total antioxidant activity, DPPH radical scavenging activity, super oxide radical scavenging activity and hydroxyl radical scavenging were carried out for authenticating the antioxidant potential of the selected jackfruit types.

5.1.4.1. Total antioxidant activity

During the metabolism of oxygen, antioxidants are used by aerobic organisms to protect the cells from oxidative damage by oxidants. Reactive oxygen species (ROS) have an important role in several non communicable diseases. Tissue damage is mainly caused by oxidants and free radicals such as singlet molecular oxygen ($-O_2$), superoxide (-O), hydroxyl (OH) peroxide (O-O-H) and lipid peroxides (LOO). These free radicals cause several degenerative diseases such as cancer, cataract, coronary heart disease, dementia, diabetes mellitus, muscular degeration, pulmonary disfunction and radiation sickness. Fruits such as the cempedak (*Artocarpus interger*), jackfruit (*Artocarpus heterophyllus*) and breadfruit (*Artocarpus altilis*) are known to be rich in antioxidants (Kolar *et al.*, 2011; Almeida *et al.*, 2011; Fu *et al.*, 2011).

In the present study, the total antioxidant activity of different types, stages of maturity and edible portion of jackfruit were carried out. The results revealed that the antioxidant activity ranged in IC_{50} values from 33.53µg/ml to 40.90 µg/ml in the five types of jackfruit. The highest antioxidant capacity was observed in Local cv koozha (33.53 µg/ml) and lowest antioxidant capacity was observed in Sindoor (40.90 µg/ml). In the case of stages of maturity, the raw stage of jackfruit

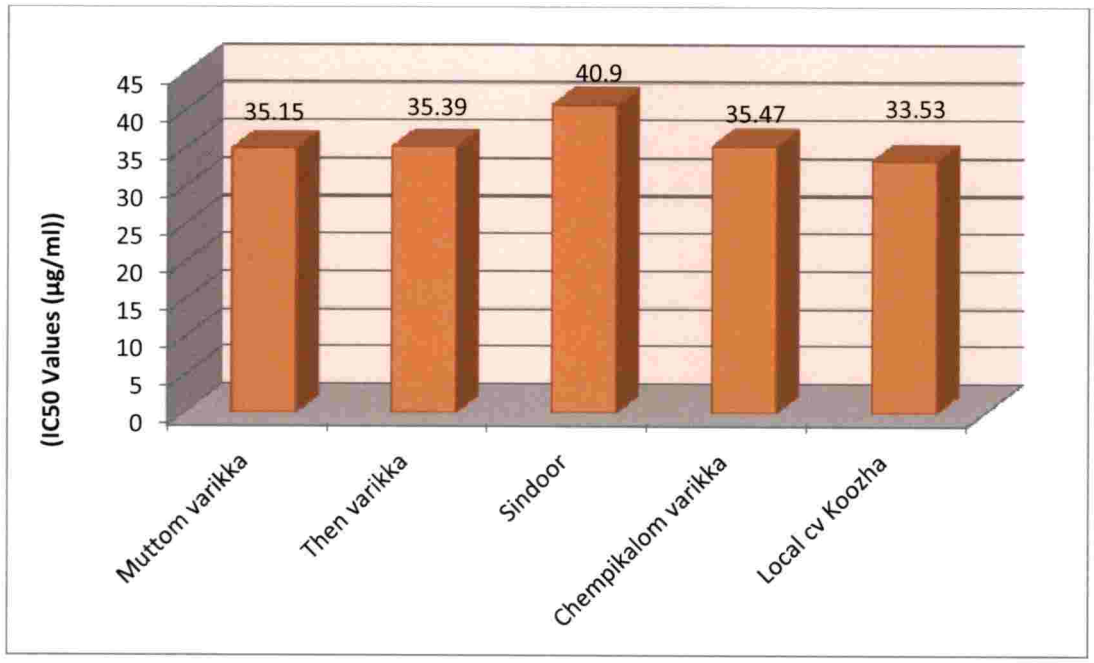


Figure 10. Total antioxidant activity of selected jackfruit types

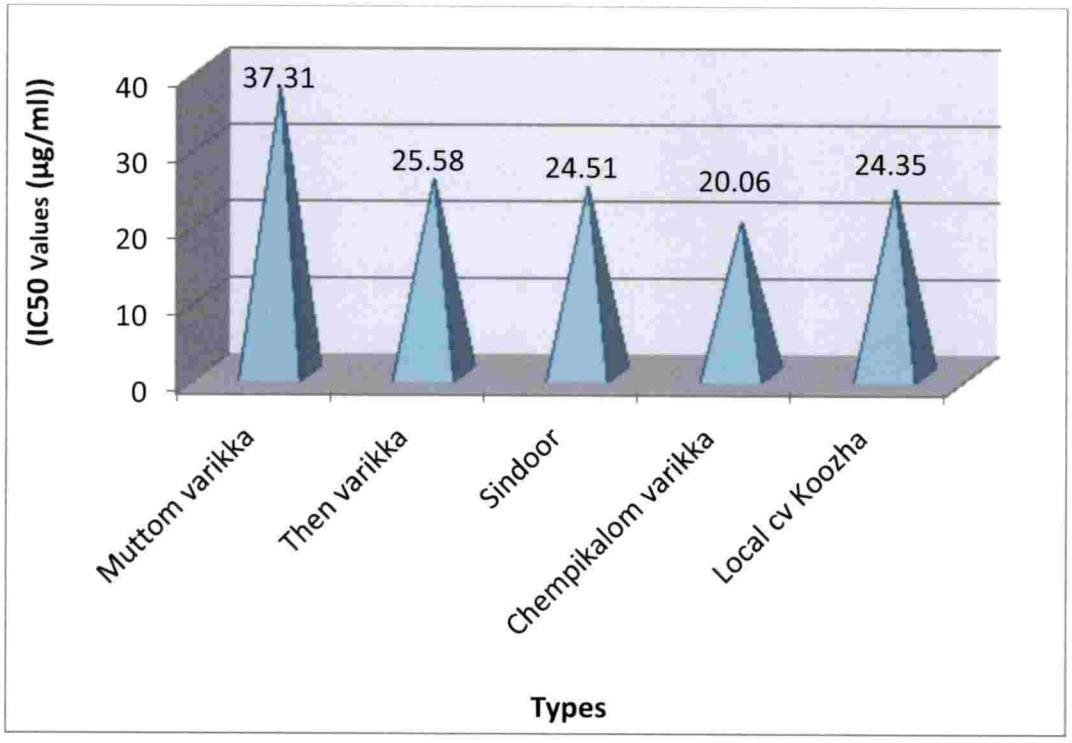


Figure 11. DPPH radical scavenging activity of selected types of jackfruit

had IC_{50} value of 35.82 µg/ml and ripe stage of jackfruits had IC_{50} value of 36.36 µg/ml. In the case of edible portions it was observed that the antioxidant activity was higher in seeds (34.98µg/ml) than jackfruit bulb (37.20 µg/ml).The interaction effects of types, stages and edible portion (Three way interaction) showed that the highest antioxidant activity was observed in raw seeds of Koozha (30.35µg/ml) and lowest antioxidant activity was observed in raw bulbs of Sindoor (41.75µg/ml).

5.1.4.2. DPPH radical scavenging activity

Zhou and Yu (2004) reported that the DPPH· method is used worldwide in the quantification of free radical scavenging activity, *in vitro* and is foreign to biological system. One of the mechanisms to investigate antioxidant activity is to study the scavenging effect on proton radicals.

In the present study, Chempikalom varikka had the highest DPPH activity with an IC_{50} value of 20.06 µg/ml, followed by Local cv koozha (24.35 µg/ml), the lowest DPPH radical scavenging activity was found in Muttom varikka (37.31 µg/ml). The DPPH activity was higher in ripe stage (21.95 µg/ml) of jackfruit than raw stage (30.77 µg/ml). In vitro antioxidant evaluation of chloroform extracts of *Artocarpus heterophyllus* fruit pulp by DPPH assay confirmed that the Jackfruit pulp is a good source of antioxidant compounds (Gupta *et al.*, 2011). *Artocarpus heterophyllus* seeds were examined for their DPPH, ABTS scavenging effects and metal ion chelating activity and was found to be an appreciable source of antioxidants (Narayanaswamy and Balakrishnan, 2011; Nagala *et al.*, 2013). In vitro evaluation of antioxidant activity of methanolic extract of fruits of Artocarpus hirsutus revealed potential DPPH scavenging activity and reducing power (Jeyam *et al.*, 2013). The edible portions of the jackfruit showed that, jackfruit seed had the highest DPPH activity with an IC_{50} value of 25.81 µg/ml, followed by bulbs (26.92 µg/ml). The interaction effects of types, stages and edible portion reveals that higher DPPH radical scavenging activity was observed in Chempikalom ripe seeds (2.31 µg/ml) and the minimum activity was observed

in Muttom varikka ripe seeds (43.50 µg/ml) which was on par with raw bulbs of Then varikka (43.67 µg/ml).

In a study, the investigation of total antioxidant capacity was measured as the cumulative capacity of the compounds present in the sample to scavenge stable organic free radicals with a deep violet color, which gives the maximum absorbance within 515–528 nm range, using the DPPH reaction (Jagtap *et al.*, 2010). All the assessed extracts were able to reduce the stable, purple colored DPPH· radical reaching 50 per cent of reduction. The minimum and maximum IC_{50} value was 0.4 mg/ml and 0.7 mg/ml for methanolic extract. From the above results, the methanolic and water extracts of jackfruit pulp proved their efficiency as an antioxidant. Jagtap *et al.* (2011) reported that jackfruit wine was effective in DPPH radical scavenging (69.44 ± 0.34%). The jackfruit wine was also able to protect H_2O_2 + UV radiation and γ-radiation (100 Gy) induced DNA damage in *pBR322* plasmid DNA. The antioxidant and DNA damage protecting properties of jackfruit wine confirmed to health benefits (Loizzo *et al.*, 2010).

5.1.4.3. Hydroxyl radical scavenging activity

The hydroxyl assay is based on quantification of degradation product of 2-deoxy ribose by condensation with TBA. Hydroxyl radical was generated by the Fe3+ -Ascorbate -EDTA -H2O2 system (Fenton reaction).

In the present study, Muttom varikka had the highest hydroxyl radical scavenging activity with an IC_{50} value of 33.13 µg/ml, the lowest DPPH radical scavenging activity was found in Then varikka (35.61 µg/ml). The hydroxyl radical scavenging activity was higher in raw stage (34.35 µg/ml) of jackfruit than ripe stage (34.60 µg/ml). Considering the activity of edible portions of the jackfruit, jackfruit seeds had higher activity with an IC_{50} value of 33.13 µg/ml and lower activity was observed in jackfruit bulbs with IC_{50} value of 35.82 µg/ml. The interaction effects of types, stages and edible portion revealed that the maximum hydroxyl radical scavenging activity was observed in Koozha raw seeds (30.42 µg/ml) and the minimum activity was observed in Then varikka ripe bulbs (36.92

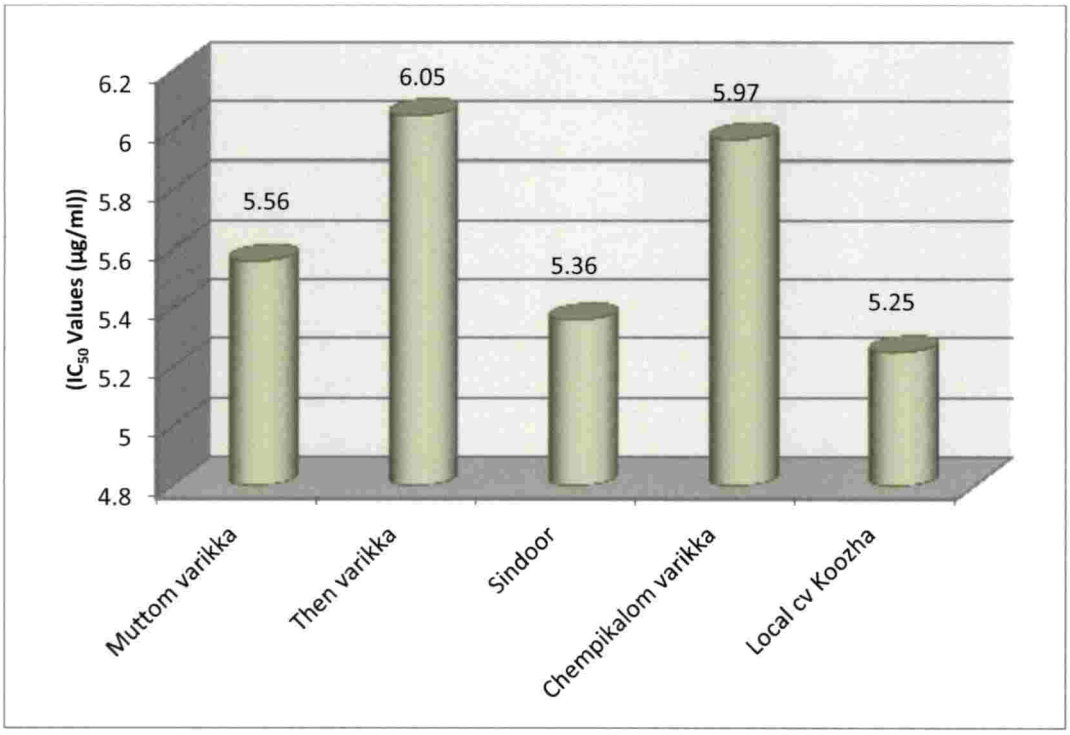


Figure 12. Superoxide radical scavenging activity of selected jackfruit types

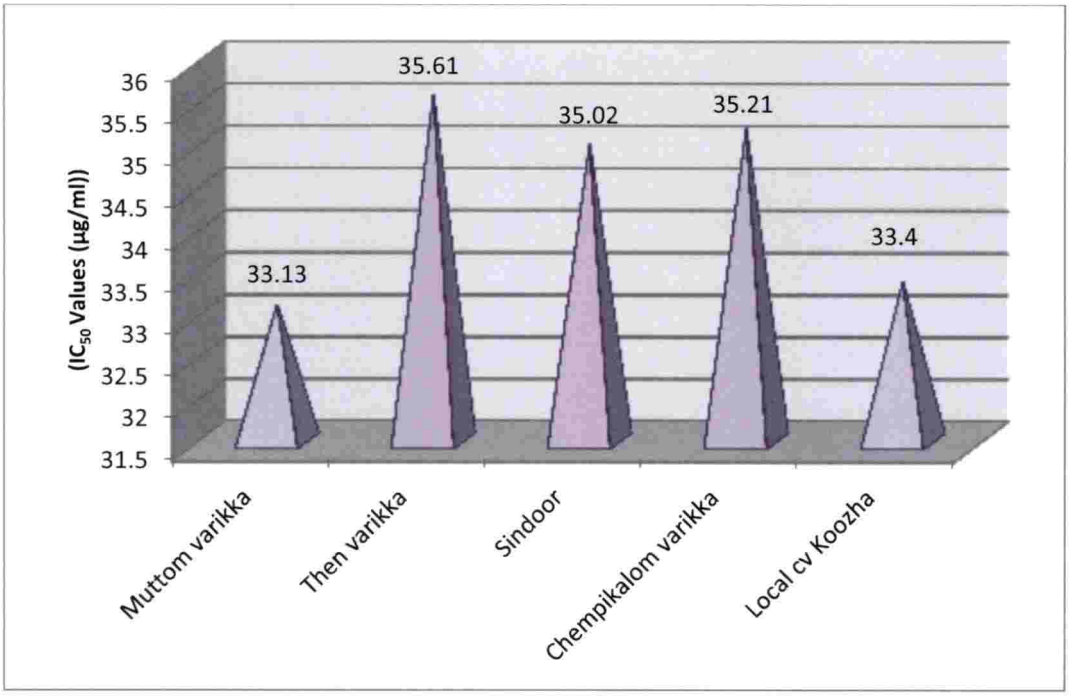


Figure 13. Hydroxyl radical scavenging activity of selected jackfruit types

µg/ml). Tanjung *et al.* (2014) reported that jackfruit extract has 36.623 ± 1.124 per cent hydroxyl radical scavenging activity.

5.1.4.4. Super oxide radical scavenging activity

Superoxide radicals (O2-) are generated from the photoreduction of riboflavin and was deducted by nitro blue tetrazolium dye (NBT) reduction method. In the present study, revealed that Local cv koozha had the highest superoxide radical scavenging activity with an IC_{50} value of 5.25 µg/ml, the lowest superoxide radical scavenging activity was found in Then varikka (6.05 µg/ml). The superoxide radical scavenging activity was higher in raw stage (5.57µg/ml) of jackfruit than ripe stage (5.70 µg/ml). The edible portions of the jackfruit showed that, jackfruit seeds had the higher activity with IC_{50} value of 5.29 µg/ml and lower activity was observed in jackfruit bulbs with IC_{50} value of 5.99 µg/ml. The interaction effects of types, stages and edible portion reveals that the maximum superoxide radical scavenging activity was observed in Koozha raw seeds (4.34 µg/ml) and the minimum activity was observed in Chempikalom varikka ripe bulbs (6.44 µg/ml).

SOD activity was found to be maximum in *A. integer* with 12.3±0.02, *A.integrifolia* with 6.5±0.0 units followed by *A. heterophyllus* (6.42±0.02) and minimum in *A.incisus* (5.87±0.02) and *A.hircitus* with 5.68±0.02 units/ mg protein (Sirisha *et al.*, 2014). SOD plays an important role in protecting cells against ROS (reactive oxygen species) according to Yamaguchy (1991). SOD detoxifies the superoxide radicals and generates H202.

5.2. Analysis of measures for reducing antinutrients in raw jackfruit

Jackfruit bulbs and seeds are potential local food sources, which can be derived as flour. However, both this bulbs and seeds contains several oligosaccharides such as raffinose and stachyose, which can cause flatulence for humans, and these substances will also create a darker color during flour processing. Wichienchot *et al.* (2010) reported that one of the problems in

processing jackfruit seed to become food raw material, is the oligosaccharides content. These oligosaccharide types which include raffinose, stachyose and verbascose are difficult to be digested because the small intestine of mammals does not have the enzymes which can degrade this kind of oligosaccharide (Han and Baik, 2006). When these oligosaccharides pass into large intestine, after fermentation by intestine microflora, it produces gas and cause flatulence. Flatulence is considered to be a serious problem although it is not toxic. An increase of gas in the rectum will cause pathological symptoms including headache, dizziness, and even mental disorder. Therefore, it is necessary to eliminate these kind of oligosaccharides from the jack bean seed before its use as food.

5.2.1. Treatments with enzyme α galactosidase

In the present study, the enzyme α galactosidase was premixed with the dry flour of jackfruit seed and jackfruit bulb separately in the ratio 1:100. The moisture level was made to vary from 25 – 200 per cent (dough to batter stage). The hydrolysis was carried out for 90 minutes in both jackfruit bulb and seed flours and breakdown of oligosaccharides was evaluated.

Guimaraes *et al.* (2001) found that incubation of soymilk with α galactosidase for 8 hours at 30^0C resulted in a 73.3 per cent reduction in raffinose and a 40.6 per cent reduction in stachyose. In another study conducted by Matella *et al.* (2005), it was found that incubation of black, red and navy beans with α galactosidase for 1 hour at 23^0C was more effective (30%-50% reduction) in the reduction of RFOs than soaking of beans for 5 hours at 23^0C (1%-35% reduction). Song and Chang (2006) found that two hours of incubation with α galactosidase at 55-60^0C removed 100 per cent of RFOs in pinto beans. This is a significantly greater reduction than was achieved by soaking followed by boiling for 90 minutes (54.2%).

The results revealed that the oligosaccharide (Raffinose) content in pre treated and treated jackfruit bulb flour treated with enzyme at different moisture

levels differed customarily in HPTLC assays and the retention factor of standared Raffinose was 0.58 minutes. Retention factor recorded by jackfruit bulb flour (control) and bulb flour with enzyme treated at varying moisture levels were 0.58, 0.58, 0.58, 0.58, 0.58, 0.57, 0.57, 0.57, 0.57 at 25%, 50%, 75%, 100%, 125%, 150%, 175%, 200% respectively. The enzyme α galactosidase can have the ability to hydrolyse stachyose and raffinose reported by Adya and Elbein, 1997; Civas *et al.* (1984); Gherardini *et al.* (1985); Ferreira *et al.* (2011); Katrolia *et al.* (2012).

These values were compared to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 0.97in control (without treatment). In M_1 (25%) it was 0.89, M_2 (50 %) - 0.85, M_3 (75 %) - 0.80, M_4 (100%) - 0.71, M_5 (125%) - 0.74, M_6 (150 %) - 0.83, M_7 (175 %) - 0.75, M_8 (200%) - 0.82μg g^{-1} respectively. The level of Raffinose after treatment was seen to decrease with increase in moisture content (25-100%). Thereafter the variation was not uniform (125%, 150%, 175%, 200%). However it may be noted that the level of oligosaccharides decreased in comparison to control (0.97 μg g^{-1}), which indicate the effect of enzyme on breakdown of oligosaccharides. Brain (2013) reported the dependence of enzyme α galactosidase activity on the moisture content of the system with a steady increase in the proportion of both stachyose and raffinose hydrolysed with increasing moisture content. The results also showed a steady decrease in the concentration of sucrose and a steady increase in the concentration of galactose as moisture content increased. Sucrose and galactose are the hydrolysis products of stachyose and raffinose.

Fasina *et al.* (2001) found that heating of various legume seeds to a surface temperature of 140^{0}C via infrared heating followed by soaking for 24 hour reduced raffinose concentration by 75.7 per cent - 84.4 per cent compared to reductions of 20.8 per cent - 67.1 per cent for soaking alone.

Retention factor recorded by pretreated (0.61 minutes) and treated jackfruit seed flour was compared to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 1.16 and 0.83, 0.68, 0.63, 0.56, 0.50, 0.58,

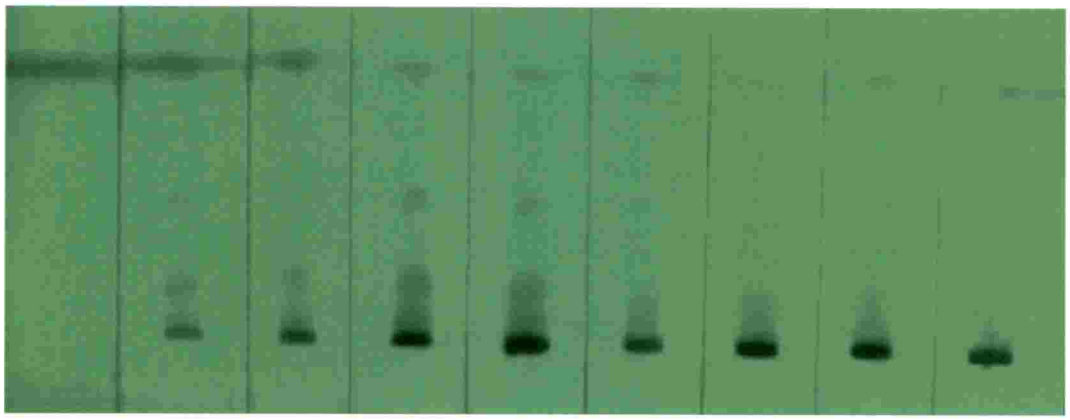


Plate 11. HPTLC plates of reference standard Raffinose and methanolic extract of enzyme treated flour of varying moisture level viewed at 254 nm

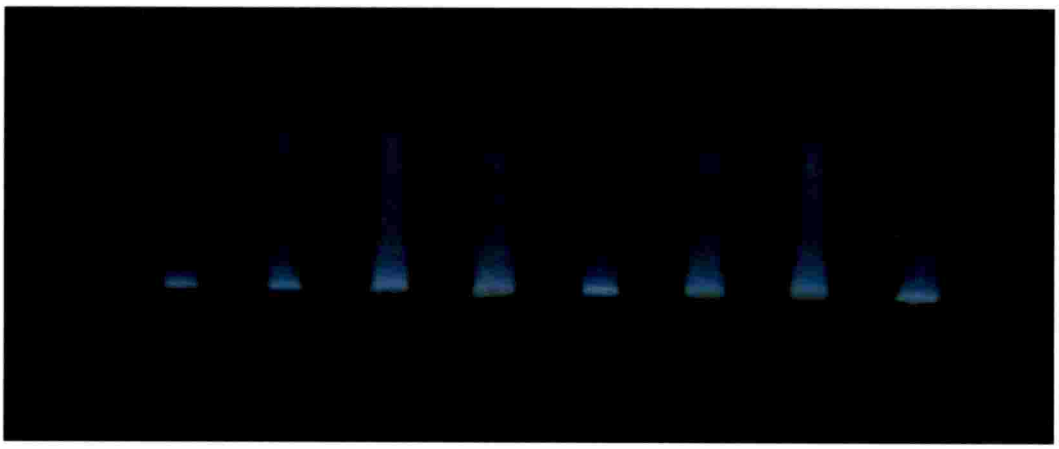


Plate 12. HPTLC plates of reference standard Raffinose and methanolic extract of enzyme treated flour of varying moisture level viewed at 366 nm

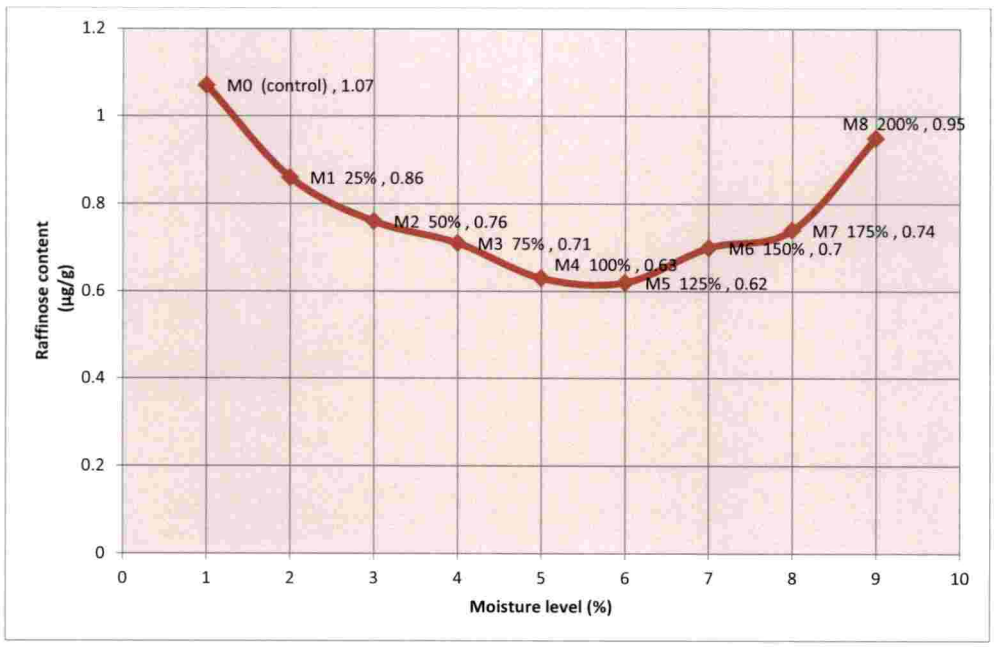


Figure 14. Raffinose content with varying moisture levels

0.74 and 1.08 μg g^{-1} at control, 25%, 50%, 75%, 100%, 125%, 150%, 175% and 200% respectively. The level of Raffinose content in seed flour after treatment was seen to decrease with increase in moisture content (25-100%). Here the raffinose content was seen to reduce up to 125%. Thereafter the variation was not uniform (150%, 175%, 200%). However it may be noted that the level of oligosaccharide had decreased in comparison to control (1.16 μg g^{-1}), which indicate the effect of enzyme on breakdown of oligosaccharides.

α-Galactosidase (α-galactoside galactohydrolase EC 3.2.1.22) is widely distributed in microorganisms, plants and animals. Dey and Pridham (1972) observed that generally α-galactosidase may hydrolyze a variety of simple α-d-galactosides as well as more complex molecules, such as oligosaccharides and polysaccharides. There are several reports available in the literature of the use of α-galactosidase from plant and fungal sources for the removal of raffinose family sugars from soybean flour and soymilk (Sugimoto and Bureu, 1970; Thananunkul *et al.*, 1976; Lin *et al.*, 1979; Shivanna *et al.*, 1989; Mulimani and Ramalingam,1995; Mulimani *et al.*, 1997; Kotwal *et al.*, 1998).

Alpha-1,6-galactosidase is an enzyme which breaks the α-1,6 bonds between the galactose and sucrose molecules in RFOs. The absence of this enzyme leads to the oligosaccharides continuing through to the lower intestine undigested. Endogenous microflora in the lower intestinal tract metabolize the undigested oligosaccharides producing the hydrogen, carbon dioxide and methane that is responsible for flatulence (Wagner *et al.*, 1976; Wagner *et al.*, 1977; Reddy *et al.*, 1984; Guillon and Champ, 2002; Minorsky, 2003).

5.2.2. Treatments with *Saccharomyces cerevisiae*

To reduce the level of oligosaccharides, flours were made into batter and subjected to fermentation with *Saccharomyces cerevisiae* @ 5gms/kg for 6 hrs and 8 hrs and 12 hrs respectively (Krishnaja, 2014). Oluseyi and Temitayo (2015) reported that fermentation resulted in proteolytic degradation of proteins into

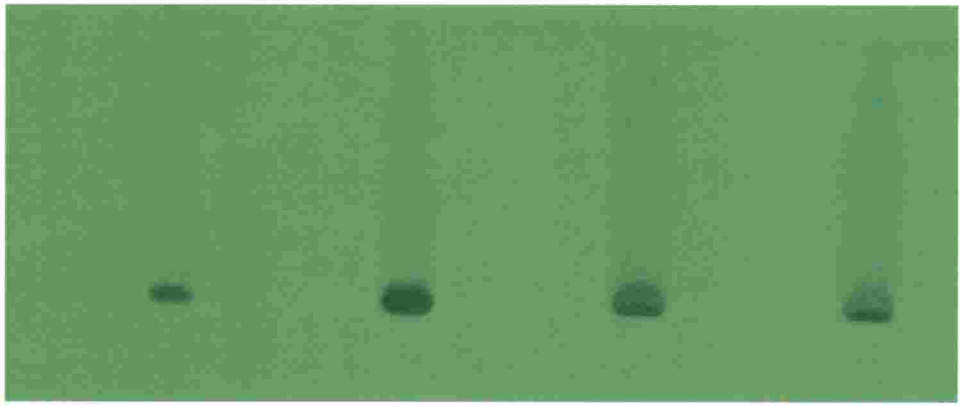


Plate 13. HPTLC plates of reference standard Raffinose and methanolic extract of yeast treated flour of varying moisture level viewed at 254 nm

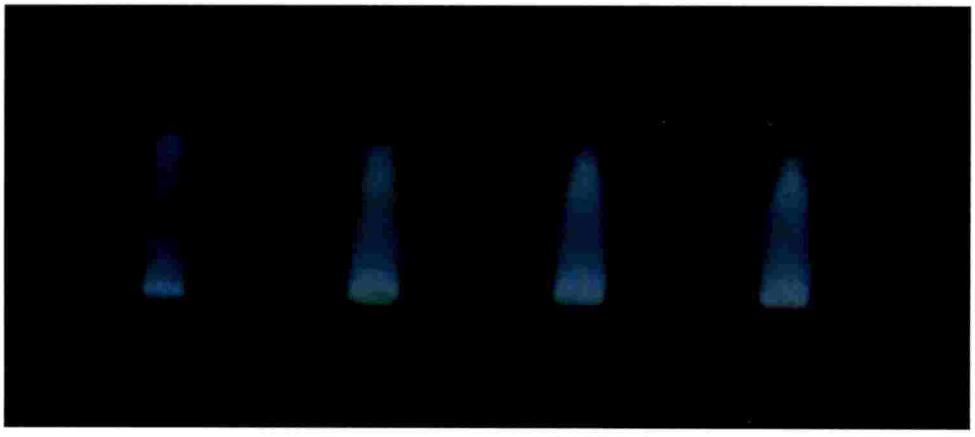


Plate 14. HPTLC plates of reference standard Raffinose and methanolic extract of yeast treated flour of varying moisture level viewed at 366 nm

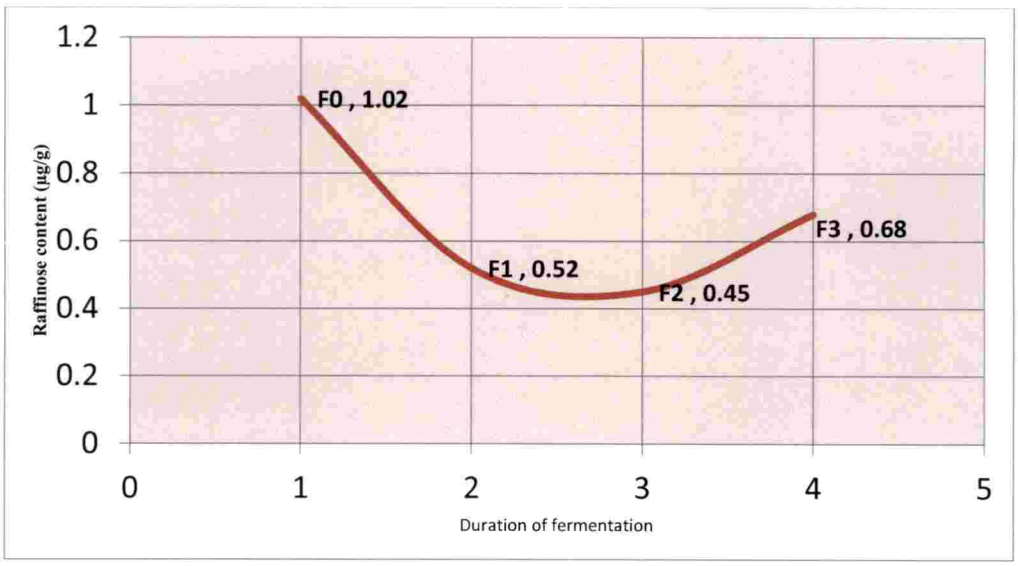


Figure 15. Raffinose content in varying fermentation time

amino acids and amylolytic breakdown of carbohydrate into sugars and organic acids.

In the present investigation, the oligosaccharide (Raffinose) content in treated and pre treated jackfruit bulb flour treated with *Saccharomyces cerevisiae* at different deviations of fermentation differed in the HPTLC assay and the retention factor of standared Raffinose was 0.79. Retention factor recorded by pre treated jackfruit bulb flour was 0.79 and bulb flour with 6 hrs fermentation (0.79), 8 hrs fermentation (0.79) and 12 hrs was (0.80) respectively were comparable to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 0.75 $\mu g\ g^{-1}$, 0.63 $\mu g\ g^{-1}$, 0.58 $\mu g\ g^{-1}$and 0.74 $\mu g\ g^{-1}$ in control, F_1, F_2, F_3 respectively. In the case of jackfruit bulb flours 8 hours fermentation was found to contain the least oligosaccharides.

In the case of oligosaccharide (Raffinose) content in treated and pre treated jackfruit seed flour, the retention factor of standared Raffinose was 0.57. Retention factor recorded in both pre treated and treated jackfruit seed flours were compared to that of the standard Raffinose. Raffinose content in jackfruit seed flour was 1.28 $\mu g\ g^{-1}$, 0.42 $\mu g\ g^{-1}$, 0.31 $\mu g\ g^{-1}$and 0.62 $\mu g\ g^{-1}$ in control, F_1, F_2, F_3 treatments respectively. Raffinose content was found to reduce in these three treatments and F_1 ie; 8 hours fermentation was selected as the best treatment.

5.2.3. Antinutrient levels of treated flours

Agte *et al.* (1999) reported that some of the antinutrients such as tannins, trypsin inhibitors, oxalates, phytates, lectins may cause harmful biological responses. Therefore, we have to properly address the issue by adopting adequate processing methods (Egli *et al.*, 2002; El-Hady and Habiba, 2003; Korus *et al.*, 2007). In the present study antinutritional levels of pretreated and treated flour were studied and it was observed that antinutrients such as oligosaccharides, tannins, phytates and trypsin inhibitors were reduced in both enzyme treated and yeast fermented flours. From these two treatments, fermentation process was selected as the best treatment because of its ease of processing. In the case of bulb

flour, tannin content was reduced from 23.34 mg to 10.32 mg, Phytates from 12.63mg to 7.04 mg, trypsin inhibitors from 38.22mg to 18.50mg. Besides, fermented foods play an important role in conferring the required stability, safety and sensory properties to the product (Stanton *et al.*, 2005). Fermentation helps in degradation of antinutritional factors and increases mineral bioavailability, protein digestibility of tannin rich cereals, and degradation of flatulence causing oligosaccharides. Jack fruit seed flour was prepared after removing the outer peel and boiling the seeds for 20 minutes in order to inactive the powerful trypsin inhibitor (Helen *et al.*, 2006).

Phytates in food lower the availability of several dietary minerals like iron, zinc, phosphorus etc. (Siddhuraju and Becker, 2001). Tannin rich foods exert negative effect on bioavailability of proteins, digestive enzymes, utilization of vitamins and minerals and iron absorption (Tniko and Uyano, 2001). A study shows that reduction in tannin content might be due to thermal degradation, denaturation as well as formation of insoluble complexes (Okaka and Okaka, 2001) or by leaching while washing (Rehman and Shah, 2001). Similar reports by Alcantara *et al.* (2013) existed for raw and powdered taro (32.24 mg/100g) too eventhough, it is not a significant value in view of the total acceptable tannic acid intake for an adult man (560 mg).

Fermentation is one of the processes known to reduce these anti-nutrients. Fermentation also leads to an increase in protein content (Nor *et al.*, 2015) enhancement of carbohydrate accessibility (Elkhalifa *et al.*, 2004), improvement in amino acid balance, decrease in antinutritional factors like tannin and phytic acid (Osman, 2004). Correia *et al.* (2010) reported that household fermentation technologies have been upgraded to an industrial scale in order to provide value added products that meet urban population demand for traditional products.

Phytate content was reduced in yeast fermented bread and locust bean seeds (Eka, 2001) and dough fermentation of whole grain flour (Nergiz and Gokgoz, 2007). Reduction in phytic acid during fermentation could be due to the

enzymatic action of the fermenting microorganisms which hydrolyze phytate into inositol and orthophosphate. Porres *et al.* (2003) found that fermentation leads to an increase of phytate compounds degradation and reduction of ash content, so that the flour color becomes brighter. Non-enzymatic browning reactions can occur when reducing sugars react with compounds having NH2 groups (protein, amino acids, peptides, and ammonium). Reduced levels of the protein in the flour prevents browning upon heating or drying process (Agustawa, 2012).

Furthermore, immersion of jackfruit seeds in saline solution may inactivate enzymes capable for supporting browning reaction. According to Agustawa (2012), soaking in a salt solution resulted in color closer to white. This is because Na ions from the salt bind to the phenol -OH group, avoiding the formation of the brownies color of quinines (Muzquiz *et al.*, 2000; Perlas and Gibson, 2002). Adegbehingbe (2015) reported a significant reduction in the antinutrient content of fermented sorghum where the highest reduction of antinutrients were found in samples fermented with starter cultures compared to the samples fermented naturally. He reported highest reductions in the phytic acid, saponins and flavonoids contents of *Lactobacillus plantarum* fermented sample, and in oxalate and tannin contents of samples fermented with *Saccharomyces cerevesiae* and *Lactobacillus acidophilus* respectively. Sonia (2018) reported in a study that fresh milk yam tubers when processed to powder by adopting different pretreatments like peeling, shredding, washing and drying in hot air oven at 60^0 C could reduce 69.84 per cent tannins, 81.02 per cent phytic acid, 94.69 per cent oxalates and 86.83 per cent trypsin inhibitors.

5.2.4. Storage studies

Storage studies are essential parameters to be assessed, since they determine the suitability of a particular ingredient for product development. Best treatment from enzyme treated and best treatment from fermentation was selected for storage studies.

5.2.4.1. Moisture levels of treated flour

Moisture content is an index of storage stability of the flour and it provides a measure of the water content present in the flours. Shankar (2003) opinioned that shelf life quality of a food product can be determined by measuring moisture content present in it. Low moisture content is suitable for longer shelf life. In the present study, the moisture content was recorded periodically up to 6 months. Compared to enzyme treated flours, moisture level was lower in yeast fermented flours. During the initial storage period, the moisture content obtained for bulb flour was 7.63 per cent and seed flour was 7.41 per cent and it was seen to increase after each month of storage period. Midhila (2013) studied the effect of storage on the dried banana blossom flour and reported that with advancement in the storage period, the moisture level enhanced. But the increase in moisture content did not influence the quality of the developed product because the increase in moisture content was negligible.

Bobbio *et al.* (1978) have reported 13 per cent moisture content in the jack fruit seed starch. Tulyathan *et al.* (2002) have reported 8.57 per cent moisture in the jack fruit seed flour. Moisture content in the jack fruit seed flour was also reported as 7.32 per cent (Anon, 1970). Begum *et al.* (1989) reported moisture content in the jack fruit seed meal as 7.6 g per 100 grams.

In another study conducted by Ocloo *et al.* (2010) reported that the moisture content of the jackfruit seed flour was 6.09 per cent. The lower the moisture content of flour, the better its shelf stability and hence the quality. Moisture contents of flours generally depends upon the duration of the drying process. The moisture content of the jackfruit bulb flour was 5.2 per cent as reported by Munishamanna (2012). The moisture content of the seed flour was 7.75 per cent as observed by Abraham and Jayamuthunagai (2014).

5.2.4.2. Microbial load of the selected treated bulb flour and seed flour

Berghofer *et al.* (2003) reported that flours are generally regarded as safe products due to their lower water activity, but during processing a variety of pathogenic and non pathogenic microorganisms can contaminate the flour. Zagory (2003) reported that spoilage by microbes is the one of the causes for the end of shelf life of products hence reducing initial microbial population is a strategy to extend shelf life.

In the current study it was evident that during the six months of storage period no pathogenic organisms were found to appear in the treated flour. But bacterial colonies were observed from the Vth month and VIth month ($2x10^7$cfu g^{-1}). Simultaneosly, fungi were detected in the IInd month onwards in enzyme treated bulb flour ($1.5x\ 10^3$ cfu g^{-1}) and IIIrd month onwards in yeast treated jackfruit bulb flour ($3x\ 10^3$ cfu g^{-1}) and seed flour ($2x\ 10^3$ cfu g^{-1}). Even though bacteria and fungi were detected, they were present within permissible limits.

5.2.4.3. Peroxide value (mEq/Kg^{-1}) of selected treatments

Peroxides are the primary products formed as a result of oxidation of lipids. The extent of rancidity or oxidation of a product can be measured by determining the concentration of peroxide (Sharma, 2006). In the present study the peroxide value was recorded for a period of six months. The peroxide content was not observed for both enzyme treated and yeast fermented bulb flour and seed flour for the first three months of the study. It was observed that the enzyme treated bulb flour reported peroxide contents from the IVth Month (0.24 mEq/Kg^{-1}) which increased in Vth Month to (0.26 mEq/Kg^{-1}) and 0.27 mEq/Kg^{-1} in VIth Month. In the case of enzyme treated seed flour, the peroxide content was observed from Vth Month (0.19 mEq/Kg^{-1}) which increased VIth Month(0.21 mEq/Kg^{-1}). In the case of yeast fermented bulb flour, peroxide contents were observed from the IVth Month (0.21 mEq/Kg^{-1}) which increased in Vth Month (0.23 mEq/Kg^{-1}) and VIth Month(0.24 mEq/Kg^{-1}) and in the case of seed flour, peroxide content was obsrved from the IVth Month (0.20 mEq/Kg^{-1}) which raised

from Vth Month (0.21 mEq/Kg^{-1}) and VIth Month(0.23 mEq/Kg^{-1}). However it could be noted that the peroxide contents in all the samples were within the permitted limits. This shows that both the enzyme treated and yeast fermented bulb flour and seed flour can be stored for a period of six months without any discriminate changes, thereby enhancing their market values.

Krokida and Marolis (2001) reported that peroxide value of a food product increased during storage period. In a study conducted by Neelofer (2004), it was revealed that the peroxide value of therapeutic and malted health drink mix were 0.32 meq/100g and 0.54 meq/100g. In the study reported by Midhila (2013), the developed banana RTC product showed an increase in peroxide value owing to the oxidative deterioration of lipids in the coconut. Krishnendu (2015) reported that there was no peroxide content observed in bitter gourd powder in the first four months of the study but the results further observed peroxide content from the 5th month (0.10 meq/100g) and 6th month (0.12 meq/ 100g) of storage. The peroxide content in the bittergourd powder was minimal and within permitted limits and this could be stored for a period of six months without any discriminate changes.

5.3. Development of raw jackfruit based textured vegetable protein

The jackfruit is commonly consumed in its fresh state or minimally processed form to extend the shelf life. There are only a few jackfruit-based products present in markets, which include canned slice fruit and vacuum-dried. Due to the increasing consumer demand towards ready-to-eat, healthy products, jackfruit can be one of the potential sources for the productions value-added products. The demand for convenience foods among the literate consumers is on the rise around the globe. It has been argued that convenience is a barrier to achieving proper nutrition using adequate servings. In order to incorporate the fruit based nutritional benefits, it has become important to develop newer and novel foods that could have consumers' acceptance. With this background an attempt was visualized to develop jackfruit based textured vegetable protein to

benefit all the age group of consumers. In the present study, jackfruit based TVP was formulated by using ingredients - jackfruit bulb flour and seed flour, gluten, yeast and soya flour to form chunks with varying combinations.

Incorporation of jackfruit seed flour at 5, 10 and 20 per cent was attempted by Tulyathan *et al.* (2002) to make wheat bread. Praveenasri *et al.* (2006) studied that the incorporation of jack fruit seed flour on the extruded product - vermicelli. Jack fruit seed flour was substituted from 30-50 % levels. They also investigated the effect of incorporation of both samples on the extrusion behavior and sensory evaluation. They found that incorporation at 40 % level gave the best results.

Vijayakumar and Mohankumar (2009) studied the effect of incorporation of millet flour blends on the improvement of quality of composite flours in terms of increasing nutrient density, thinner gruel (by lowered viscosity) and increase in the level of syneresis which could improve the resistant starch content on storage. Thus the millet flour incorporation significantly modified the properties of composite flour in such a way that it was found to be suitable for preparation of pasta, crackers, rusk or suji toast, biscuits, chapathi, etc., but was not suitable for bread and cake preparations.

Chakraborty *et al.* (2013) worked on developing nutritionally enriched breakfast cereal by utilizing jackfruit seed flour and defatted soy flour by twin-screw extrusion technology. Jackfruit seed flour and defatted soy flour were used as major sources of raw materials in four different sets of compositions and were subjected to extrusion to prepare nutritious extruded breakfast cereals. Abraham *et al.* (2014) reported that jackfruit seed flour (JSF) was a cheap source of protein (13.49 %), ash (2.47 %) and carbohydrate (70.73 %). Its calorific value was 357.665 kcal/100g. It was also rich in potassium (6466 ppm), magnesium (4582 ppm) and sodium (8906 ppm).

5.3.1. Cooking characteristics

Cooking not only affects sensory qualities but also leads to changes in physical and chemical properties of food. The chunks formed from the eleven treatments were subjected to cooking procedures analysed for their cooking characters. From these procedures the best treatment was identified.

5.3.1. a. *Appearance*

Appearance is the criteria for the desirability of any food product. Cooked TVP was evaluated for overall visual quality (OVQ), by the sensory panel. On evaluation of OVQ scores, the treatment P_7 got highest score (93.50), which was on par with P_8 (86.50), P_{10} (86.50) and P_{11} (82.10). The lowest score was obtained for P_4 (11.35) followed by P_5 (15.75). The scores obtained for other treatments were P_1 (47.75), P_2 (39.70), P_3 (42.30), and P_6 (35.55), which were on par and P_9 (69.50) on par with P_8, P_{10} and P_{11} (Table 110). Veenakumari (2015) identified the dimension of jackfruit bulb slices by analysing the OVQ scores.

5.3.1.b. *Cooking Time*

Cooking time is the time taken for the white core to depart when the sample is boiled in water (Chen *et al.*, 2002). According to Sozer *et al.* (2007) image analysis and texture assessment are the two methods used to observe the degree of cooking. Products which need less energy to cook have great demand, hence cooking time of the developed products were determined. Pszczola (2000) conducted a cooking experiment and revealed that the time required for cooking jackfruit was high compared to banana, mango and papaya. Das (2014) also reported that the pasta made with jackfruit pulp also needed more cooking time in minutes compared to pasta made with banana and papaya. In the present study cooking time of the different treatments ranged from 7.33 min to 15.0 min. The results further revealed that among the treatments P_7 took the least time (7.33 min) for cooking. The second treatment which took less time for cooking was P_8 and P_9 (7.66 min) and it was seen to be par with P_{10} (8.33 min) and P_{11} (8.66 min). More

time was taken for cooking P_4 (15.0 min), which was followed by P_1 (14.66 min) and P_2 (14.33 min). P_5 took 11.0 min for cooking which was on par with P_6 (10.33 min) and P_3 (10.33 min). Liji (2014) observed that 10 minutes was enough for the preparation of the jackfruit based olath and 15 minutes was necessary for cooking jackfruit based avial and koottu. Veenakumari (2015) reported from the disappearance of the core of the noodle strand during cooking by pressing between glass slides in 2 min intervals. Cooking time of the treatments of noodles ranged from 8.26 to 9.36 minutes. The treatments which contained highest amount of bulb flour took more time for cooking.

5.3.1.c. *Cooked Weight*

Cooked weight is an indicator of the extent of absorption of moisture by a food after complete cooking. In the current study the data shown that highest increase of weight was obtained for P_4 (41.23g) and the lowest weight was obtained for P_{10} (23.33 g), which was on par with P_8 (23.43 g) and P_9 (23.56 g). The raw jackfruit bulb flour and seed flour are hygroscopic in nature and have the ability to absorb and hold water during heat treatment. Gelatinization occurring during cooking process is the main reason for increased weight of products. Omeire et al. (2015) reported that the higher starch content and protein content contributes to the weight of a cooked product.

5.3.2. Sensory evaluation of TVP

Munishamanna *et al.* (2007) explored the possibility of value addition through the use of jack fruit seeds. Products, like vada, fortified jack seed chapathi etc., were prepared out of jack fruit seed flour. The process protocol of these products was standardized. The organoleptic characters like colour, texture, appearance, flavor, taste and overall acceptability of the developed products were found to be highly acceptable. The cost-benefit ratios for the jack fruit halwa, jack fruit chips, jack fruit candy and RTS beverages were observed to be 1: 2.40, 1: 1.20, 1: 2.94 and 1: 6.31, respectively. The study indicated that processing of jack fruit into value-added products would certainly serve as one of the sources

towards sustaining farm income of jack fruit growers through enhancing their returns by 2.5 to 6 times more compared to marketing of raw jack fruits.

Sensory evaluation is used to assess the quality of products, troubleshooting problems and new product development (Munishamanna, 2012). Sensory evaluation does not just deal with likes and dislikes, but the process scientifically elicits, measures, analyses and interprets psychological and physiological responses to physical stimuli produced by a food product. All the eleven treatments were cooked and evaluated by ten panel members.

Appearance is the one of the important criteria for the desirability of any food product. From Table 113, it was observed that T_7 scored the highest (99.60) among all the eleven treatments for appearance. Treatment T_7 was immediately followed by T_8 with a score of 88.40. The lowest score was obtained for T_4 (15.15). The values obtained for other treatments were 79.40, 69.60, 60.80, 51.00, 47.40, 41.25, 35.10 and 22.80 for T_9, T_1, T_2, T_{10}, T_3, T_{11}, T_6, T_5 respectively. Utilization of bread fruit (*Artocarpus incisa*) flour for confectionery products was studied by Ayodele and Oginni (2003). Bread fruits were processed into flour and used to make bread, cake, buttered biscuit and pancake. Biscuits made from breadfruit flour had dark brown colour. The bread from bread fruit flour had the colour of the wheat flour 'brown bread'. The physical appearance of the buttered biscuit and the texture of the bread were not acceptable to some panel members.

Colour is another important visual attribute that has been used to judge the overall quality of products. If the colour is unattractive, a potential consumer may not be impressed by any other attributes. The highest score was secured by T_7 (91.75) followed by T_8 (78.60), T_9 (67.05), T_6 (55.30), T_2 (51.55), T_{10} (51.50), T_1 (47.70), T_{11} (47.60), T_3 (43.70), T_5 (39.85) and T_5 (35.90).

Taste is one of the major attributes which determine the acceptability of a food. The highest score for TVP was obtained by T_7 (100.15) followed by T_8 (93.35), T_9 (69.55), T_1 (58.50), T_2 (58.50), T_{10} (50.00), T_{11} (41.50), T_3 (40.05), T_6 (40.05), T_5 (34.40) and the lowest score was obtained by T_4 (24.45).

Odour preference is generated by stimulation of sensory cells by specific volatile compounds present in foods. The highest score was obtained by T_7 (83.40) followed by T_6 (71.05), T_8 (63.40), T_{11} (54.40), T_9 (54.00), T_3 (51.85), T_{10} (51.45), T_5 (46.75), T_4 (46.35), T_2 (45.00) and the lowest score was obtained by T_1 (42.85).

Texture contributes to the physical property of food stuffs as apprehended by the eye, skin and muscle senses located in the mouth. In the case of TVP, texture is an important parameter that is to be considered. The highest score was obtained by T_7 (101.70) which was followed by T_8 (91.30), T_9 (75.50), T_1 (60.25), T_2 (60.25), T_{10} (52.40), T_{11} (41.60), T_3 (39.40), T_6 (35.80), T_5 (28.20) and the lowest score was obtained by T_4 (25.50). The treatments such as T_7, T_8 and T_9 were on par and other treatments were significantly different from these three.

In the case of TVP texture is an important attribute which determine the quality of this product. Based on the sensory attributes such as appearance, colour, flavour, texture and taste (overall acceptability) the highest score was obtained for T_7 which was followed by T_8 and these two treatments were on par.

The sensory quality scores of biscuit with flax seed flour incorporated with wheat flour decreased with increase in the replacement of flax seed flour (Hussain *et al.*, 1999). Similar observations were made in jack seed flour incorporated biscuits. Ranasalva and Visvanathan (2014) opinioned that developing a processed product with good sensory qualities and prolonged shelf life would bring benefit to consumers in preparation as well as health promotion. This would also allow exploring more marketing niches in the countries. Airani (2007) observed that the overall acceptability of biscuits showed that the control biscuits scored higher values (7.33) with very good acceptability. The 25 per cent seed flour based biscuits recorded the value of 6.33 which indicates moderate acceptability. The 75 and 100 per cent seed flour incorporated biscuits recorded the values of 2.66 and 1.66 for their very fair and poor overall acceptable quality.

Sensory properties were evaluated for colour and overall visual acceptability of the extruded products using a 9 point hedonic scale. The results suggested that the two extrusion variables, barrel temperatures and screw speeds, influenced the extrudate physio-chemical and sensory properties. Among jackfruit seed flour pasta products 30 per cent incorporation of jackfruit seed flour was found to be the best accepted treatment with high scores for appearance (7.82), texture (7.92), colour (7.66), flavor (8.04), taste (7.78) and overall acceptability (7.89). Least scores were observed for jackfruit seed flour pasta product prepared by 10 per cent incorporation of jackfruit seed flour with acceptable scores for appearance (7.43), texture (7.40), colour (7.35), flavor (7.63), taste (7.56) and overall acceptability (7.21) (Malathidevi, 2015).

5.3.3. Quality analysis of TVP

Quality is the ultimate criteria for the desirability of any food product.

5.3.3.1. Functional quality analysis of TVP

Functional properties express how ingredients behave during preparation and cooking, how they affect the finished food product in terms of how it looks, tastes, and feels. Noor *et al.* (2014) reported the chemical, physico-chemical and functional properties of flour and starch from three varieties of jackfruit seed. All varieties of jackfruit seed flour had moisture content ranging from 6.28 - 9.16 per cent, protein 9.19 - 11.34 per cent, fat 1.18 - 1.40 per cent, ash 1.53 - 2.66 per cent, amylose 26.49 - 30.21 per cent and starch contents 81.05 - 82.52 per cent. Gala variety had the highest amount of water soluble index, swelling water capacity and water absorption index than Khaja and Durasha varieties. On the other hand, isolated starch varied from 8.39 to 12.20 per cent moisture, 1.09 to 3.67 per cent protein, 1.18 to 1.40 per cent fat, 0.03 to 0.59 per cent ash content. Results from this study suggest that jackfruit seed flour can be used as partial replacement of wheat flour and good source of starch.

5.3.3.1.a. *Yield of TVP*

Drying removes moisture, as a result the product shrinks and decreases in size and weight, thus requiring less space for storage. Mostly foods lose volume or weight as they are processed. Yield of dried products are directly related to how much water is contained in the original product. Yield ratio of the different combinations were analysed and the results are presented in the Table 114. Yield ratio of different treatments ranged from 0.650 - 0.770 per cent. Results further revealed that P_3 having G: JFBF: JFSF in the ratio of 50:10:40 had the highest value (0.770). The lowest value was obtained by P_9 (0.650). Yield ratio obtained for other treatments were 0.670, 0.670, 0.746, 0.723, 0.693, 0.750, 0.723, 0.670 and 0.683 for P_1, P_2, P_4, P_5, P_6, P_7, P_8, P_{10}, P_{11} respectively.

Related study on jackfruit based product shows that the yield of jackfruit based RTC mixes ranged from 35.90-37.32 per cent. The yield percent of jackfruit based avial mix was 37.22, koottu mix - 35.9 and olath mix - 37.32 (Liji, 2014). Another study conducted by Sahoo (2016) reported that with higher amount of jackfruit bulb flour the yield was higher and it was also revealed that the jackfruit based rusk obtained highest yield (63.15%) than the control rusk (56.38%).

5.3.3.1.b. *Texture*

Texture analysis is the mechanical testing of food products in order to measure their physical properties. Texture is the physical feel of something smooth or rough or fuzzy or slimy and many more such surface characteristics. Crispness, hardness, toughness, and firmness are the textural properties that are generally on the same property spectrum. Cohesiveness is the tendancy of a product to cohere or stick together. In the present study the texture profile analysis showed that the crispness value obtained for TVP was 2.22 and Soyachunks was 0.42. Hardness value obtained for TVP was 1.32 and chunks was 1.02. Stringiness is an important attribute and jackfruit based TVP had a value of 22.20 and soya chunks had 17.04. In a study conducted by Morita *et al.* (2002) it

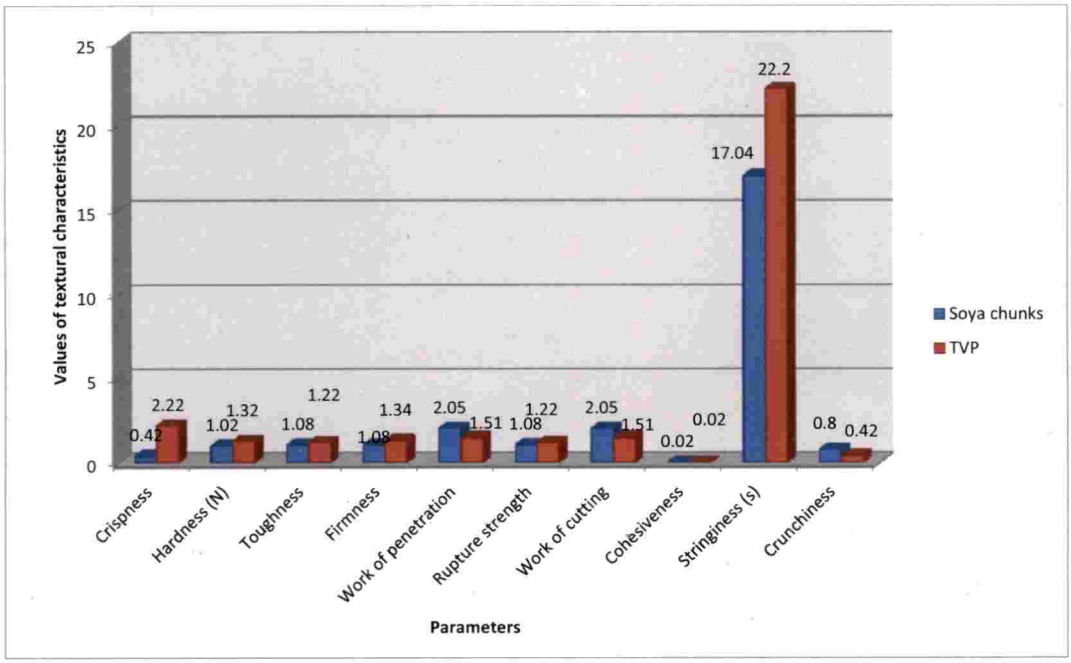


Figure 16. Textural properties of TVP

was reported that waxy wheat flour and Chinese spring flour yielded breads with lower crunchiness and crispiness than control.

In a study by Xia *et al.* (2014) was reported that the hardness, springiness and adhesiveness of fermented whole soya bean cotyledon sufu were 249.703± 0.500g, 0.606 ± 0.088 and 8.393 ± 0.032 J, respectively. The values obtained for traditional sufu were 264.863 ± 0.572g, 0.615 ± 0.007 and 7.516 ± 0.031 J respectively. This shows that fermentation has significant effect on textural properties.

5.3.3.1.c. *Rehydration Ratio*

Rehydration is an essential factor to analyze dried products. A high value of rehydration ratio means the dried product has a good eminence because the pores allow water to reenter the cells (Noomhorm, 2007). Rehydration ratio was highest for the treatments P_9, P_{10}, P_{11} (0.456) followed by P_7 and P_8 (0.423). Treatment P_2 and P_3 (0.413) had the least rehydration ratio. Rehydration is a process which is intended at restoring the properties of a raw matter when the dried matter comes in contact with water (An *et al.*, 2013). Liji (2014) reported that the rehydration ratio of jackfruit based avial mix was 0.34, koottu mix 0.42 and olath mix was 0.35.

5.3.3.1.d. *Water Absorption Index (WAI)*

Water absorption index is an indicator of the ability of flour to absorb water (Abbey and Ibeh, 1988). Rehman *et al.* (1999) reported that water absorption capacity is specific for each type of starch, and it depends on several factors such as amylase: amylopectin ratio, intra and inter molecular forces and size of granules. The water absorption capacity is higher in smaller sized granules (Singh *et al.*, 1991). Nevertheless highest WAI denotes the excellent binding capacity of ingredients. In the present study the values ranged from 104.33 - 140.66 per cent. Water absorption of TVP was found to be higher in P_5 treatment (140.66) which contained more amount of seed flour. In these treatments it was

seen that the increase in concentration of both bulb flour and seed flour increased water absorption.

Water absorption index is used to quantify the extent of starch damage during extrusion cooking since damaged starch granules tend to absorb more water and swell. The variation in WAI for a extruded product are due to the variation in shear rate caused by different screw speeds as reported by Sawant (2013). Malathidevi (2015) in a study reported that WAI of extrudates for jackfruit seed and bulb based products were high 5.08 (± 0.04) per cent to 6.87 (± 0.03) per cent).

Ocloo *et al.* (2010) observed that the water absorption capacity for the Jackfruit seed flour was 25 % (2.5 ml/g), this value was higher than 2.3 ml/g as reported for raw jackfruit flour (Odoemelam, 2005) and 1.7 ml/g as reported for African yam bean (Eke and Akobundu, 1993). It is however comparable to 3.4 ml/g as reported for raw conophor flour (Odoemelam, 2003). Values of 1.26 -1.37 ml/g have also been reported for tiger nut flours (Oladele and Aina, 2007). Water absorption capacity describes flour – water association ability under limited water supply. The results obtained here is lower than those reported by Singh *et al.* (1991) - 141 % and Tulyathan *et al.* (2002) - 205 % for whole jackfruit seed flour and jack fruit seeds without brown spermoderm. The disparities observed could be attributed to the method used as well as the varietal differences. The result obtained shows that the flour has a good capability to bind water. This result suggests that Jackfruit seed flour could be used in bakery industry.

5.3.4. Nutrient content and chemical composition of TVP

Nutrient content and chemical composition has significance in determining the degree of acceptability of the product based on its quality and sensory attributes (Kalia, 2010). Jones *et al.* (2008) reported that high protein diets have been proposed as a new strategy for successful weight loss and management of lifestyle diseases. Gopalan *et al.* (2009) reported that proteins are essential components of tissues and cells of the body. It has the ability to increase insulin

response without increasing plasma glucose concentrations in subjects with lifestyle diseases (ADA, 2004). In the present investigation, the nutrient composition of finalized TVP were analyzed. The carbohydrate content of the finalized TVP was 34.97 g/ 100g, total protein content 61.50 g/100 g, fat 14.40g/100g, calories 440.26 Kcal, fiber 4.20 g/100g and total minerals 2.4 g/100g.

Tulyathan *et al.* (2002) have reported the jack fruit seeds contained 11.17 per cent where as the protein content of the starch was 1.84 per cent. Berry and Kalra (1988) reported that in the jack fruit seeds the protein content was 6.6 per cent where as in the jack fruit seed starch protein content was 0.32 per cent per 100 grams. Begum *et al.* (1989) reported that the jack fruit seed protein content was 13.6 g. In the present study the protein content values were higher. This indicates that the developed TVP can address the protein.

Jackfruit pasta products were found to contain fairly sufficient amount of proteins. In a study conducted by Malathidevi (2015) it was reported that the protein content of jackfruit pasta product varied in range of 10.29 - 13.78 per cent and in a related study of Noor *et al.* (2014), the protein content of jackfruit seed flour product was reported to be in the range of 9.19 - 11.34 per cent.The range of fat content in jackfruit pasta was estimated to be 2.39 to 2.86 per cent. These findings are in agreement with the Abraham and Jayamuthunagai (2014).

Further, the Jackfruit pasta product was observed to contain ash in range of 1.61 to 1.89 per cent which was found to be in agreement with the findings of Noor *et al.* (2014). The crude fibre content of jackfruit based pasta production was found to be varying from 3.54 to 4.50 per cent. The findings are in agreement with Ocloo *et al.* (2010). The carbohydrate content of jackfruit pasta product was found to be varying from 70.83 to 76.8 per cent (w.b). The level of micronutrients namely, iron, copper, sodium, zinc, magnesium, calcium, and potassium that were in line in the values reported by Abraham and Jayamuthunagai (2014).

5.3.5. Storage studies

Shelf stability of a product depends upon many factors like the raw materials used and chemical composition of the product. Storage studies offer significant information to product developers, enabling them to certify that the consumers will receive high quality products for a significant period of time after production. There are many ways in which quality and nutrients can be lost and they may not result in the product being harmful but can mean that it is no longer of an acceptable standard. Moisture gain, chemical changes, light induced changes, temperature changes, physical damage etc may affect the product (Kumar, 2001). Shelf life study of the finalized TVP was conducted for three consecutive months. At intervals of one month, the finalized TVP were analysed for moisture content and microbial growth. When a food material is being processed without adopting good manufacturing practices there exists possibility of entry of microorganisms to the product. Contamination of the product may occur from air, dust, water, utensils etc. (Moussa *et al.*, 2012).

5.3.5.1 Moisture level of the TVP

Moisture content is one of the most commonly measured properties of food materials. Knowledge of the moisture content is often necessary to predict the behaviour of foods during processing. The moisture content of the developed jackfruit based TVP in PP covers was analysed. In the present study, the initial moisture content of the finalized TVP was 7.41 per cent. At the end of first month TVP showed little increase (7.65%) in moisture content. At the end of second month of storage moisture content of TVP was 8.72%. The moisture content increased further by the end of third month. However the levels were within permitted limits of safety. The moisture content of jackfruit pasta products were recorded in the range of 6.81 - 8.84 per cent (Malathidevi, 2015) which was in line with the results of Loreny *et al.* (1976) - 7.9 % - 14.3 %. The marginal variation observed was perhaps due to some varietal effect or condition of the raw material.

In another study conducted by Saranya (2012), it was reported that the moisture content of stored enriched soup mix (ESM) was found to enhance gradually during the storage period and the increase in moisture content did not influence the quality of the RTC product. Krishnaja (2014) reported that the moisture content of the developed functional food supplement (FFS) was found to enhance gradually during the period of storage. But the increase in moisture content did not influence the quality of the developed product because the increase in moisture content was negligible.

5.3.5.2 Assessment of Microbial profile of the TVP

Assessment of microbial profile is an important factor, which helps to assess the quality and safety of the product. Rao and Das (2003) opined that off odour and off taste of a product due to spoilage causing microorganisms lead to economic losses. From the present study, it was found that during the three months of storage bacterial colonies appeared in the third (1.0×10^7) month of storage in developed TVP, while fungal colonies were within the second (1.5×10^3) month. Even though bacteria and fungi were detected, it was present only in negligible levels and within the permissible limits. No coliforms could be detected in the product. In an earlier study Nasheeda (2006) obtained a bacterial population which ranged from 6.68-6.88 x 10^3 cfu g^{-1} in banana powder packed in poly propylene covers.

Oluwole *et al.* (2013) studied the microbial profile in the food products as determined by the total plate count under storage conditions and showed that maximum total plate counts were 0.5×10^4 and 5.4×10^4 cfu/g at 9 °C ± 2° C and 28 °C ± 2 °C, respectively.

In similar microbial studies conducted on the selected pasta products at the end of two months, the yeast and mould count in pasta products were found to be negligible. The dryness of the products and thus comparatively lesser water activity of the pasta could have contributed to the negligible microbial growth

(Malathidevi, 2015). A similar observation was reported by Chakraborty *et al.* (2013) for products from jackfruit seed flour.

The composition of jackfruit types have been discussed with supporting reference. The measures to reduce antinutrients have also been substantiated. The final product evolved has been studied and compared with related value added products.

Summary

6. SUMMARY

Jackfruit or *Panasa* scientifically known as *Artocarpus heterophyllus* Lam. belongs to the family Moraceae. The fruit is the gigantic syncarp and is known as the largest fruit of the world. It is an indigenous fruit crop of Kerala and is widely grown as an important tree in Kerala's homesteads. It is also seen as a shade crop in many coffee plantations. It is popularly known as the poor man's fruit in the eastern and southern parts of India. As no fertilizer is applied to the jackfruit tree maintained in homesteads, it also has the potential to be identified as a therapeutic fruit grown organically in Kerala by default. Considering its nutritional and health benefits there is need to promote this fruit for health and prevention of lifestyle diseases. Since systematic documentation of nutrient/ chemical constituents is lacking, an evaluation of nutrient and phytochemical profile of local varieties would enlighten the health conscious population of Kerala regarding the nutritive and health excellence of this fruit. Measures to improve digestibility would help to enhance the consumption of this fruit. A textured vegetable protein developed from raw jackfruit will aid in promoting consumption of this fruit among all populations.

The present investigation entitled ''**Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein (TVP)**'' was carried out to ascertain the bioactive compounds and nutrients present in different jackfruit types. The study also envisages the improvement of digestive quality of jackfruit through removal of oligosaccharides and developing a jackfruit based textured vegetable protein. The experiment was carried out in the Department of Community Science, College of Agriculture, Vellayani, Thiruvananthapuram during the period of 2015-2018. Major findings of the study are summarized below.

The study was conducted in three experiments; viz. analysis of nutrient and chemical profile along with antioxidant activity of the selected types of jackfruit; analysis of measures for reducing antinutrients in raw jackfruit and development of raw jackfruit based textured vegetable protein.

For the component wise analysis, five types of jackfruits viz Muttom varikka, Then varikka, Sindoor, Chempikalom varikka and Local cv Koozha were selected; their raw and ripe stages as well as both bulbs and seeds were analysed separately. Analysis of proximate composition, vitamins, minerals, bioactive compounds, antinutrients and antioxidant activity were covered in the first experiment.

The carbohydrate levels in different types, stages of maturity and edible portions of jackfruit showed that Chempikalom varikka had the highest carbohydrate content (34.69g/100g) which was significantly different from others. The lowest carbohydrate content was seen in Then varikka (11.06g/100g) followed by Muttom varikka (15.36). Sindoor contained 21.11g/100g which was on par with Local cv Koozha 21.24g. In the case of stages of maturity, ripe jackfruit (22.63g/100g) contained significantly higher carbohydrate than raw stage of jackfruit (18.76g/100g), both these values were significantly different too. Carbohydrate content in edible portions showed that jackfruit bulbs had higher content (21.00g/100g) than jackfruit seeds (20.39g/100g). The carbohydrate content of the various edible portions were also significantly different.

The level of protein in different types, stages of maturity and edible portion of jackfruit indicate that Local cv Koozha had higher protein content (5.09g/100g). The lowest protein content was seen in Muttom varikka (2.33g/100g) followed by Then varikka (3.70g/100g). Sindoor contained 4.15g/100g and Chempikalom varikka contained 4.22g. The protein content in these types were significantly different too. In the case of stages of maturity raw stages (3.98g/100g) contained higher protein than ripe stage (3.82g/100g), and the values were significantly different from each other. Protein content in the edible

portions showed that seeds of jackfruit contained higher carbohydrate (4.74g/100g) content than bulbs of jackfruit (3.06g/100g).

The dietary fibre content of different types, stages of maturity and edible portion of jackfruit showed that Local cv Koozha had the highest fibre content (1.82g/100g) followed by Chempikalom varikka (1.53g). The moisture content revealed that Chempikalom varikka had the highest moisture content (69.92%) followed by Then varikka (68.44%), Muttom varikka (64.86%), Sindoor (64.00%) and Local cv koozha (62.87%). There was significant difference between each type of jackfruit. In the case of stages of maturity ripe stages of jackfruit (69.38%) had higher moisture content than raw stage of jackfruit (62.66%). There was significant difference between these two stages. Moisture content in edible portions showed that bulb of jackfruit (78.10%) had higher content than seed (53.94%).

The β carotene content of different types, stages of maturity and edible portion of jackfruits reveal that the beta carotene content was higher in Sindoor (253.86 µg) which was followed by Then varikka (166.78 µg). The lowest content was observed in Muttom varikka (40.70 µg). In the case of stages of maturity the ripe stages of jackfruit contained 129.30 µg and raw stage contained 100.51 µg. The edible portions of the jackfruit bulb contained 187.65 µg and the jackfruit seeds contained 42.16 µg.

The Vitamin C content in different types, stages of maturity and edible portion of jackfruits showed that the Vitamin C content was higher in Sindoor (21.30 mg) which was followed by Local cv Koozha (20.84 mg) and Chempikalom varikka (20.68 mg). The lowest content was observed in Muttom varikka (19.14 mg). In the case of stages of maturity the ripe stage of jackfruit contained 21.09 mg of Vitamin C and raw stage contained 19.91 mg. The edible portions of jackfruit bulbs contained 20.35mg and the jackfruit seeds contained 20.65mg.

Local cv Koozha had the highest total mineral content (0.91mg) which was followed by Chempikalom varikka (0.89mg), Sindoor (0.87mg), Then varikka (0.85mg) and Muttom varikka (0.80mg). In the case of stages of maturity both the ripe (0.87mg) and raw (0.86mg) stages were on par with each other. The total mineral content in edible portions showed that the seeds contained higher content of minerals (0.88mg) than bulbs (0.85mg).

Local cv Koozha had the highest calcium content (110.01mg/100g) and the lowest calcium content was obtained for Muttom varikka (69.76 mg/100g). Then varikka contained 82.68 mg, Sindoor contained 79.44mg and Chempikalom had 70.19 mg. All the five types had significantly different values. In the case of stages of maturity, ripe stages contained significantly higher calcium (87.76 mg) than raw stage (77.07 mg). Calcium content with respect to edible portions revealed that jackfruit bulbs (87.85 mg) had higher content than seed (76.98 mg). The phosphorus content was higher in Chempikalom varikka (47.36 mg) which was followed by Muttom varikka (44.63 mg). The lowest content was observed in Local cv koozha (29.16 mg). In the case of stages of maturity, the raw stage of jackfruit contained 42.83 mg and ripe stage contained 35.72 mg. The edible portion of the jackfruit bulb contained 36.27 mg and the jackfruit seeds contained 42.28 mg.

The sodium content was higher in Muttom varikka (8.18 mg) which was on par with Local cv koozha (7.83 mg) and the lowest content was observed in Then varikka (6.17 mg). In the case of stages of maturity, raw stages of jackfruit contained 7.73 mg and ripe stage contained 6.63 mg. The edible portions of the jackfruit bulb contained 7.63 mg and the jackfruit seeds contained 6.74 mg. The potassium content was highest in Chempikalom varikka (416.67 mg) and the lowest content was observed in Local cv koozha (362.50 mg). In the case of stages of maturity the raw stage of jackfruit contained 373.30 mg and ripe stage contained 399.33 mg. The edible portions of the jackfruit bulb contained 353.30 mg and the jackfruit seeds contained 419.33 mg.

The iron content was higher in Then varikka (1.55 mg) which was on par with Sindoor (1.49 mg). The lowest content was observed in Muttom varikka (0.97 mg). In the case of stages of maturity the raw stage of jackfruit contained 1.34 mg and ripe stage contained 1.21 mg. Considering the edible portions of the jackfruit bulbs contained 1.1 mg and the jackfruit seeds contained 1.44 mg.

The magnesium content was higher in Chempikalom varikka (107.80 mg) which was followed by Then varikka (100.04 mg). The lowest content was observed in Muttom varikka (56.73 mg). Considering the stages of maturity the raw stage of jackfruit contained 84.74 mg and ripe stage contained 87.01 mg. The edible portions of the jackfruit bulb contained 82.87 mg and the jackfruit seeds contained 88.88 mg.

The manganese content was higher in Chempikalom varikka (1.21mg) which was followed by Then varikka (1.06 mg). The lowest content was observed in Sindoor (0.86 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.94 mg and ripe stage contained 1.02 mg. With respect to edible portions of the jackfruit, bulbs contained 1.01 mg and seeds contained 0.95 mg.

The copper content was higher in Then varikka (0.36 mg) which was on par with Sindoor (0.33 mg). The lowest content was observed in Muttom varikka (0.12 mg). In the case of stages of maturity, the raw stage of jackfruit contained 0.21 mg and ripe stage contained 0.23 mg and there was no significant difference. The edible portions of the jackfruit bulbs and the jackfruit seeds contained 0.22 mg. The zinc content was higher in Muttom varikka (0.80 mg). The lowest content was observed in Then varikka (0.23 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.52 mg and ripe stage contained 0.48 mg. The edible portions of the jackfruit, bulbs contained 0.51 mg and seeds contained 0.49 mg.

In the case of bioactive compounds, the results revealed the presence of the bioactive compounds such as alkaloids, flavonoids, saponins, tannins and polyphenols. After the confirmation of presence of these bioactive compounds by

preliminary qualitative tests, the fresh jackfruit samples were taken for quantitative estimation.

The results revealed that the alkaloid content was higher in Muttom varikka (52.52 mg). The lowest content was observed in Then varikka (7.68 mg). In the case of stages of maturity the raw stages of jackfruit contained 33.89 mg and ripe stage contained 27.57 mg. The edible portions of the jackfruit bulb contained 29.59 mg and the jackfruit seeds contained 31.87 mg. The flavanoid content was higher in Chempikalom varikka (304.26 mg).The lowest content was observed in Muttom varikka (101.99 mg). In the case of stages of maturity, the raw stage of jackfruit contained 182.93 mg and ripe stage contained 212.58 mg. The edible portions of the jackfruit bulbs contained 136.07 mg and the jackfruit seeds contained 259.44 mg.

The lycopene content was higher in Muttom varikka (2.14 mg) which was on par with Koozha (2.10 mg). The lowest content was observed in Then varikka (0.77 mg). In the case of stages of maturity, the raw stage of jackfruit contained 1.69 mg and ripe stage contained 1.72 mg and there was no significant difference between them. The edible portions of the jackfruit bulb contained 1.77 mg and the jackfruit seeds contained 1.65 mg.

The saponin content was higher in Sindoor (208.85 mg).The lowest content was observed in Local cv koozha (82.75 mg). In the case of stages of maturity raw jackfruit contained 113.67 mg and ripe stages contained 171.35 mg. The edible portions of the jackfruit bulb contained 154.08 mg and the jackfruit seeds contained 130.94 mg.

The tannin content was higher in Sindoor (102.50 mg).The lowest content was observed in Muttom varikka (20.63 mg). In the case of stages of maturity the raw stage of jackfruit contained 88.29 mg and ripe stage contained 51.45 mg. The edible portions of the jackfruit bulb contained 72.93 mg and the jackfruit seeds contained 66.81 mg. The polyphenol content was higher in Sindoor (3.50 mg). The lowest content was observed in Muttom varikka (1.04 mg). In the

case of stages of maturity, the raw stage of jackfruit contained 2.11 mg and ripe stage contained 2.62 mg. The edible portions of the jackfruit bulb contained 3.04 mg and the jackfruit seeds contained 1.69 mg.

The results revealed that the lectin content was higher in Then varikka (1.40 mg), lowest content was observed in Muttom varikka (0.15 mg). In the case of stages of maturity the raw stage of jackfruit contained 0.54 mg and ripe stages contained 0.56 mg. The edible portions of the jackfruit bulb contained 0.42 mg and the jackfruit seeds contained 0.67 mg. The lignin content was higher in Then varikka (9.56 mg). The lowest content was observed in Chempikalom varikka (2.86 mg). In the case of stages of maturity the raw stages of jackfruit contained 6.47 mg and ripe stage contained 5.12 mg. The edible portions of the jackfruit bulb contained 5.35 mg and the jackfruit seeds contained 6.25 mg.

The results for the trypsin inhibitor content was higher in Sindoor (22.83 mg), which was on par with Then varikka (22.50 mg).The lowest content was observed in Muttom varikka (2.75 mg). In the case of stages of maturity the raw jackfruit contained 16.97 mg and ripe stage contained 14.93 mg. The edible portions of the jackfruit bulb contained 14.83 mg and the jackfruit seeds contained 17.07 mg.

The results revealed that Sindoor had the highest raffinose content (0.93µg/µl). The lowest raffinose content was observed in Local cv koozha (0.78 µg/µl). Considering the stages of maturity, both the raw and ripe stage contained 0.85 µg/µl. There was significant difference between the two stages. Raffinose content in edible portions showed that bulb of jackfruits (1.05 µg/µl) had higher content than seeds (0.65 µg/µl).

Antioxidants can inhibit the propagation of free-radical reactions and protect the human body from diseases. Free-radicals and other reactive oxygen species (ROS), such as superoxide anion, hydroxyl radical, and hydrogen peroxide are an entire class of highly reactive molecules derived from the normal metabolism of oxygen or from exogenous factors and agents.

The results revealed that the antioxidant activity expressed as IC_{50} values ranged from 33.53µg/ml to 40.90 µg/ml in five types of jackfruit types. The highest antioxidant capacity was observed in Local cv koozha (33.53 µg/ml) and least antioxidant capacity was observed in Sindoor (40.90 µg/ml). In the case of stages of maturity, the raw stage of jackfruit had IC_{50} value of 35.82 µg/ml and ripe stage of jackfruits had IC_{50} value of 36.36 µg/ml. In the case of edible portions it was observed that the antioxidant activity was higher in seeds (34.98µg/ml) than jackfruit bulb (37.20 µg/ml).

The DPPH antioxidant assay is based on the ability of DPPH, a stable free radical, to decolorize in the presence of antioxidants. The findings revealed that Chempikalom varikka had the highest DPPH activity with an IC_{50} value of 20.06 µg/ml, followed by Local cv koozha (24.35 µg/ml), the lowest DPPH radical scavenging activity was found in Muttom varikka (37.31 µg/ml). The DPPH activity was higher in ripe stage (21.95 µg/ml) of jackfruit than raw stage (30.77 µg/ml). The edible portions of the jackfruit showed that, jackfruit seed had the highest DPPH activity with an IC_{50} value of 25.81 µg/ml, followed by bulbs (26.92 µg/ml).

The findings reveal that Muttom varikka had the highest hydroxyl radical scavenging activity with an IC_{50} value of 33.13 µg/ml. The lowest DPPH radical scavenging activity was found in Then varikka (35.61 µg/ml). The hydroxyl radical scavenging activity was higher in raw stage (34.35 µg/ml) of jackfruit than ripe stage (34.60 µg/ml). Considering the activity of edible portions of the jackfruit, jackfruit seeds had higher activity with an IC_{50} value of 33.13 µg/ml and lower activity was observed in jackfruit bulbs with IC_{50} value of 35.82 µg/ml.

The findings reveal that Local cv Koozha had the highest superoxide radical scavenging activity with an IC_{50} value of 5.25 µg/ml. The lowest superoxide radical scavenging activity was found in Then varikka (6.05 µg/ml). The superoxide radical scavenging activity was higher in raw stage (5.57µg/ml) of

jackfruit than ripe stage (5.70 µg/ml). The edible portions of the jackfruit showed that, jackfruit seeds had the higher activity with IC_{50} value of 5.29 µg/ml and lower activity was observed in jackfruit bulbs with IC_{50} value of 5.99 µg/ml.

The results showed that nutrient wise, raw seeds of Chempikalom and ripe bulbs of Sindoor scored higher than the rest of treatments while with respect to antioxidant activity, ripe seeds of Koozha were better than other treatments. The profiling of nutrients and bioactive compounds in the each part of the experiment is an eye opener on specific features of the common jackfruit type that can be exploited according to varying needs.

The variations in the nutrient and bioactive compound levels is attributed to regional differences in soil quality, cultural practices and climate.

In the second experiment, one treatment with enzyme α galactosidase and another treatment with *Saccharomyces cerevisiae* was carried out on milled raw jackfruit bulbs and seeds of cv koozha to reduce the level of anti nutrients. Enzyme α galactosidase was premixed with the dry flour of jackfruit seed and jackfruit bulb separately in the ratio 1:100 and the moisture level was varied from 25 – 200% (dough to batter stage). The hydrolysis was carried out for 90 minutes in both jackfruit bulb flour and seed flour. The products were evaluated for the breakdown of oligosaccharides (Raffinose) using HPTLC method.

The oligosaccharide (Raffinose) content in pre treated and treated jackfruit bulb flour (JFBF) treated with enzyme at different moisture levels differed customarily in HPTLC assays. In HPTLC analysis, the retention factor of standared Raffinose was 0.58 minutes. The distance that each component of a mixture travels can be quantified using retention factors (Rf). Retention factor recorded by jackfruit bulb flour (control) and bulb flour with enzyme treated at varying moisture levels were 0.58, 0.58, 0.58, 0.58, 0.58, 0.57, 0.57, 0.57, 0.57 at 25%, 50%, 75%, 100%, 125%, 150%, 175%, 200% respectively.

These values were compared to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 0.97in control (without treatment) and in M_1 (25%) - 0.89, M_2 (50 %) - 0.85, M_3 (75 %) - 0.80, M_4 (100 %) - 0.71, M_5 (125 %) - 0.74, M_6 (150 %) - 0.83, M_7 (175 %) - 0.75, M_8 (200 %) - 0.82$\mu g\ g^{-1}$ respectively. The level of Raffinose after treatment was seen to decrease with increase in moisture content (25-100%). Thereafter the variation was not uniform (125%, 150%, 175%, 200%). However it may be noted that the level of oligosaccharides decreased in comparison to control (0.97 $\mu g\ g^{-1}$), which indicates the typical effect of enzyme on breakdown of oligosaccharides.

The oligosaccharide (Raffinose) content in pre treated and treated jackfruit seed flour (JFSF) treated with enzyme at different moisture levels differed in HPTLC assay and the data is tabulated in Table 97. In the HPTLC analysis, the retention factor of standard Raffinose was 0.61 minutes. Retention factor recorded by pretreated (0.61 minutes) and treated jackfruit seed flour was compared to that of the standard Raffinose. Raffinose content in jackfruit bulb flour was 1.16 and 0.83, 0.68, 0.63, 0.56, 0.50, 0.58, 0.74 and 1.08 $\mu g\ g^{-1}$ at 25%, 50%, 75%, 100%, 125%, 150%, 175%, 200% respectively. The level of Raffinose content in seed flour after treatment was seen to decrease with increase in moisture content (25-100%). Here the raffinose content was seen to reduce up to 125%. Thereafter the variation was not uniform (150%, 175%, 200%). However it may be noted that the level of oligosaccharide decreased in comparison to control (1.16 $\mu g\ g^{-1}$), which indicates the asymptotic effect of enzyme on breakdown of oligosaccharides.

The oligosaccharide (Raffinose) content in treated and pre treated jackfruit bulb flour treated with Saccharomyces cerevisiae at different duration of fermentation time differed in the HPTLC assay and the data is tabulated in Table 100. In HPTLC analysis, the retention factor of standared Raffinose was 0.79. Retention factor recorded by pre treated jackfruit bulb flour was 0.79, bulb flour with 6 hrs fermentation showed 0.79, 8 hrs fermentation - 0.79 and 12 hrs - 0.80 respectively, which were comparable to that of the standard Raffinose. Raffinose

content in jackfruit bulb flour was 0.75 µg g^{-1}, 0.63 µg g^{-1}, 0.58 µg $g^{-1}$and 0.74 µg g^{-1} in F_1, F_2, F_3 treatments respectively. In the case of jackfruit bulb flours 8 hours fermentation was found to contain the least oligosaccharides.

The oligosaccharide (Raffinose) content in treated and pre treated jackfruit seed flour treated with *Saccharomyces cerevisiae* at different durations of fermentation was also observed in HPTLC assay. In HPTLC analysis, the retention factor of standard Raffinose was 0.57. Retention factor recorded in both pre treated and treated jackfruit seed flours were compared to that of the standard Raffinose. Raffinose content in jackfruit seed flour was 1.28 µg g^{-1}, 0.42 µg g^{-1}, 0.31 µg $g^{-1}$and 0.62 µg g^{-1} in F_1, F_2, F_3 treatments respectively. Raffinose content was found to reduce in these three treatments and F_1 ie; 8 hours fermentation was selected as the best treatment.

From the findings of antinutritional levels of pretreated and enzyme treated flour, it was observed that antinutrients such as oligosaccharides, tannins, phytates and trypsin inhibitors were reduced after enzyme treating. From this result it was observed that oligosaccharide content in bulb flour was reduced from 0.97 - 0.71µg and seed flour from1.16 - 0.50 µg.Tannin content in the bulb flour was 23.34 mg, which was reduced upto 8.80 mg and for seed flour from 36.52 mg to 11.87 mg. Phytates and trypsin inhibitors are the other two major antinutrients present in jackfruit. The level of phytates present in pretreated bulb flour was 12.63 mg which was reduced upto 8.56mg and the seed flour contained 15.68 mg, which was reduced to 10.33mg. The level of trypsin inhibitors in pretreated bulb flour was 38.22 mg to 18.83mg and from seed flour 42.35 to 23.50mg.

Yeast fermented bulb flour and seed flour showed reduction in antinutrient contents from raw flour. In the case of bulb flour, tannin content was reduced from 23.34 mg to 10.32 mg, Phytates reduced from 12.63mg to 7.04 mg, trypsin inhibitors from 38.22mg to 18.50mg. Fermented foods play an important role in conferring the required stability, safety and sensory properties to the product (Stanton et al., 2005). Fermentation helps in degradation of antinutritional

factors and increases mineral bioavailability, protein digestibility of tannin rich cereals and degradation of flatulence causing oligosaccharides.

The results indicated that antinutrients such as oligosaccharides, tannins, phytates and trypsin inhibitors were reduced in both enzyme treated and yeast fermented flours. From these two treatments fermentation process was selected as the best treatment because of its ease of processing.

Moisture content is one of the important properties of food materials to be considered. Knowledge of the moisture content is often necessary to predict the storage behaviour of foods. For estimating the moisture content, the selected best treatment was packed in PP covers, sealed air tight and stored at ambient conditions. The moisture content was recorded periodically for 6 months. Compared to enzyme treated flours, moisture level was lower in yeast fermented flours. During the initial storage period, the moisture content obtained for bulb flour was 7.63 per cent and seed flour was 7.41 per cent and it was seen to increase after each month of storage period.

The findings show that during the six months of storage bacterial colonies were observed from the V^{th} month and VI^{th} month ($2x10^7$ cfu g^{-1}). Simultaneosly, fungi were detected from the II^{nd} month onwards in enzyme treated bulb flour (1.5×10^3 cfu g^{-1}) and III^{rd} month onwards in yeast treated jackfruit bulb flour ($3x10^3$ cfu g^{-1}) and seed flour (2×10^3 cfu g^{-1}). Even though bacteria and fungi were detected, it was present within the permissible limit. However after fourth month the level of fungal colonies were above the permissible limits (4×10^4 cfu g^{-1}). No coliforms could be detected in both enzyme treated and yeast fermented flours.

Peroxide value gives an indication about the extent of peroxidation having taken place in stored food materials. The peroxide value was recorded for a period of six months. The peroxide content was not observed for both enzyme treated and yeast fermented bulb flour and seed flour for the first three months of the study. The above table indicates that the enzyme treated bulb flour reported

peroxide contents from the IVth Month (0.24 mEq Kg^{-1}). In the case of enzyme treated seed flour, the peroxide content was observed from Vth Month (0.19 mEq Kg^{-1}).

In the case of yeast fermented bulb flour, peroxide formation was observed from the IVth month (0.21 mEq Kg^{-1}) and in the case of seed flour, peroxide content was observed for the IVth month (0.20 mEq Kg^{-1}). However it could be noted that the peroxide contents in all the samples were within the permitted limits. This shows that both the enzyme treated and yeast fermented bulb flour and seed flour can be stored for a period of six months without any discriminate changes, thereby enhancing their market values.

In the third experiment, Jackfruit based TVP was formulated by using the ingredients - jackfruit bulb flour and seed flour along with gluten, yeast and soya flour to form chunks using standardized methods. Totally eleven combinations of TVP were worked out. All the eleven treatments were cooked and evaluated by a panel of ten members. Based on the sensory attributes such as appearance, colour, flavour, texture, taste and overall acceptability, the highest score was obtained for T_7 which was followed by T_8 and these two treatments were seen to be on par. The lowest score was obtained by treatment T_4; T_7 was taken up for quality analysis, it had a protein content of 61.50g, carbohydrate content of 34.97g and lesser cooking time (7.33 minutes). The physico chemical and textural qualities were on par with soyachunks available in the market. Processed TVP showed good storage stability up to three months.

Appearance is the criteria for the desirability of any food product. Cooked TVP was evaluated for overall visual quality (OVQ), as rated by the sensory panel. On evaluation of OVQ scores, the treatment P_7 got highest score (93.50), which was on par with P_8 (86.50), P_{10} (86.50) and P_{11} (82.10). The lowest score was obtained by P_4 (11.35) followed by P_5 (15.75). The scores obtained for other treatments were 47.75, 39.70, 42.30, and 35.55 for P_1, P_2, P_3 and P_6.

Statistical interpretation showed that there was significant difference in cooking time among the treatments. Cooking time of the different treatments ranged from 7.33 min to 15.0 min. The results further revealed that among the treatments P_7 took the least time (7.33 min) for cooking. The second treatment which took less time for cooking was P_8 and P_9 (7.66 min) and it was seen to be par with P_{10} (8.33 min) and P_{11} (8.66 min). More time was taken for cooking P_4 (15.0 min), which was followed by P_1 (14.66 min) and P_2 (14.33 min). P_5 took 11.0 min for cooking which was on par with P_6 (10.33 min) and P_3 (10.33 min).

Cooked weight is an indicator of the extent of absorption of moisture by a food after complete cooking. It was determined by assessing the increase in weight of raw material (10 g) after complete cooking. Cooked weight of TVP was calculated as the increase in weight of raw TVP after cooking. The data revealed that highest increase of weight was obtained for P_4 (41.23g) and the lowest weight was obtained for P_{10} (23.33 g), which was on par with P_8 (23.43 g) and P_9 (23.56 g). The next highest score was obtained by P_3 (29.93) and P_1 (29.93) which were on par with P_5 (29.73) and P_6 (29.63). The scores obtained for P_2, P_7, P_{11} were 26.16, 24.96, 24.93 respectively.

The functional qualities help in the quality assessment and acceptability of any product. Functional qualities such as yield, appearance, rehydration ratio and water absorption index were studied. Yield ratio of different treatments ranged from 0.650 - 0.770 per cent. Results further reveal that P_3 having G: JFBF: JFSF in the ratio of 50:10:40 had the highest value (0.770). The lowest value was obtained by P_9 (0.650). Yield ratio obtained for other treatments were 0.670, 0.670, 0.746, 0.723, 0.693, 0.750, 0.723, 0.670 and 0.683 for P_1, P_2, P_4, P_5, P_6, P_7, P_8, P_{10}, P_{11} respectively.

Texture profile analysis showed that the crispness value obtained for TVP was 2.22 and Soyachunks was 0.42. Hardness value obtained for TVP was 1.32 and chunks was 1.02. Values for stringiness is an important attribute for which TVP had 22.20 and soya chunks had 17.04.

Rehydration ratio was highest for the treatments P_9, P_{10}, P_{11} (0.456) followed by P_7 and P_8 (0.423). Treatment P_2 and P_3 (0.413) had the least rehydration ratio. The rehydration ratio obtained for other treatments were 0.417, 0.416, 0.416, 0.415 for P_1, P_4, P_5, P_6 respectively. Water absorption of TVP was found to be higher in P_5 (140.66) treatment which contained more amount of seed flour. The treatment P_6 (138.33) was on par with P_5 which contained more amount of bulb flour. In these treatments it was seen that the increase in concentration of both bulb flour and seed flour increased water absorption.

The nutrient composition of carbohydrates, total protein, fat, calories, fiber and total minerals of finalized TVP were analyzed. The carbohydrate content of the finalized TVP was 34.97 g/ 100g, total protein content 61.50g/100 g, fat 14.40g/100g, calories 440.26 Kcal, fiber 4.20g/100g and total minerals 2.4g/100g.

The moisture content of the developed jackfruit based TVP in PP covers was analysed. The evaluation of TVP was conducted periodically for three months and the data is shown in Table 116. Initial moisture content of TVP was 7.41 per cent. At the end of first month TVP showed little increase (7.65) in moisture content. At the end of second month of storage moisture content of TVP were 8.72. The moisture content increased further by the end of third month. However the levels were within permitted limits of safety.

Assessment of microbial profile is an important factor, which helps to determine the quality and safety of the product. Microbial contamination of the TVP developed in the study was assessed to determine the keeping quality of the products. There are a lot of chances of contamination through various means including conditions of storage of the products. It is evident from Table 117, that during the three months of storage period, bacterial colonies were found to appear in the third month of storage period (1.0×10^7) in developed TVP, while fungal colonies were observed for the second (1.5×10^3). Even though bacteria and fungi were detected, it was in negligible levels and within the permissible limits. No coliforms could be detected in the product.

The physico chemical and textural qualities were on par with soyachunks available in the market. Processed TVP showed good storage stability up to three months. The third part of the study concluded with a positive note on scope of commercializing this jackfruit based protein concentrate. The product is both novel and healthy, raising its popularity for sailing up.

Thus, the study finds that there is variation in jackfruit types with respect to nutrients, chemical and bioactive compounds. The efficacy of enzyme α galactosidase and *Saccharomyces cerevisiae* to reduce oligosaccharide levels in jackfruit flour is feasible. A highly acceptable meat analogue was also standardized based on jackfruit flour, which can be recommended for commercialization. The scope of commercialization can be improved with demonstration of various recipes with the standardized products like curries, snacks, TVP based rice and pasta preparations.

References

7. REFERENCES

[Anonymus]. 1970. Chemical studies on mango kernel and jack fruitpart 1. *Indian Food Packer*. 22(2): 39-42.

AACC [American Association of Cereal Chemists]. 2000. Approved methods of analysis (10^{th} Ed.), St. Paul, Minnesota. 1298p.

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

Abraham, A. and Jayamuthunagai, J. 2014. An analytical study on jackfruit seed flour and its incorporation in pasta. *Res. J. Pharma. Biol. Chem. Sci.* 5(2): 1597-1610.

Abraham, D., Rodimeire, G., Rodrigues, M., Carla, S.S., and Amanda, C. F. 2014. The air drying behaviour of osmotically dehydrated jackfruit (*Artocarpus heterophyllus* Lam.) slices. Proceedings of the Fourteenth International Drying Symposium, pp.29 -31.

AbuBakar, M. F., Karim, A. F., and Perisamy, E. 2015. Comparison of phytochemicals and antioxidant properties of different fruit parts of selected Artocarpus species from Sabah, Malaysia. Sains Malaysiana. 44(3):355–363.

ADA [American Diabetes Association]. 2004. Summary of revisions for the 2004 clinical practice recommendations. pp.141-142.

Adegbehingbe, K. T. 2015. Effect of starter cultures on the anti-nutrient contents, minerals and viscosity of Ogwo, a fermented sorghum–Irish potato gruel. *Int. Food Res. J.* 22 (3): 1247-1252.

Adeleke, R.O. and Odedeji, J.O. 2010. Functional properties of wheat and sweet potato flour blends. *Pakist. J. Nutr.* 9(6): 535.

Adya, S. and Elbein, A. D. 1977. Glycoprotein enzymes secreted by aspergillus niger: purification and properties of alpha galactosidase. *J. Bacteriol.* 850-856.

Agte, V. V., Tarwadi, K. V., and Chiplonkar, S. A.1999. Phytate degradation during traditional cooking : Significance of the phytic acid profile in cereal based vegetarian meals. *J. Food Anal.* 12: 161-167.

Agung, B., Efrilia, T., Iskandar, K., Khairina, M., and Eko, S. 2015. Antidiabetic and Antioxidant Activity of Jackfruit (*Artocarpus heterophyllus*) Extract. *J. Med. Bioeng.* 4(4) : 318-323.

Agustawa, R., 2012. Modifikasi Pati Ubi Jalar Putih (Ipomea batatas L) Varietas Sukuh dengan Proses Fermentation dan method, heat, moisture treatment (HMT) Terhadap Karakteristik Fisik dan Kimia Pati. Thesis. Brawijaya Universitas, Indonesia, 68p.

Ahmed, K., Malek, M., Jahan, K., and Salamatullah, K. 1986. Nutritive value of food stuff (3rd Ed.). Institute of Nutrition and Food Science, University of Dhaka, Bangladesh, pp.16 – 17.

Airani, S. 2007. Nutritional quality and value addition to jack fruit seed flour. MSc.Thesis, Department of Food Science and Nutrition, College of Rural Home science, Dharwad University of Agricultural sciences, 114p.

Ajayi, I.A. 2008. Comparative study of the chemical composition and mineral element content of *Artocarpus heterophyllus* and *Treculia Africana* seeds and seed oils. *Bioresource Technol.* 99(11): 5125-5129.

Akanbi, T.O., Nazamid, S., Adebowale, A.A., Farooq, A., and Olaoye, A.O. 2011. Breadfruit starch-wheat flour noodles: preparation, proximate compositions and culinary properties. *Int. Food Res. J.* 18: 1283-1287.

Akinyele, I.O. and Akinlosotu, A. 1991. Effect of soaking, dehulling and fermentation on the oligosaccharides and nutrient content of cowpeas (*Vigna unguiculata*). *Food Chem.* 41:43–53.

Alcantara, R.M., Hurtada, W.A., and Dizon, E.I. 2013. The nutritional value and phytochemical components of taro (*Colocasia esculenta* (L.) Schott) powder and its selected processed foods. *J. Nutr. Food Sci.* 3(3): 207.

Almeida, M. M. B., De Sousa, P. H. M., Arriaga, A. M. C., Prado, G. M., Magalhaes, C. E., Maia, G. A., and Lemos, T. L. G. 2011. Bioactive compounds and antioxidant activity of fresh exotic fruits from Northeastern Brazil. *Food Res. Int.* 44: 2155-2159.

An, K., Ding, S., Tao, H., Zhao, D., Wang, X., and Wang, Z. 2013. Response surface optimisation of osmotic dehydration of Chinese ginger (*Zingiber officinale Roscoe*) slices. *Int. J. Food Sci. Technol.* 48:28-34.

Anderson, R. P., van Heel, D. A., TyeDin, J. A., Barnardo, M., Salio, M., Jewell, D. P., and Hill, A. V. 2006. T cells in peripheral blood after gluten challenge in coeliac disease. *Gut.* 54:1217–1223.

Anneahira, J. K. 2010. Zat Penyebab Kankerdan Sumbernya. Available: http://www.anneahira.com/zat-penyebab-kanker.htm.[11 July 2010].

AOAC [Association of Official Analytical Chemists]. 1990. Official methods of analysis (15th Ed.), Washington, D. C. 156p.

AOAC [Association of Official Analytical Chemists]. 2000. Official methods of analysis (17th Ed.),Washington D.C. 1212p.

AOAC [Association of Official Analytical Chemists]. 2005. Official methods of analysis. pp.97- 424.

Arung, E. T, Shimizu, K., and Kondo, R. 2007. Inhibitory effect of artocarpanone from *Artocarpus heterophyllus* on melanin biosynthesis. *Biological and Pharmaceutical Bulletin.* 29(9):1966–1969.

Arung, E. T., Shimizu, K., and Kondo, R. 2006a. Inhibitory effect of isoprenoid-substituted flavonoids isolated from *Artocarpus heterophyllus* on melanin biosynthesis. *Planta Medica.* 72 : 847-850.

Arung, E. T., Shimizu, K., and Kondo, R. 2006b. Inhibitory effect of artocarpanone from *Artocarpus heterophyllus* on melanin biosynthesis. *Biological and Pharmaceutical Bulletin.* 29 : 1966-1969.

Arung, T., Shimizu, K., Tanaka, H., and Kondo, R. 2010. 3-Prenyl luteolin, a new prenylated flavone with melanin biosynthesis inhibitory activity from wood of *Artocarpus heterophyllus*. *Fitoterapia.* 81: 640-643

Athar, H.U.R., Khan, A., and Ashraf, M. 2008. Exogenously applied ascorbic acid alleviates salt induced oxidative stress in wheat. *Environ. Exp. Bot.* 63(3):224-231.

Ayodele, M. S. and Oginni, E. O. 2003. Utilization of breadfruit (*Artocarpus incisa*) flour for confectionery products, FTA. 38(12):710.

Azad, A.K.2000. Genetic diversity of jackfruits in Bangladesh and development of propagation methods. Ph.D Thesis, University of Southampton, UK. 61p.

Bakar, M. F. A., Mohamed, M., Rahmat, A., and Fry, J. 2009. Phytochemicals and antioxidant activity of different parts of bambagan (*Mangifera pajang*) and tarap (*Artocarpus odoratissimus*). *Food Chem.* 113:479–483.

Baliga, M.S., Shivashankara, A.R., Haniadka, R., Dsouza, J., and Bhat, H.P. 2011. Phytochemistry, nutritional and pharmacological properties of *Artocarpus heterophyllus* Lam. (Jackfruit): A review. *Food Res. Int.* 44(7):1800-1811.

Banerjee, S. and Datta, S. 2015. Effect of dry heat treated jackfruit seed powder on growth of experimental animals. *J. Pharmacy Biol. Sci.* 10(6):42-46.

Barampama, Z. and Simard, R. E. 1994. Effects of soaking, cooking and fermentation on composition, in-vitro starch digestibility and nutritive value of common beans. *Plants Foods Human Nutr.* 48:349 - 365.

Barbara, L. M. 2009. Fermented soy is only soy food fit for human consumption. 38p.

Barberan, T. F. and Espin, J. C. 2001. Phenolic compounds and related enzymes as determinants of quality of fruits and vegetables. *J. Sci. Food Agric.* 81:853–876.

Barik, B. R., Bhaumik, T.A.K., and Kundu, A.B.1997. Triterpenoids of *Artocarpus heterophyllus*. *J. Indian Chem. Soc.* 74 : 163-164.

Barua, A.G. and Boruah, B.R. 2004. Minerals and functional groups present in jackfruit seeds –a spectroscopic inventory. *J. Food Sci. Nutr.* 55: 479-483.

Beard, W. P. C. and Ryan, L. 2011. Review: Improving public health? : The role of antioxidant-rich fruit and vegetable beverages. *Food Res. Int.* 44(10): 3135-3148.

Begum, K. and Umapathy, P.K. 1989. Effect of partial replacement of cereal in rice and ragi diets by jack fruit seed flour on the nutritive value of diets. *Indian. J. Nutr. Dietet*, 26 :141-143.

Begum, K., Umapathy, P. K., Daniel, V. A., and Swaminathan, M., 1989. Nutritive value of jack fruit (*Artocapus integrifola*) seed meal and effect of

supplementing with methionine and tryptophan or milk proteins. *Indian. J. Nutr. Dietet.* 26 :68-74.

Berghofer, L.K., Hocking, A.D., Miskelly, D., and Jansson, E. 2003. Microbiology of wheat and flour milling in Australia. *Int. J. Food Microbiol.* 85:137-149.

Bernard, G. and Dromard, A. 2011. *Book of etymology and medical terminology: Lexicon etymology* (in French). pp.1-4.

Berry, S.K., and Kalra, C.L.1988. Chemistry and Technology of jackfruit (*Artocarpus heterophyllus*): A review. *Indian Food packer*. 42: 62-76.

Beuchat, L. R. 1997. Functional and electrophoretic characteristics of succinylated peanut flour protein. *J. Agic. Food Chem.* 25:258.

Biesalski, H. K. 2009. Bioactive compounds: Safety and efficacy. *Nutr.* 25(11-12): 1206-1211.

Bobbio, F. O., El-Dash, A. A., Bobbio, P. A., and Rodrigues, L. R. 1978. Isolation and characterization of the physicochemical properties of the starch of jackfruit seeds (*Artocarpus heterorphyllus*). *Cereal Chem.* 55: 505-11.

Bose, T. K. 1985. Jackfruit. In: Mitra, B.K. (ed.), *Fruits of India: Tropical and Subtropical*. Naya Prokas, Culcutta, pp.488–497.

Brain, C. J. 2013. Strategies for the removal of raffinose family oligosaccharides from navy bean flour. Ph.D Thesis, Massey University, Palmerston North, New Zealand. 110p.

CAC [Codex alimentarius commission]. 2001. Joint FAO/WHO food standards programe, codex committe on food additives and contaminants. Thirty-third session, Netherlands.124p.

Chakraborty, P., Bhattacharyya D. K., Bandyopadhyay, N. R., and Ghosh, M. 2013. Study on utilization of jackfruit seed flour and de-fatted soy flour mix in preparation of breakfast cereal by twin-screw extrusion technology Discovery. *J. Food Eng.* 4(11):32-37.

Chandrika, V.G., Jangz, E.R., and Warnasuny, N.D. 2004. Analysis of carotenoids in ripe jackfruit in Kerala and study the bioconservation. *J. Sci. Food Agric.* 85(2): 186-190.

Chatterjee, B.P., Vaith, P., Chatterjee, S., Karduck, D., and Uhlenbruck, G. 1979. Com-parative studies of new marker lectins for alkali-labile carbohydrate chains in glycoproteins. *Int. J. Biochem.* 10: 321–327.

Cheeseman, K. H. and Scater, T. F. 2003. Free radical in medicine. *In British medical bulletin.* Churchill, livingstone, London. 9:479-724.

Chen, Z., Sagis, L., Legger, A., Linssen, J.P.H., Schols, H. A., and Voragen, A. G. J. 2002. Evaluation of starch noodles made from three typical Chinese starches. *J. Food Sci.* 67:3342-3347.

Chickwendu, N.J. 2005. Production and availability of ground bean (*Kerstingiella geocarpa*) in a typical Nigerian community: implication for nutrition education and nutritional development. *J. Home Econ. Res.* 6: 135 - 141.

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 Appl. Biol.* 2(3) 36-37.

Christine, H. and Rosalind, S. G. 2006. Traditional food processing and preparation practices to enhance the bioavailability of micronutrients in plant based diets. Symposium: Food based approaches to combating micronutrient deficiencies in children of developing countries. *J. Nutr.* 45p.

Civas, A., Eberhard, R., Dizet, P. L., and Petek, F. 1984. Glycosidases induced in *Aspergillus tamarii*: secreated at D galactosidases and f/D-mannanase. *Biochem. J.* pp.857-863.

Clemente, A. and Domoney, C. 2001.Anticarcinogenic activity of protease inhibitors in legumes. *in*: Proceedings of the 4th European conferences on grain legumes, Towards the sustainable production of healthy food, Feed and Novel Products, Trocadero, Paris, France, pp.114–115.

Corcuera, J. I., Cavalieri, R. P., and Powers, J. R. 2004. *In: Encyclopedia of agriculture, Food Biol. Eng.* 38p.

Correia, A., Nunes, S., and Guedes, A. S. 2010. Screening of lactic acid bacteria potentially useful for sorghum fermentation. *J. Cereal Sci.* 52: 9-15.

Cox, B. D., Whichelow, M. J., and Prevost, A. T. 2000. Seasonal consumption of salad vegetables and fresh fruit in relation to the development of cardiovascular disease and cancer. *Public Health Nutr.* 3: 19-29.

Dai, J. and Mumper, J.R. 2010. Plant Phenolics: Extraction, Analysis and Their Antioxidant and Anticancer Properties. *Molecules*. 15 : 7313–7352.

Das, K.P. 2014. Development and quality evaluation of fruit based instant snack and pasta product. Ph.D. Thesis. Kerala Agricultural University, Thrissur.pp1-122.

Dayal, R. and Seshadri, A. R. 1974. Colourless compounds of the roots of *Artocarpus heterophyllus*; Isolation of new compound artoflavone. *Indian J. Chem.* 12 : 895-896.

De Beer, D., Joubert, E., Gelderblom, W. C., and Manley, M. 2002. Phenolic compounds: A review of their possible role as in vivo antioxidants of wine. *S. Afr. J. Enol. Vitic.* 23(2):48-58.

Deshpande S.S. 2002. *Handbook of food toxicology*. pp 370-378.

321

Devaraj, S. and Jialal, I. 2006. The role of dietary supplementation with plant sterols and stanols in the prevention of cardiovascular disease. *Nutr. Rev.* 64: 348 – 354.

Devi, P. S., Talaulikar, S., Gupta, M. J., Thangam, M., and Singh, N. P. 2014. A Guide on Jack Fruit - Cultivation and Value Addition. *Technical Bulletin No.* 41, ICAR (RC), Goa. pp.3- 66.

Dey, P.M. and Pridham, J.B. 1972. Biochemistry of α-galactosidase. *Adv Enzymol.* 36: 91-130.

Duenas, M., Hernandez, T., Estrella, I., and Fernandez, D. 2009. Germination as a process to increase the polyphenol content and antioxidant activity of lupin seeds (*Lupinus angustifolius* L.). *Food Chem.* (117): 599-607.

Duhan, A., Khetarpaul, N., and Bishnoi, S. 2001. ''Saponin content and trypsin inhibitor activity in processed and cooked pigeon pea cultivars'', *Int. J. Food Sci. Nutr.* 52(1): 53-9.

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(2): 284 -291.

Egli, I., Davidsson, L., Juillerat, M. A., Barclay, D., and Hurrell, R. 2002. The influence of soaking and germination on the phytase activity and phytic acid content of grains and seeds potentially useful for complementary feeding. *J. Food Sci.* 67:3484- 3488.

Eka, O.U. 2001. The Chemical Composition of Yam Tubers. In: Osuji, C. (ed.), Advances in Yam Research. *The Biochemistry and Technology of Yam Tubers.* Vol. 1, Biochemical Society of Nigeria in Collaboration with Anambra State University of Technology (ASUTECH), Enugu, Nigeria, pp.51-57

322

Eke, O. S. and Akobundu, E. N. T. 1993. Functional properties of African yam bean (*Sphenostylis stenocarpa*) seed flour as affected by processing. *Food Chem.* 48: 337-340.

El-Hady, E.A.A. and Habiba, R.A.2003. Effect of soaking and extrusion conditions on antinutrients and protein digestibility of legume seeds. *LWT-Food Sci. Technol.* 36: 285-293.

El-Hag, N., Haard, N. F., and Morse, R. E. 1987. Influence of sprouting on the digestibility coefficient, trypsin inhibitor and globulin protein of red kidney bean. *J. Food Sci.* 43: 1874-1885.

Elkhalifa, E. O., Schiffler, B., and Bernhard, R. 2004. Effect of fermentation on the starch digestibility, resistant starch and some physicochemical properties of sorghum Flour. *Afr. J. online*. 48: 91 - 94.

Emelike, N. J. T., Barber, L.I., and Ebere, C.O. 2015. Proximate, mineral and functional properties of defatted and undefatted cashew (*Anacardium occidentale* Linn.) kernel flour. *Eur. J. Food Sci. Technol.* 3(4):11-19.

Esmaillzadeh, A. and Azadbakht, L. 2008. Major dietary patterns in relation to general obesity and central adiposity among Iranian women. *J. Nutr.* 138: 358–363.

Evans, W. C. 1996. Trease Evans Pharmacognosy (14th Ed). London, WB Saunders Ltd. pp.119-159.

Fang, S. and Yen, G. 2008. Antiinflammatory effect of phenolic compounds isolated from the fruits of *Artocarpus heterophyllus*. *J. Agric. Food chem.* 56: 4463-4468.

Faria, D.A.F., Rosso, V.V., and Mercadante, A. Z. 2009. "Carotenoid composition of jackfruit (*Artocarpus heterophyllus*) determined by HPLC-PDA-MS/MS," *Plant Foods Hum. Nutr.* 64 : 108–115.

Fasina, O., Tyler, B., Pickard, M., Zheng, G., and Wang, N. 2001. Effect of infrared heating on the properties of legume seeds. *Int. J. Food Sci. Technol.*36: 79-90.

Fazelshamsa, K., Monsef, H., Ghamooshi, R., and Verdianrizi. M. 2008. Spectrophotometric determination of total alkaloids in some Iranian medicinal plants. *Thai. J. Pharma. Sci.* 32: 17-20.

Fernando, M. R., Wickramasinghe, M. I. Thabrew, P.L., and Ariyananda, E. H. 1991. Effect of *Artocarpus heterophyllus* and *Asteracanthus longifolia* on glucose tolerance in normal human subjects and in maturity-onset diabetic patients. *J. Ethnopharmacol.* 31: 277-282.

Ferreira, J.G., Reis, A. P., Guimaraes, V.M., Falkoski, D. L., Fialho, L. D. S., and Rezende, S. T. D. 2011. Purification and characterisation of Aspergillus terreus alpha galactosidases and their use for hydrolysis of soymilk oligosaccharides. *Appl. Biochem. Biotechnol.* 164:1111-1125.

Fredrikson, M., Andlid, T., Haikara, A., and Sandberg, A. S. 2002. Phytate degradation by microorganisms in synthetic media and pea flour. *J. Appl. Microbiol.* 93: 197–204.

Fu, L., Xu, B. T., Xu, X. R., Gan, R. Y., Zhang, Y., Xia, E. Q., and Li, H. B. 2011. Antioxidant capacities and total phenolic contents of 62 fruits. *Food Chem.* 129: 345-350.

Gherardini, F., Babcock, M., and Salyers, A. A. 1985. Purification and characterisation of two alpha galactosidase associated with catabolism of guar gum and other oa galactosides by bacteroides ovatus. *J. Bacteriol.*pp.500-506.

Goncalves, J.L.S., Lopes, R.C., Oliveira, D.B., Costa, S.S., Miranda, M.M.F.S., Romanos, M.T.V., Santos, N.S., and Wigg, M.D. 2005. In vitro

antirotavirus activity of some medicinal plants used in Brazil against diarrhoea. *J. Ethnopharmacol.* 99: 403- 407.

Gopalan, C., Rama Sastri, B.V. and Balasubraminian, S.C. 1991. Nutritive value of Indian foods. National institute of nutrition. ICMR, Hyderabad. India, 82p.

Gopalan, C., Ramasastri, B.V., and Balasubramanian, S.C. 2009. Nutritive value of Indian foods. NIN, ICMR, Hyderabad, 47p.

Goswami, C., Hossain, M. A., Kader, H. A., and Islam, R. 2011. Assessment of physicochemical properties of jackfruits' (*Artocarpus heterophyllus* Lam) Pulps. *J. Hortic. For. Biotechnol.* 15(3):26–31.

Guillon, F. And Champ, M.M.J. 2002. Carbohydrate fractions of legumes: uses in human nutrition and potential for health. *Br. J. Nutr.* 88: 293-306.

Guimaraes, V.M., Rezebde, S. T. D., Moreira, S. T., Barros, E. G. D., and Felix, C. R. 2001. Characterisation of alpha galctosidase from germinating soyabean seed and their use for hydrolysis of oligosaccharides. *Phytochem.*67-73.

Gupta, D., Mann, S., Sood, A., and Gupta, R. K. 2011. Phytochemical, nutritional and antioxidant activity evaluation of seeds of jackfruit (*Artocarpus heterophyllus*). *Int. J. Pharma. Bio Sci.* 2(4):333–343.

Gurtas, S. F., Ak, M. M., and Evranus, E.O. 2001. Water diffusion coefficients of selected legumes grown in Turkey as affected by temperature and variety. *Turkish J. Agric. For.* pp.297-304.

Hakim, E. H., Achmad, S. A., Juliawaty, L. D., Makmur, L., Syah, Y. M., Aimi, N., Kitajima, M., Takayama, H., and Ghisalberti, E.L. 2006. Prenylated flavanoids and related compounds of the Indonesian *Artocarpus* (Moraceae). *J. Nat. Med.* 60(3):161-184.

Halliwell, B. 1996. Antioxidants in human health and disease. *Ann. Rev. Nutr.* 16: 33–50.

Han, H. and Baik, B. 2006. ''Oligosaccharide content and composition of legumes and their reduction by soaking, cooking, ultrasound and high hydrostatic pressure.'' *Cereal Chem.* 83: 428-433.

Haq, N. 2006a. Jackfruit (*Artocarpus heterophyllus*) Southampton Centre for Underutilized Crops. Southampton, UK, University of Southampton. 55:44–52.

Haq, N. 2006b. Jackfruit (*Artocarpus heterophyllus*). In: Tropical Fruit Trees, Williams, J.T., Smith, R.W., and Dunsiger, Z. (eds), Southampton, UK: Southampton Centre for Underutilised Crops, University of Southampton. 98p.

Hardy, G. 2000. *Nutrition.* 16:688-689.

Havsteen, B. H. 2002. The biochemistry and medical significance of the flavonoids. *Pharmacol. Ther.* 96: 67–202.

Hedge, J.E. and Hofreiter, B.T. 1962. Carbohydrate chemistry. Academic Press, New York, 17p.

Helen, S.A., Praveensari, B., and Priya, R. 2006. Value added product from jack fruit seed flour, ICFOST, Hyderabad, 66p.

Hertog, M.G.L., Feskens, E.J.M., Hollman, P.C.H., Katan, M.B., and Kromhout, D. 1993. Dietary antioxidant flavonoids and risk of coronary heart disease: the zutphen elderly study. 342:1007–11.

Hesse, P. R. 1971. *A textbook of soil chemical analysis.* Chemical Pub. Co., *Thechnol. Eng.* 520p.

Hosu, A., Cristea, V. M., and Cimposu, C. 2014. Analysis of total phenolic, flavonoids, anthocyanins and tannins content in Romanian red wines: Prediction of antioxidant activities and classification of wines using artificial neural networks. *Food Chem.* 150:113–118.

Hussain, S., Anjum, F.M., Butt, M.S., Khan, M.I., and Asghar, A. 1999. Physical and sensonic attributes of flaxseed flour supplemented cookies. *J. Food Sci. Technol.* 52 (2): 87-91.

IOM [Institute of Medicine]. 2001. Food and Nutrition Board. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. National Academy Press, Washington, DC, pp.442-501.

Jagadeesh, S. L., Reddy, B. S., Swamy, G.S.K., Gorbal, K., Hegde., and Raghavan, G. S. V. 2007. "Chemical composition of jackfruit (*Artocarpus heterophyllus* Lam.) selections of Western Ghats of India," *Food Chem.* 102 : 361–365.

Jagdeesh, S. L., Reddy, B. S., Basavraj, N., Swamy, G.S.K. and Hegde, L. 2010. Variability studies in physico-chemical qualities of jackfruit (*Artocarpus heterophyllus* Lam.) of coastal zone of Karnataka. *Karnataka J. Agric. Sci.* 23: 293-297.

Jagetia, G. C. and Baliga, M. S. 2006. Evaluation of anticancer activity of the alkaloid fraction of *Alstonia scholaris* (Sapthaparna) in vitro and in vivo. *Phytother. Res.*20(2):103-9.

Jagtap, B. U., Panaskar, N.S., and Bapat, V.A. 2010. Evaluation of antioxidant capacity and phenol content in Jackfruit (*Artocarpus heterophyllus* Lam.) Fruit Pulp. *Plant Foods Hum. Nutr.* 65(2): 99-104.

Jagtap, B. U., Waghmare, R.S., Lokhande, H.V., and Bapat, A.V. 2011. Preparation and evaluation of antioxidant capacity of Jackfruit (*Artocarpus heterophyllus* Lam.) wine and its protective role against radiation induced DNA damage. *Ind. Crops Products.* 34(3): 1595-1601.

Jagtap, U.B. and Bapat, V.A. 2010. Artocarpus : A review of its traditional uses, phytochemistry and pharmacology. *J. Ethnopharmacol.* 129(2): 142-166.

Jahan, S., Gosh, T., Begum, M., and Saha, K.B. 2011. Nutritional profile of some tropical fruits in Bangladesh: Specially antioxidants, vitamins and minerals. Bangladesh, *J. Medical Sci.* 10(2): 96-103.

Jaiswal, P. C. 2003. Soil, plant and water analysis. Kalyani Publishers, New Delhi, 74p.

Jeyam, M., Peelaja, R., Shalini, G., and Ravikumar, P. 2013. Evaluation of *Artocarpus hirsutus* fruit pulp against alzheimer"s disease. *Arch. Pharmacol. Biol. Sci.* 2(1): 30-40.

Joel, T. 2011. Antinutrients in legume foods and their removal. Department of Food Technology and Nutrition. Makerere University, Kampala, 36p.

Jones, D. P., Westman, E., Mattes, R. D., Wolfe, R. R., Astrup, A., and Plantenga, M. W. 2008. Protein, weight management, and satiety. *Am. J. Clin. Nutr.* 87(5): 155–156.

Kagan, M., Howard, D., Bendele, T., and Terstappen, L. W. 2002. A sample preparation and analysis system for identification of circulating tumor cells. *J. Clin. Ligand Assay.* 25(1): 104-110.

Kakade, M. L., Simons, N., and Liener, I. E. 1969. An evaluation of natural versus synthetic substrates for measuring the antitryptic activity of soybean samples. *Cereal Chem.* 46:518.

Kalcher, K., Svancara, I., Buzuk, M., Vytras, K., and Walcarius, A. 2009. Electrochemical sensors and biosensors based on heterogeneous carbon materials. *Monatsh. Chem.* 140: 861-889.

Kalia, M. 2010. *Food quality management*. Udaipur, India: Agrotech Publishing Academy.

Kannan, V.R., Stalin, G., Rajasekar, P., Rajesh, V., Balasubramanian, N., Ramesh, E., Solomon, K., Nivas, D., and Chandru, S. 2012. Anti diabetic activity on ethanolic extracts of fruits of *Terminalia chebula* Retz. alloxan induced diabetic rats. *Am. J. Drug Discovery Dev.* 2: 135-142.

Karthy, E.S., Ranjitha, P., and Mohankumar, A. 2009. Antimicrobial potential of plant seed extracts against multidrug resistant Methicillin Resistant *Staphylococcus aureus* (MDR-MRSA). *Int. J. Biol.* 1: 34-40.

Katrolia, P., Jia, H., Yan, Q., Song, S., Jiang, Z., and Haibo, X. 2012. Characterization of a protease resistant alpha galactosidase from the thermophilic fungus *Rhizomucor miehei* and its application in removal of raffinose family oligosaccharides. *Bioresource Technol.* pp.578-586.

Khan, M., Omoloso, A., and Kihara, M. 2003. Antibacterial activity of *Artocarpus heterophyllus*. *Fitoterapia.* 74(5): 501–505.

Khare, S. K. 2000. Application of immoblised enzymes in soybean processing. The third international soybean processing and utilization conference (ISPCTC): 2000 of the innovation Era for soy beans. Tsukuba, Ibaraka, Japan, pp.381-382.

Khattab, R.Y. and Arntfield, S. D. 2009. Nutritional quality of legume seeds as affected by some physical treatments 2. Anti-nutritional factors. LWT - *Food Sci.Technol.* 42: 1113-1118.

Kiran, K. S. and Padmaja, G. 2003. Inactivation of trypsin inhibitors in sweet potato and taro tubers during processing. *Plant Food Hum. Nutr.* 58(2):152-163.

Ko, F. N., Cheng, Z. J., Lin, C. N., and Teng, C. M. 1998. Scavenger and antioxidant properties of prenylflavones isolated from *Artocarpus heterophyllus*. *Free Radical Biol. Med.* 25(2):160–8.

Ko, F. N., Cheng, Z. J., Lin, C. N., and Teng, C. M. 2003. Scavenger and antioxidant properties of prenylflavones isolated from *Artocarpus heterophyllus*. *Food Hum. Nutr.* 25:160-168.

Ko, M.J., Cheigh, C.L., and Chung, M.S. 2014. Relationship analysis between flavanoids structure and subcritical water extraction (SWE), *Food Chem.* p.147-155.

Kolar, F. R., Kamble, V. S., and Dixit, G. B. 2011. Phytochemical constituents and antioxidant potential of some underused fruits. *Afr. J. Pharmacy Pharmacol.* 5(18): 2067-2072.

Korus, J., Gumul, D., and Czechowska, K. 2007. Effect of extrusion on the phenolic composition and antioxidant activity of dry beans of Phaseolus vulgaris L. *Food Technol. Biotechnol.* 45: 139-146.

Kotowaroo, M. I., Mahomoodally, M. F., Fakim, A. G., and Subratty, A. H. 2006. Screening of traditional antidiabetic medicinal plants of Mauritius for possible alpha-amylase inhibitory effects in vitro. *Phytotherapy Res.* 20: 228-231.

Kotwal, S.M., Gote, M.M., Sainkar, S.R., Khan, M.I., and Khire, J.M. 1998. Production of α-galactosidase by thermophilic fungus *Humicola* sp. in solid-state fermentation and its application in soymilk by hydrolysis. *Process Biochem.* 33(3): 337-343.

Krinsky, N. I., Landrum, J. T., and Bone, R. A. 2003. Biologic mechanisms of the protective role of lutein and zeaxanthin in the eye. *An. Rev. Nutr.* 23:171-201.

Kris, E. P. M., Hecker, K.D., Bonanome, A., Coval, S.M., Binkoski, A.E., Hilpert, K.F., Kumarasamy, Cox, P .J., Jaspers, M., Nahar, L., and Sarker, S.D. 2002. Screening seeds of Scottish plants for antibacterial activity. *J. Ethnopharmacol.* 83: 73–77.

Krishnaja, U. 2014. Development, quality assessment and clinical efficacy of 'functional food suppliment' (FSS) for life style disease management. Ph.D (FSN) thesis, Kerala Agricultural University, Thrissur, 36p.

Krishnendu, J. R. 2015. Nutrient composition, antioxidant and hypoglycaemic effect of bitter gourd (*Momordica charantia* L.). PhD. Thesis. Kerala Agricultural University, Thrissur. pp.1-184.

Krogdahl, A., Lea, T.B., and Olli, J.J. 1994. Soybean proteinase inhibitors affect intestinal trypsin activities and amino acid digestibilities in rainbow trout. *Comparative Biochemistry and Physiology* Part A. 107:215-219.

Krokida, M. K. and Marolis, Z. B. 2001. Structural properties of dehydrated products during rehydration. *Int. J. Food Sci. Technol.* 36:529 - 538.

Kumar, A.J.K. 2001. Shelflife determinants in dry bakery products. *Indian Food Ind.* 20(3): 69-72.

Kumar, G.S., Appukuttan, P. S., and Basu, D. 1982. α-d-Galactose-specific lectin from jackfruit (*Artocarpus integra*) seed. *J. Biosci.* 4 : 257.

Kumar, S., Singh, A. B., Abidi, A. B., Upadhyay, R. G., and Singh, A. 1988. Proximate composition of jack fruit seeds. *J. Food Sci. Technol.* 25:308-309.

Kumar, S.R., Baskaran, R., and Balusamy, M. 2002. Medicinal values of underutilized fruits. *Kisan World.* 30: 51-52.

Kumari, S. and Grewal, R. B. 2007. Nutritional evaluation and utilization of carrot pomace powder for preparation of high fibre biscuits. *J. Food Sci. Technol.* 44(1): 56-58.

Lambo, A. M., Oste, R., and Nyman. M. 2005. Dietary fibre in fermented oat and barley beta-glucan rich concentrates. *Food Chem.* 89(2):283–293.

Lampe, J.W. and Chang, J. L. 2007. Inter individual differences in phytochemical metabolism and disposition. 17 (5) : 347-353.

Lee, H., Yoon, H., Ji, Y., Kim, H., Park, H., Lee, J., Shin, H., and Holzapfel, W. 2012. Functional properties of Lactobacillus strains isolated from kimchi. *Int. J. Food Microbiol.* 145: 155–161.

Liji, A. J. 2014. Development of jackfruit based ready to cook (RTC) instant mixes. M.Sc. (FSN) Thesis, Kerala Agricultural University, Thrissur, 201p.

Lin, C. N. and Lu, C. M. 1993. Heterophylol, a phenolic compound with novel skeleton from *Artocarpus heterophyllus*. Tetrahedron Letters, 34(17): 8249-8250.

Lin, C. N., Lu, C. M., and Huang, P.L. 1995. Flavonoids from *Artocarpus heterophyllus*. *Phytochemistry*, 39 (6) : 1447-1451.

Lin, C.N., Lu, C.M., and Huang, P.L. 2000. Flavonoids from *Artocarpus heterophyllus*. *Phytochemistry* 39(6) : 1447–1451.

Lin, H.C., Chou, C.C., and Chang, W. H. 1979. Production of α-galactosidase and removal of oligosaccharides from soymilk. *Food Sci.* 6:123-135.

Liu, R. H. 2013. Health-promoting components of fruits and vegetables in the diet. *Adv. Nutr.* 4(3): 384-392.

Lobo, V., Patil, A., Phatak, A., and Chandra, N. 2010. Free radicals, antioxidants and functional foods: Impact on human health. *Pharmacognosy Reviews*. 4(8):118.

Loizzo, M. R., Tundis, R., Chandrika, U.G., Abeysekera, A. M., Menichini, F., and Frega, N. G. 2010. Antioxidant and antibacterial activities on food borne pathogens of *Artocarpus heterophyllus* Lam.(Moraceae) leaves extracts. *J. Food Sci.* 75(5) : 291-295.

Lopez Amoros, M.L., Hernandez, T., and Estrella, I. 2006. Effect of germination on legume phenolic compounds and their antioxidant activity. *J. Food Composition Anal.* 19: 277-283.

Lu, C. M. and Lin, C.N. 1993. Two 2′,4′,6′-trioxygenated flavanones from *Artocarpus heterophyllus*. *Natural Products Research Center*. 33: 909-911.

Luthria, D. and Pastor Corrales, M. 2006. Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties. *J. Food Composition Anal.* 19: 205-211.

Maia, J. G. S., Andrade, E. H. A., and Zoghbi, M. D. G. B. 2004. Aroma volatiles from two fruit varieties of jackfruit (*Artocarpus heterophyllus* Lam.). *Food Chem.* 85(2): 195-197.

Malathidevi, T. 2015. Development of extruded product using jackfruit bulbs and seed flours, Processing and food engineering, University of agricultural sciences, Bengaluru. pp.1- 103.

Matella, N.J., Dolan, K.D., Stoeckle, A.W., Bennink, M.R., Lee, Y. S., and Uebersax, M. A. 2005. Use of hydration, germination and alpha

galactosidase treatments to reduce oligosaccharides in dry beans. *J. Food Sci.* 70: 203-207.

Matuschek, E., Towo, E., and Svanberg, U. 2001. Oxidation of polyphenols in high-tannin cereals and the effect on iron bioavailability. In: Bioavailability, Abstract book, Abt, B., Amado, R., and Davidsson, L. (eds), Zu¨rich: ETH Swiss Federal Institute of Technology. 56p.

Mcanuff, M. A., Harding, W. W., Omoruyi, F. O., Jacobs, H., Morrison, E.Y., and Asemota, H. N. 2005. Hypoglycemic effects of steroidal sapogenins isolated from Jamaican bitter yam, Dioscorea polygonoides. *Food Chem. Toxicol.* 43:1667 - 1672.

McCleary, B.V. 1999. Enzyme purity and activity in fiber determinations. *Cereal Food World,* 44: 590-596.

Mezadri, T., Villano, D., Pachon, M. S. F., Parrilla, M.C. G., and Troncoso, A.M. 2008. Antioxidant compounds and antioxidant activity in acerola (*Malpighia emarginata* DC.) fruits and derivatives. *J. Food Composition Anal.* 21 (4): 282-290.

Midhila, M. 2013. Developmental and quality evaluation of ready to cook dehydrated product from banana blossom. MSc. Thesis. Kerala Agricultural University. Thrissur. pp.32-66.

MIIL [Megazyme International Ireland Limited]. 2004. Raffinose-series oligosaccharides assay procedure. 63p.

Minorsky, P.V.2003. Raffinose oligosaccharides. *Plant Physiol.* pp.1159-1160.

Mitsou, E. K., Panopoulou, N., Turunen, K., Spiliotis, V., and Kyriacou, A. 2010. Impact of a jelly containing short-chain fructo-oligosaccharides and Sideritis euboea extract on human faecal microbiota. *Int. J. Food Microbiol.* 135:112–117

Mohan, S. C., Balamurugan, V., Salini, S.T., and Rekha, R. J. 2012. Antioxidant and phytochemical potential of medicinal plant kalanchoe pinnata. *Chem. Pharm. Res.* 4(1):197-202.

Molyneux, P. 2004. The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. *Songklanakarin J. Sci. Technol.* 26: 211-219.

Moussa, F. B., Adjanohoun, A., Anihouvi, V. B., Sanni, S., Omansen, T. F., Kotchoni, S. O., and Moussa, L. B. 2012. Quality based microbial contamination analysis of nutraceuticals. *Int. Res. J. Biol. Sci.* 2(1):41-56.

Mukprasirt, A. and Sajjaanantakul, K. 2004. Physico chemical properties of flour and starch from jackfruit seed. *Int. J. Food Sci. Technol.* 39(3):271-276.

Mulimani, V.H. and Ramalingam, K. 1995. Enzymic hydrolysis of raffinose and stachyose present soymilk by crude α-galactosidase from *Gibberella fujikuroi. Biochem. Mol. Biol. Int.* 36:897-905.

Mulimani, V.H., Thippeswamy, S., and Ramalingam, K. 1997. Enzymatic degradation of oligosaccharides in soybean flours. *Food Chem.* 59 (2): 279-282.

Mungole, A.J., Awati, R., Chaturvedi, A., and Zanwar, P. 2010. Preliminary phytochemical screening of *Ipomoea obscura* (L.)- A hepato protective medicinal plant. *Int. J. Pharma. Tech. Res.* 2(4): 2307- 2312.

Munira, S. 2014. Antioxidant and antidiarrhoeal activities of methanolic extract of *Artocarpus heterophyllus* seed. *Int. J. Pharma. Drug Anal.* 2(11): 890-895.

Munishamanna, K. B. 2012. Development of value added products from jackfruit bulb. *Mysore J. Agric. Sci.* 46(2): 426-428.

Munishamanna, K.B., Ranganna, B., Subramanya, S., Chandru, R., and Palanimuthu, V. 2007. Development of value added products from jack fruit bulbs (*Artocarpus heterophyllus* L.) to enhance farm income of rural people. Proceedings of the International conference on 21st centaury challenges to sustainable agri-food system. pp.508-516.

Munishamanna, K.B., Ranganna. B, Subramanya, S., Palanimuthu, V., and Chandru, R. 2007. Development of value added products from jack fruit seeds, paper presented at ISAE held at Junagadh during Jan 29- Feb 24th.

Muzquiz, M., Burbano, C., Cuadrado, C., and Martin, M. 2000. Analytical methods for determination of compounds with no nutritive value. *In Handbook on Common Bean Related Laboratory Methods.* Spain:Galicia. pp.11-26.

Nagala, S., Yekula, M., and Tamanam, R. R. 2013. Antioxidant and gas chromatographic-analysis of five varities of artocarpus seed oils. *Drug Invention Today.* 4(5) :315-320.

Nahlar, G. 2013. Dictionary of Pharmaceutical Medicine (3rd Ed), B letter, Springer-Verlag Wien, pp.19-28.

Naik, K.C.1949. South Indian Fruits and Their Culture. Varadachery and Co. Madras. pp. 300-302.

Nair, S.S., Nithyakala, C. M., Noronha, I.G., Sultana, N., and Somashekharaiah, B. V. 2012. Isolation and determination of nutritional and antinutritional compounds from the seeds of selected plant species. *J. Chem. Pharma. Res.* 4(7):3529-3534.

Nakiboglu, M., Urek, O.R., Kayali, A. H., and Tarhan, L. 2007. Antioxidant capacities of endemic Sideritis sipylea and Origanum sipyleum from Turkey. *Food chem.*104:630-635.

Nancy, D. N. D. and Bill, S. M. B. A. 2006. The natural diet solution for PCOS and infertility: How to manage Polycystic Ovary syndrome naturally.pp.56.

Narayanaswamy, N. and Balakrishnan, K. P., 2011. Evaluation of some medicinal plants for their antioxidant properties. *Int. J. Pharmtech. Res.* 3(1):381-85.

Nasheeda, K. 2006. Developing multipurpose convenient mix from selected banana varieties. MSc (FS&N) thesis, Kerala Agricultural University. Thrissur. pp.68-70.

Navam, S. H., Tajudini, A. L., Srinivas, J. R, Sivarooban, T., and Kristofor, R. B. 2014. Physio-chemical and sensory properties of protein fortified extrudedbreakfast cereal/snack formulated to combat protein malnutrition in developing countries. 10(41):2157-7110.

Nergiz, C. and Gokgoz, E. 2007. Effects of traditional cooking methods on some antinutrients and in vitro protein digestibility of dry bean varieties (Phaseolus vulgaris L.) grown in Turkey. *Int. J. Food Sci.Technol.*42:868-873.

Nester, W. E., Robbert, C. E., Nancy, N. P., Danise, G. A., and Martha, T. N. 1998. Microbiology: A Human Perspective (2nd Ed.) Mc Graw-Hill Companies. USA, pp.571-573

NIH [National Institute of Health]. 2004. Office of Dietary Supplements Update, U.S. Department of Health and Human Services. 2(1): 26-27.

Nobre, H. V., Maia, F. D., Oliveira, R. A., Bandeira, M. M., and Pessoa, C. 2007. Neuroprotective Actions of Tannins from Myracrodruon urundeuva on 6 Hydroxydopamine-Induced Neuronal Cell Death. *J. Herbs Spices Med. Plants.* 13: 41-57.

Noomhorm, A. 2007. Overview of dehydration method on quality of fruit and vegetables. SWU. *Sci. J.* 23:9–22.

Noor, M. D., Rahman, J., Mahomud, S., Akter, S., Oluwole, S. O., Awonorin, F., Henshaw, G. N., Elemo, O. A., and Ebuehi, T., 2014. Assessment of microbial changes and nutritional qualities of extruded white yam and bambara groundnut blends. *Food Nutr. Sci.* 4:100-107.

Nor, A.M., Wan, Z., Wan, I., and Amar, S. 2015. Effects of protein content in selected fish towards the production of lactic acid bacteria (*Lactobacillus* spp) during production of Pekasam. *Curr. Res. Nutr. Food Sci.* 3(3):54.

Nualla, O., Chetpattananondh, S., and Yamsaengsung, P. R. 2009. Extraction of prebiotics from jackfruit seeds. *J. Eng.* 36: 213-220.

Nuallaong, S., Chetpattananondh, P. and Yamsaengsung, R. 2009. Extraction of prebiotics from jackfruit seeds. *J. Eng.* 36: 213-220.

Nyarko, A. A. and Addy, M. E. 1990. Effects of aqueous extract of *Adenia cissampeloides* on blood pressure and serum analyte of hypertensive patients. *Phytother. Res.* 4:25-8.

Obdoni, B.O. and Ochuko, P.O. 2001. Phytochemical Studies and Comparative Efficacy of the Crude Extracts of Some Homeostatic Plants in Edo and Delta States of Nigeria. *Global J. Pure Appl. Sci.* 8 : 203-208.

Ocloo, F., Bansa, D., Boatin, R., Adom, T., and Agbemavor, W. 2010. Physico-chemical, functional and pasting characteristics of flour produced from jackfruits (*Artocarpus heterophyllus*) seeds. *Agric. Biol. J. N. Am.* 1(5):903–908.

Odoemelam, S.A. 2005. Functional properties of raw and heat processed jackfruit (*Artocarpus heterophyllus*) flour. *J. Pakist. Nutr.* 4 (6): 366-370.

Odoemelan, S. A. 2003. Chemical composition and functional properties of conophor nut flour (*Tetracarpidium conophorum*) flour. *Int. J. Food Sci. Technol.* 38: 729-734.

Ojure, M.A. and Quadri, J.A. 2012. Quality evaluation of noodles produced from unripe plantain flour using xanthan gum. *Int. J. Res. Rev. Appl. Sci.* 13: 740-752.

Okaka, J. C. and Okaka, A.N.O. 2001. Food composition, spoilage and shelflife extension. Acadamic Publishers, Enugu, Nigeria, 56p.

Okaka, J. C., Enoch, N. J., and Okaka, N. C.1992. Human Nutrition: An integrated approach. Enugu, ESUT Publications. pp.57-58.

Okoye, E. I. 2016. Extraction, characterization and anti microbial activity of *Artocarpus heterophyllus* seed oil . Department of Pure and Industrial Chemistry, Chukwuemeke Odumegwu Ojukwu University, Uli, Anambra State, Nigeria. *J. Sci. Eng. Res.* 3(3):473-476. Available: www.jsaer.com.

Okoye, E. I., Anyaegbunam, L. C., Ibemenuga, K. N., and Obi, Z. C.2012. Phytochemical analysis and anti microbial screening of *Artocarpus heterophyllus* seed (Jackfruit). Siren Research Center for African Universities Port-Harcourt, Rivers State, Nigeria. *Afr. Sci. Technol. J.* 5(2): 182-188.

Okudu, H.O. 2015. The evaluation of the nutrient composition and antinutritional factors of jackfruit (*Artocapus heterophyllus*). *J. Sustain. Agric. Environ.* 16 (1): 1-3.

Oladele, A. K. and Aina, J. O. 2007. Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperusesculentus*). *Afr. J. Biotechnol.* 6 (2): 2473-2476.

Olguin, M. C., Hisano, N., Ottavio, A. E. D., Zingale, M.I., Revelant, G. C., and Calderari, S. A. 2003. Nutritional and anti-nutritional aspects of an Argenitian soy flour assessed on weaning rats. *J. Food Composition Anal.* 16: 441-449.

Oliveri, C. S. 2000. Nutraceuticals, phytochemicals, and antioxidants- what are they all about, OSU Extension Fact Sheet. pp.16 - 688.

Oluseyi, E. O. and Temitayo, O. M. 2015. Chemical and functional properties of fermented, roasted and germinated tamarind (*Tamarindus indica*) seed flours. *J. Nutr. Food Sci.* 45 : 97-111.

Oluwole, O. B., Awonorin, S. O., Henshaw, F., Elemo, G. W., and Ebueh, O. A. T. 2013. Assessment of microbial changes and nutritional qualities of white yams and bambara groundnuts blends. *J. Food Sci.* 4:100-107.

Omeire, G. C., Nwosu, J. N., Kabuo, N.O., and Nwosu, M. O. 2015. Cooking properties and sensory evaluation of enriched cassava/wheat noodles. *Int. J. Innovative Res. Technol. Sci.* 3(2):46-50.

Ong, B.T., Nazimah, S. A. H., Osman, A., Quek, S.Y., Voon, Y.Y., Hashim, D., Chew, P.M., and Kong, Y.W. 2006. Chemical and flavour changes in jackfruit (*Artocarpus heterophyllus Lam.*) cultivar J3 during ripening. *Postharvest Bio. Technol.* 40(3): 279-286.

Osman, M. A. 2004. Change in sorghum enzyme inhibitors phytic acid, tannins and in vitro protein digestibility occurring during Khamir (local bread) fermentation. *J. Saudi Soc. Agric. Sci.* 88: 129-134.

Pandey, M., Abidi, A. B., Singh, S., and Singh, R. P. 2006. Nutritional evaluation of leafy vegetable paratha. *J. Hum. Ecol.* 19(2): 155-156.

Patel, K., Gadewar, M., Tripathi, R., Prasad, S. K., and Dinesh, K. P. 2012. A review on medicinal importance, pharmacological activity and

bioanalytical aspects of beta-carboline alkaloid ''Harmine''*Asian. P. J. Trop. Biomed.* 2(8): 660–664.

Pavanasasivam, G., Uvais, G., and Sultanbawa, G. 1973. Cycloartenyl acetate, cycloartenol and cycloartenone in the bark of *Artocarpus* species. *Phytochemistry*, 12 : 2725-2726.

Perlas, L. and Gibson, R. S. 2002. Use of soaking to enhance the bioavailability of iron and zinc from rice-based complementary foods used in the Philippines. *J. Sci. Food Agric.* 82:1115–21.

Porres, J.M., Aranda, P., Pezjurado, M., and Urbano, G. 2003. Effect of Natural and Controlled Fermentation on Chemical Composition and Nutrient Dialybility from Beans (*Phaseolus vulgaris* L.). *Agric. Food Chem.* 51:5144 - 5149.

Pourmorad, F., Hosseinimehr, S. J., and Shahabimajd, N. 2006. Antioxidant activity, phenol and flavonoid contents of some selected Iranian medicinal plants. *Afr. J. Biotechnol.* 5: 1142-1145.

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

Prasad, M. P., Kirti, P., and Ceera, M. 2012. Phytochemical, Antioxidant Activity and Determination of Genetic Diversity in *Artocarpus heterophyllus* Using RAPD Molecular Markers. *Int. J. Sci. Res.*3(10): 44-49

Prashanth, S. J. and Mulimani, V. H. 2005. Soymilk oligosaccharide hydrolysis by Aspergillus oryzae [alpha]-galactosidase immobilized in calcium alginate. *Process Biochem.* 40:1199-1205.

Praveenasri, B., Priya, R., and Helen, S.A., 2006, Studies on incorporation of jack fruit seed flour on extruded products, ICFOST, Hyderabad, 66p.

Preet, K. and Punia, D.2000. ''Antinutrients and digestibility (in vitro) of soaked, dehulled and germinated cowpeas'', *Nutrition and Health*. 14(2):109-117.

Pszczola, B.2000. Development of recipes from fruits. *Int. J. Nutr. Sci.* 24:439.

Purwandari, U., Khoiri, A., Muchlis, M., Noriandita, B., Zeni, N.F., Lisdayana, N., and Fauziyah, E. 2014. Textural cooking quality and sensory evaluation of gluten-free noodle made from breadfruit, konjac, or pumpkin flour. *Int. Food Res. J.* 21: 1623-1627.

Pusztai A, 1991. Plant Lectins. Cambridge University Press, 52p.

Rahman, A.K., Huq, E., Mian, A.J., and Chesson, A. 2005. Microscopic and chemical changes occurring during the ripening of two forms jackfruit (*Artocarpus heterophyllus* Lam). *J. Food Chem.* 52: 405-410.

Rahman, M. A., Nahar, N., Mian, A.J., and Moshiuzzaman, M. 1999. Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic condition. *Food Chem.* 65: 91-97.

Rajan,V. M., Kumar, P. K., Satheesh, K., Swathi, K. R., and Haritha. S. 2012. *J. Chem. Pharm. Res.* 4(6):2860-2868.

Ramakrishna, V., Rani, P.J., and Rao, P.R. 2006. Antinutritional factors during germination in Indian Bean (*Dolichos lablab* L.) Seeds. *World J. Dairy Food Sci.* 1(1): 6-11.

Ranasalva, N. and Visvanathan, R. 2014. Development of cookies and bread from cooked and fermented pearl millet flour. *Afr. J. Food Sci.* 8 (6): 330-336.

Ranganna, S. 1995. *Handbook of analysis and quality control for fruit and vegetable products* (2nd Ed.). McGraw- Hill, New Delhi, pp.123-142.

342

Rao, P.K. and Das, H. 2003. Fuzzy logic based optimization of ingredients for production of mango bar and its properties. *Ind. J. Food Sci. Technol.* 40:576-581.

Rasha, M. K. A.Y., Gibriel, N. M. H., Rasmy, F. M., Salem, A., and Esmat A. A. 2011. Influence of legume processing treatments individually or in combination on their trypsin Inhibitor and total phenolic contents. *Aust. J. Basic Appl. Sci.* 5(5): 1310-1322.

Reddy, N. R., Pierson, M. D., Sathe, S. K., and Salunkhe, D.K.1984. Chemical, nutritional and physiological aspects of dry bean carbohydrates- a review. *Food Chem.* 13:25-68.

Rehman, M. 1999. Comparative study of physical and elastic properties of jute and glass fiber. Pilot plant and process development center of Bangladesh council of scientific and industrial resource. Bangladesh 183p.

Rehman, Z. and Salariya, A. 2005. The effects of hydrothermal processing on antinutrients, protein and starch digestibility of food legumes. *Int. J. Food Sci. Nutr.* 30: 695-700.

Rehman, Z. U. and Shah, W.H. 2001. Tannin contents and protein digestibility of black grams (*Vigna mungo*) after soaking and cooking. *Plant Foods Hum. Nutr.* 56: 265-273.

Robin, D. G. and Ross, M. W. 1996. Breeding for staple food crops with high micronutrient density. pp.6-9.

Robok, J. and Gryglewski, R. J. 1988. "Flavonoids Are Scavengers of Superoxide Anions," *Biochem. Pharmacol.* 37(5): 837-841.

Rodriguez, E. B., Flavier, M. F., Amaya, D. B. A., and Farfan, J. A. 2006. Phytochemicals and functional foods: Current situation and prospect for developing countries. *Segurança Aliment. Nutr.* 13: 1-22.

Sadasivam, S. and Manickam, A. 1992. Biochemical Methods for Agricultural Sciences. Wiley Eastern Ltd., New Delhi, 85p.

Sadasivam, S. and Manickam, A. 2008. Biochemical methods (3rd Ed.), New Age International Publishers, New Delhi, India. 56p.

Sahoo, A. 2016. Value added baked products from raw jackfruit. MSc. Thesis, Kerala Agricultural University, Thrissur, 154p.

Saito, T., Miyake, M., Toba, M., Okamatsu, H., Shimizu, S., and M. Noda, D. 2002. Inhibition by apple polyphenols of ADP-ribosyltransferase activity of cholera toxin and toxin-induced fluid accumulation in mice. *Microbiol. Immunol.* 46 : 249-255.

Saito, T., Mizutani, F., Iwanga, Y., Morikawa, K., and Kato, H. 2002. Laxative and antidirrhoeal activity of Polycarbophil in Mice and Rats. *Jpn. J. Pharmacol.* 89:133-141.

Salunkhe, D.K. and Kadam S.S. 1989. Handbook of World Food Legumes. 3:145.

Samaddar, H. N. 1985. Jackfruit. In T. K. Bose (ed.). Fruits of India:Tropical and subtropical Calcutta: Naya Prokash. pp.487- 497.

Sandberg, A. S. 2002. In vitro and in vivo degradation of phytate. *In Food Phytates*. Boca Raton, Florida: CRC Press. pp.139-155.

Sangronis, E. and Machado, C. J. 2007. Influence of germination on the nutritional quality of Phaseolus vulgaris and Cajanus cajan. LWT. *J. Sci. Technol.* 40: 116-120.

Saranya, S. 2012. Development and quality evaluation of enriched Moringa based soup mix (ESM). MSc. Thesis. Kerala Agricultural University, Thrissur. 49p.

Sato, M., Fujiwara, S., Tsuchiya, H., Fujii, T., Iimuna, M., Tosa, H., and Ohkawa, Y. 1996. Flavones with antibacterial activity against carcinogenic bacteria. *J. Ethnopharmacol.* 54 : 171–176.

Sawant, A. A., Thakor, N. J., Swami, S. B., and Divate, A. D. 2013. Physical and sensory characteristics of Ready-To-Eat foodprepared from finger millet based composite mixer by extrusion. *Agric Eng Int. CIGR. J.* 15(1): 100-105.

Selvaraj, Y. and Pal, D.K. 2009. Biochemical changes during ripening of jackfruit (*Artocarpus heterophyllus* Lam.). *J. Food Sci.* 26:304-307.

Shahidi, F. 1997. Beneficial Health Effects and Drawbacks of Antinutrients and Phytochemicals in Foods. 78p.

Shahidi, F. 2010. Functional foods: Their role in health promotion and disease prevention. *J. Food Sci.* 69 :146-149.

Shankar, G. 2003. Role of moisture, temperature and humidity during storage of food grains. Third international food convention. 20-23 October 2000. Central food technology research institute, Mysore. pp.11-16

Shanmugapriya, K., Saravana, S., Payal, H., Mohamed, P., and Binnie, W. 2011. Antioxidant activity, total phenolic and flavonoid contents of *Artocarpus heterophyllus* and *Manilkara zapota* seeds and its reduction potential. *Int. J. Pharm Pharm Sci.* 3(5):256–260.

Shanthakumari, S., Mohan, V.R., and Debritto, J. 2008. Nutritional evaluation and elimination of toxic principles in wild yam (*Dioscorea sp.*). Tropical and Subtropical Agro ecosystems. 8: 225-319.

Sharma, V. B. 2006. A text book of food science and technology. International book distributing Co. Lucknow. 56p.

Shimelis, E.A. and Rakshit, S. K. 2007. Effect of processing on anti-nutrients and in vitro protein digestibility of kidney bean (*Phaseolus vulgaris* L.) varieties grown in East Africa. *Food Chem.* 103: 161-172.

Shirley, W. B. 2001. Flavonoid Biosynthesis. A Colorful Model for Genetics, Biochemistry, Cell Biology, and Biotechnology. *Plant physiol.* p.110.

Shivanna, B.D., Ramakrishna, M., and Ramadoss, C.S. 1989. Enzymic hydrolysis of raffinose and stachyose in soymilk by α-galactosidase from germinating guar (*Cyamopsis tetragonolobus*). *Process Biochem.* 24: 197-201

Shreepadre. 2015. Kerala pioneer eyes new horizons for jackfruit industry. India together, News letter. Available : www.indiatogether.org. [25 May 2015].

Siddhuraju, P. and Becker, K.2001. Species/ variety differences in biochemical composition and nutritional value of Indian tribal legumes of the genus Canvalia. *Mol. Nutr. Food Res.* 45(4): 224-233.

Silva, G. P., Moreno, A., Marques, F., Oliver, C., Jamur, M. C., Panunto, C. A., and Roque, M. C. 2006. Neutrophil activation induced by the lectin KM+ involves binding to CXCR2. *Biochem.* 1760(1): 86-94.

Singh, R. 2002. Hand book of Analysis of quality control for fruit and vegetable products. Second edition, Tata Me Graw Hill pub. Co. Ltd. New Delhi, 38p.

Sirisha, N. and Rao, R. T. 2014. Physiochemical and phytochemical analysis of five varieties of artocarpus seed oils. Department of Biochemistry, College of Science and Technology, Andhra University, Visakhapatnam. *Int. J. Pharmacognosy*. 1(12): 785-791.

Sirisha, N., Rao, K. V.R., Rao, D.B., and Rao, T.R. 2014. Evaluation of antioxidant activities, phytochemical constituents and protein profiling of five varieties of Jackfruit (Artocarpus species) seeds. *Int. J. Pharma. Sci.* 4 (4): 626-631.

Smirhoff, N. 2000. Ascorbic acid, metabolism and functions of multi facetted molecule. *Curr. Opinion Plant Biol.* 3(2): 229-235.

Soetan, K.O. and Oyewole, O.E. 2009. The need for adequate processing to reduce the antinutritional factors in plants used as human foods and animal feeds: a review. *Afr. J. Food Sci.* 3(9): 223-232.

Solomon, H. K. and William, W. W. 2003. Bioactive food components, *Encyclopedia of Food and Culture* (2nd Ed.). Acceptance to Food Politics, B Letter, Charles Scribner's Sons. 1: 201.

Song, D. and Chang, S. K. C. 2006. ''Enzymatic degradation of oligosaccharides in pinto bean flour.'' *J. Agric. Food Chem.* 54: 1296-1301.

Sonia, N.S. 2018. Developmental morphology of tuberisation and phytochemical profiling in milk yam (*Ipomoea digitata* L.). Ph.D Thesis, Department of plantation crops and spices, Kerala Agricultural University, Thrissur. pp.1-206.

Soong, Y. Y. and Barlow, P. J. 2004. Antioxidant activity and phenolic content of selected fruit seeds. *Food Chem.* 88:411–417.

Soudy, I.D., Delatour, P., and Grancher, D. 2010. Effects of traditional soaking on the nutritional profile of taro flour (*Colocasia esculenta* L. Schott.). *Revue de Medecine Veterinaire*. 1: 37-42.

Sozer, N., Dalgic, A. C., and Kaya, A. 2007. Thermal, textural and cooking properties of spaghetti enriched with resistant starch. *J. Food Eng.* 81: 476-484.

Sreevidya, N. and Mehrotra, S. 2003. Spectrophotometric method for estimation of alkaloids precipitable with Dragendorff's reagent in plant materials. *J. AOAC Int.* 86: 1124-1127.

Srinivasan, K. and Kumaravel. S. 2016. Mass spectrometry analysis of volatile constitutents of jack fruit powder. *Int. J. Pharmaceut. Sci.* 8(1): 450 – 453.

Stahl, W. and Sies, H. 2005. Bioactivity and protective effects of natural carotenoids. *Biochem. Biophys. Acta.* 1740(2):101-7.

Stanton, C., Ross, R.P., Fitzgerald, G.F., and Sinderen, D. V.2005. Fermented functional foods based on probiotics and their biogenic metabolites. *Current Opinion in biotechnology* 16(2): 198-203.

Subhashini, N., Thangathirupathi, A., and Lavanya, N. 2011. Antioxidant activity of Trigonella foenum graecum using various in vitro and ex vivo models. *Int. J. Pharma. Pharmcol. Sci.* 3:96-102.

Sugimoto, H. and Bureu, J.P.V. 1970. Removal of oligosaccharides from soymilk by an enzyme from *Aspergillus saitoi. J. Food Sci.* 35: 655-660.

Suhartati, T., Achmad, S. A., Aimi, N., Hakim, E. H., Kitajima, M., and Takeya, K. 2001. Artoindinesianin, a new prynylated flavonoid with cytotoxicity activity from artocarpus. 72 : 912-918.

Swami, S. B., Thakor, N. J., Haldankar, P.M., and Kalse, S. B. 2012. Jackfruit and its many functional components as related to human health: A review Comprehensive Reviews in Food Science and Food Safety. pp.565-576.

Tanjung, E., Hafidz, M.S.M., Thalib, I., and Suhartono, E. 2014. Evaluation of antioxidant activity of some selected tropical fruits in South Kalimantan, Indonesia. *J. Trop. Life Sci.* 4(3):210-215.

Tejpal, A. and Amrita, P. 2016. Jackfruit: a health boon, Department of pharmaceutical chemistry, Delhi institute of pharmaceutical sciences and research, Newdelhi. *Int. J. Res. Ayurveda pharm.* 7 (3):59- 63.

Teucher, B., Olivares, M., and Cori, H. 2004. Enhancers of iron absorption: ascorbic acid and other organic acids. *Int. J. Vitam. Nutr. Res.* 74: 403–19.

Thananunkul, D., Tanaka, M., Chichester, C.O., and Lee, T.C. 1976. Degradation of raffinose and stachyose in soymilk by α-galactosidase from *Moretierella vinacea*. Entrapment of α-galactosidase within polyacrylamide gel. *J. Food Sci.* 41:173-175.

Thomas, C. E., Mclean, R.A., Parker, D., and Ohlweiler, F. 1992. Ascorbate and phenolic antioxidant interactions in prevention of liposomal oxidation. *Lipids.* 27(7): 543-550.

Tniko, N. and Uyano, K. 2001. Spectrophotometric determination of the tannin contents of various Turkish black tea, beer and wine samples. *Int. J. Food Sci. Nutr.* 52: 289-294.

Toda, S. and Shirataki, Y. 2006. Inhibitory effect of prenylated flavonoid in Euchresta japonica and Artocarpus heterophyllus on lipid peroxidation by interaction of hemoglobin and hydrogen peroxide. *Pharma. Biol.* 44 : 271-273.

Trindade, M. B., Lopes, J. L., Soares, C. A., Monteiro, A. C., Moreira, R. A., and Oliva, M. L. 2006. Structural characterization of novel chitin-binding lectins from the genus *Artocarpus* and their antifungal activity. *Biochimica et Biophysica Acta*. pp.146–152.

Tulyathan, V., Tananuwonga, K., Songjinda, P., and Jaiboon, N. 2002. Some physicochemical properties of Jackfruit (*Artocarpus heterophyllus* Lam) Seed flour and starch. Department of food Technology. *Sci. Asia.* 28(6):3741.

Ugwu, F. M. and Oranye, N. A. 2006. Effects of some processing methods on the toxic components of African breadfruit (*Treculia qfricana*). *Afr. J. Biotechnol.* 5 : 2329-2333.

Umesh, J. B., Pavan, S.N., and Bapal, V.A. 2010. Evaluation of antioxidant capacity and phenol content in jackfruit. *Plant Food.* 65: 99-101.

Veenakumari. 2015. Development of an extruded product from raw jackfruit. M. Sc. Thesis, Kerala Agricultural University, Thrissur. Pp.1-153.

Venkataraman, K. 2001. Wood of phenolics in the chemotaxonomy of the Moraceae. *Phytochemistry.* 11: 1571-1586

Ververis, C., Georghiou, K., Danielidis, D., Hatzinikolaou, D.G., Santas, P., Santas, R., and Corleti, V. 2007. Cellulose, hemicelluloses, lignin and ash content of some organic materials and their suitability for use as paper pulp supplements. *Bioresource Technol.* 98: 296–301.

Vidivel,V. and Janardhanen, K. 2001. Nutritional and anti-nutrient attributes of the underutilized legume *Cassia oribunda* car. *Food Chem.* 73: 209-215.

Vijay, P. and Vimukta, S. 2014. The role of natural antioxidants in oxidative stress induced diabetes mellitus. *Res. J. Pharma. Sci*, 3(4) : 242-246.

Vijayakumar, P. T. and Mohankumar, B. J.2009. Formulation and characterization of millet flour blend incorporated composite flour. *Int. J. Agri. Sci.* 1(9): 46-54.

Vinha, A.F. and Soares, M.O. 2012. Phytochemical characterisation and radical scavenging activity of aqueous extracts of medicinal plants from Portugal. *Eur. J. Med. Plants* 2(4): 335-347.

Wagner, J. R., Becker, R., Gumbmann, M.R., and Olson, A. C.1976. Hydrogen production in the rat following ingestion of raffinose, stachyose and oligosaccharide free bean residue. *J. Nutr*.pp.466-470.

Wagner, J. R., Carson, J. F., Becker, R., Gumbmann, M.R., and Danhof, I. E. 1977. Comparitive flatulence activity of beans and bean fractions for man and the rat. *J. Nutr*. pp.680-689.

Wang, S.Y. and Lin, H.S. 2000. Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage. *J Agric. Food Chem.* 48: 140-146.

Wei, B.L., Weng, J.R., Chiu, P.H., Hung, C.F., Wang, J.P., and Lin, C.N.2005. Antiinflammatory flavonoids from *Artocarpus heterophyllus* and *Artocarpus communis*. *J. Agric. Food Chem.* 53(10) : 3867–3871.

Wetprasit. N., Threesangsri, W., Klamklai, N., and Chulavatnatol, M. 2000. Jackfruit lectin: properties of mitogenicity and the inhibition of herpesvirus infection. *Jpn J. Infect Dis.* 53(4):156-61.

Wheeler, E. L. and Ferrel, R. E. 1971. A Method for Phytic Acid Determination in Wheat and Wheat Fractions. *Cereal Chem*. 48: 312-320.

WHO (World Health Organization). 2007. Mortality and global health estimates.

Wichienchot, S., Jatupornpipat, M., and Rastall, R.A. 2010. Oligosaccharides of Pitaya (Dragon Fruit) Flesh and Their Prebiotic Properties. *Food Chem.* 120: 850-857.

Wong, K. C., Lim, C.L., and Wong, L.L.1992. Volatile flavour constituents of Chempedak (*Artocarpus polyphema* Pers.) fruit and Jackfruit (*Artocarpus heterophyllus* Lam.) from Malaysia. *Flavour and Fragrance J.* 9: 319-324.

Wongsa, P. and Zamaluddien, A. 2005. Total phenolic content, antioxidant activity and inhibitory potential against alpha amylase and alpha glucosidase of fifteen tropical fruits. 37th Congress on Science and Technology of Thailand. 68p.

Wouters, D., Bos, W. I., Ham, V. M., and Zeerleder, S. 2008. C1 inhibitor: just a serine protease inhibitor? New and old considerations on therapeutic applications of C1 inhibitor. *Expert. Opin. Biol. Ther*. 8(8): 1225-1240.

Xia, X., Li, G., Zheng, J., Ran, C., and Kan, J. 2014. Biochemical, textural and microstructural changes in whole soya bean cotyledon sufu during fermentation. *Int. J. Food Sci. Technol.* 10(3): 124.

Xu, B. and Chang, K. 2009. Total phenolic, phenolic acid, anthocyanin, flavan-3-ol, and flavonol profiles and antioxidant properties of pinto and black beans (*Phaseolus vulgaris* L.) as affected by thermal processing. *J. Agric. Food Chem.* 57: 4754-4764.

Yamamoto, A., Taniguchi, T., Rikyuu, K., Tsuji, T., Fujita, T., Murakimi, M., and Muranishi, S. 1994. Effects of various protease inhibitors on the intestinal absorption and degradation of insulin in rats. *Pharm. Res.* 11: 1496 - 1500.

Yuan, G., Sun, B., and Wang, Q. 2010. Effect of 1 methylcyclopropene on shelf life, visual quality, antioxidant enzymes and health promoting compounds in broccoli florets. *Food chem*. 118: 774-781.

Zagory, D. 2003. Effect of post processing, handling and packaging on microbial population. Post harvest news and information on fresh fruit and vegetable quality and food safety. *Post harvests Biol. Technol.*15:313.

Zakarial, A. N., Ibrahim, D., and Sulaiman, S. F. 2011. Nor Afifah Supardy. *J. Chem. Pharmacol. Res*. 3(3):182-191.

Zhou, K. and Yu, L. 2004. Effects of extractions solvent on the wheat bran antioxidant activity estimation. *LWT-Food Sci. Technol.* 37:717–721.

Zuraidah, M. A. and Sakinah, A. M. 2014. Effect of lectin from *Artocarpus heterophyllus* seed on cancer cell lines. *J. Life Sci. Technol.* 2(2):55-58

Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein.

ANILA, H.L.
(2015 - 24 - 001)

ABSTRACT

Submitted in partial fulfilment of the requirement for the degree of

DOCTOR OF PHILOSOPHY IN COMMUNITY SCIENCE
(Food Science and Nutrition)

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF COMMUNITY SCIENCE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695 522
KERALA, INDIA

2018

ABSTRACT

The investigation entitled "Profiling bioactive compounds and nutrients in Jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein'', was carried out at College of Agriculture, Vellayani, Thiruvananthapuram during the period of 2015-2018. The objectives of the study were to ascertain the bioactive compounds and nutrients present in different jackfruit types. The study also envisaged the improvement of digestive quality of jackfruit through reduction of oligosaccharides and developing a jackfruit based textured vegetable protein. The study was conducted in three experiments; viz. analysis of nutrient and chemical profile along with antioxidant activity of the selected types of jackfruit; analysis of measures for reducing antinutrients in raw jackfruit and development of raw jackfruit based textured vegetable protein.

For the component wise analysis, five types of jackfruits viz Muttom varikka, Then varikka, Sindoor, Chempikalom varikka and Local cv Koozha were selected; their raw and ripe stages as well as both bulbs and seeds were analysed separately. Analysis of proximate composition, vitamins, minerals, bioactive compounds, antinutrients and antioxidant activity were covered in the first experiment. The results showed that nutrient wise, raw seeds of Chempikalom and ripe bulbs of Sindoor scored higher than the rest of treatments while with respect to antioxidant activity, ripe seeds of Koozha were better than other treatments.

The profiling of nutrients and bioactive compounds in the each part of the experiment is an eye opener on specific features of the common jackfruit type that can be exploited according to varying needs.

The delicacy factor for non acceptability of jackfruit, despite its useful composition is that, it has a flatulence factor. This study has thrown light in to the measures to reduce these causative factors. For this purpose in the second part of the

experiment, one treatment is with enzyme α galactosidase and another treatment with *Saccharomyces cerevisiae* was carried out on milled raw jackfruit bulbs and seeds of cv koozha to reduce the level of anti nutrients. Enzyme α galactosidase was premixed with the dry flour of jackfruit seed and jackfruit bulb separately in the ratio 1:100 and the moisture level was varied from 25 – 200% (dough to batter stage). The hydrolysis was carried out for 90 minutes in both jackfruit bulb flour and seed flour. The products were evaluated for the breakdown of oligosaccharides (Raffinose) using HPTLC method. The results showed that the level of Raffinose after treatment with bulb flour and seed flour was seen to decrease with increase in moisture content (25-100%). Thereafter the content slightly staggered and then reduced (125%, 150%, 175%, 200%). However the level of oligosaccharide decreased in comparison to levels in control (0.97 $\mu g\ g^{-1}$).

When flours were to be made into batter and subjected to fermentation with *Saccharomyces cerevisiae* @ 5g/kg for 6 hrs, 8 hrs and 12 hrs and analyzed through HPTLC assay; raffinose content in jackfruit bulb flour reduced from 0.75 $\mu g\ g^{-1}$ to 0.63 $\mu g\ g^{-1}$, 0.58 $\mu g\ g^{-1}$ and 0.74 $\mu g\ g^{-1}$ after 6, 8 and 12 hours respectively. Raffinose content in jackfruit seed flour reduced from 1.28 $\mu g\ g^{-1}$ to 0.42 $\mu g\ g^{-1}$, 0.31 $\mu g\ g^{-1}$ and 0.62 $\mu g\ g^{-1}$ respectively after 6, 8 and 12 hours of fermentation. Considering the reduction of raffinose content and sensory evaluation of the treated flour, eight hour fermentation (F_2) was selected as the best treatment.

The demand for convenience foods among the literate consumers is on the rise around the globe. It has been argued that convenience is a barrier to achieving proper nutrition using adequate servings. In order to incorporate the fruit based nutritional benefits, it has become important to develop newer and novel foods that could reach the consumers' acceptance. With this background an attempt was visualized to develop jackfruit based textured vegetable protein (TVP) to make jackfruit more popular among the health conscious people.

In the third experiment, Jackfruit based TVP was formulated by using the ingredients - jackfruit bulb flour and seed flour along with gluten, yeast and soya flour to form chunks using standardized methods. Totally eleven combinations of TVP were worked out. All the eleven treatments were cooked and evaluated by a panel of ten members. Based on the sensory attributes such as appearance, colour, flavour, texture, taste and overall acceptability, the highest score was obtained for T_7 which was followed by T_8 and these two treatments were seen to be on par. The lowest score was obtained by treatment T_4; T_7 was taken up for quality analysis, it had a protein content of 61.50g, carbohydrate content of 34.97g and lesser cooking time (7.33 minutes). The physico chemical and textural qualities were on par with soyachunks available in the market. Processed TVP showed good storage stability up to three months. The third part of the study concluded with a positive note on scope of commercializing this jackfruit based protein concentrate. The product is both novel and healthy, raising its popularity for sailing up.

Thus, the study finds that there is variation in jackfruit types with respect to nutrients, chemical and bioactive compounds. The efficacy of enzyme α galactosidase and *Saccharomyces cerevisiae* to reduce oligosaccharide levels in jackfruit flour is feasible. With high acceptable food like meat analogue was also standardized based on jackfruit flours, which can be recommended for commercialization.

Appendices

APPENDIX I

Composition of media used for microbial analysis

Nutrient agar (one litre)

Peptone	-	5g
NaCl	-	5g
Beef extract	-	3g
Agar	-	20g
Distilled water	-	1000ml

EMB medium (one litre)

EMB	-	36g
Distilled water	-	1000ml

Rose Bengal Agar (one litre)

Glucose	-	10g
Peptone	-	5g
KH_2PO_4	-	1g
$MgSO_4.\ 7H_2O$	-	0.5g
Streptomycin	-	30mg
Agar	-	15g
Rose Bengal	-	35mg
Distilled water	-	1000ml

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI
Department of Community Science

Title: Profiling bioactive compounds and nutrients in jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein.

Hedonic rating scale for the sensory evaluation of TVP

PARTICULATES	TREATMENTS				
	T_1	T_2	T_3	T_4	T_5
Appearance					
Colour					
Flavour					
Texture					
Taste					
Overall acceptability					

***Kindly indicate your rating between 1-9 (1 stands for poor and 9 stands for excellent)**

Like Extreamely	9
Like Verymuch	8
Like Moderately	7
Like slightly	6
Neither like nor Dislike	5
Dislike Slightly	4
Dislike Moderately	3
Dislike Verymuch	2
Dislike Extremely	1

NAME:
SIGNATURE:

APPENDIX III

COLLEGE OF AGRICULTURE, VELLAYANI
Department of Community Science

Title: Profiling bioactive compounds and nutrients in jackfruit (*Artocarpus heterophyllus* Lam.) and developing a jackfruit based textured vegetable protein.

Overall Visual Quality (OVQ) score card

Criteria	Score
Excellent and fresh appearance	**9**
Good	**7**
Fair (Limit to marketability)	**5**
Fair useable not saleable	**3**
Unusable	**1**

Date :

Name:

Signature: