DEVELOPMENT AND QUALITY EVALUATION OF A JACKFRUIT BASED NUTRI FLOUR

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(2018 - 24 - 001)

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DECLARATION

I, hereby declare that this thesis entitled **"Development and quality evaluation of a jackfruit based nutri flour"** 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.

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Certified that this thesis, entitled **"Development and quality evaluation of a jackfruit based nutri flour"** is a record of research work done independently by **Ms. Soumya, P.S (2018 - 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.

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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
BMI	Body Mass Index
CD	Critical Difference
Cfu	Colony Forming Units
CHDs	Coronary Heart Diseases
CHO	Carbohydrates
CMV	Cytomegalovirus
CRD	Completely Randomised Design
CVDs	Cardiovascular Diseases
DFRC	Derivatization Followed by Reductive Cleavage
DMEM	Dulbecco's Modified Eagle Medium
DMPD	N, N-dimethyl p-phenylendiamine
DMSO	Dimethyl Sulphoxide
DNA	Deoxyribonucleic acid
DNSA	Di Nitro Salicylic acid
DW	Distilled Water
EDTA	Ethylene Diamine Tetra Acetic Acid
EFSA	European Food Safety Authority
EMB	Eosin Methylene Blue
ESM	Enriched Soup Mix

ETOH	Ethanol
FDS	Fast Dissolved Tablets
FOS	Fructo Oligosaccharide
FSSAI	Food Safety and Standards Authority of India
GAE	Gallic Acid Equivalents
GaIU	Galactosidase Units
GI	Glycemic Index
GL	Glycemic Load
$HepG_2$	Hepatoma G_2
HDLC	High Density Lipoprotein Cholesterol
HIV	Human Immunodeficiency Virus
HMG-CoA	β- Hydroxy β- methylglutaryl CoA
HPLC	High-Performance Liquid Chromatography
IAUC	Incremental Area Under the Curve
IC_{50}	Half Maximal Inhibitory Concentration
IDF	Insoluble Dietary Fibre
IVSD	Invitro Starch Digestibility
IOM	Institute of Medicine
IU	International Units
JFBF	Jackfruit Bulb Flour
JFCF	Jackfruit Core Flour
JFKF	Jackfruit Koozha Flour
JNF	Jackfruit based Nutri Flour
JFPF	Jackfruit Perigones Flour
JFRF	Jackfruit Rind Flour

JFSF	Jackfruit Seed Flour
JFTF	Jackfruit Testa Flour
JFVF	Jackfruit Varikka Flour
Kcal	Kilo Calories
LDLC	Low-Density Lipoprotein Cholesterol
LDPE	Low Density Polyethyelene
MBC	Maximum Bacterial Concentration
NA	Nutient Agar
NADH	Nicotinamide Adenine Dinucleotide
NADP	Nicotinamide Adenine Dinucleotide Phosphate
NBT	Nitro Blue Tetrazolium
NIH	National Institutes of Health
PBS	Phosphate Buffered Saline
PE	Petrolium Ether
PNPG	P – Nitrophenyl β - Glucopyranoside
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

UFLC	Ultra-Fast Liquid Chromatography
USDA	United State Department of Agriculture
VZS	Varicella Zoster Virus
WAI	Water Absorption Index
WHO	World Health Organization

Introduction

1.INTRODUCTION

"*The Doctor of the future will no longer treat the human frame with drugs, but rather will cure and prevent disease with nutrition"* - Thomas Edison

The fact that food and optimal health are closely correlated is not a novel concept. About 2500 years ago, Hippocrates (460-377 BC), renowned Father of Modern medicine, conceptualized the relationship between the use of appropriate health foods and their therapeutic benefits and quoted, "Let food be thy medicine, and medicine be thy food".

The science of Human nutrition has moved from a focus on the prevention of nutrient deficiencies to an emphasis on the health maintenance and reduced risk of chronic diseases (Institute of Medicine, 1998).

It is evident that health is a basic pre condition for happiness and progress in the life of an individual as well as community. Quality health care is the life line for the growth of any nation. Modernization, change in lifestyles, stress and strains, improper eating habits, faster pace of life, less physical exercise etc. are creating conditions that affect the health of people by leading to chronic disorders.

Analysis of the human diet over the past decades reveals, profound changes in dietary behaviour. The dietary changes along with sedentary life styles have resulted in increased obesity and chronic diseases, including cardiovascular diseases (Stephanie *et al*., 2011).

Life style disorders like diabetes mellitus and dislipidemia are currently treated or managed by different types of synthetic drugs. These are mostly associated with several side effects and their efficacies are sometimes debatable (Michael *et al.,* 2005). Hence, lately attention has been directed towards alternatives such as nutraceuticals, originating from plant foods that are rich in phytonutrients (Niu *et al.,* 2010).

India leads the world with the largest number of diabetic subjects earning the dubious distinction of being termed as the" Diabetes capital of the world" (Mohan *et al.,*

2007). Mohan (2012), quotes an ICMR study, that there are 62.4 million people with diabetes and 77 million people with pre diabetes.

Nutraceuticals are the emerging class of natural products that makes the line between food and drug to fade (Adelaja and Schilling, 2000). The concept of nutraceuticals is increasingly becoming popular among consumers, as they are less expensive, beneficial and are better natural alternatives (Rao *et al.,* 2011).

Ayurveda, the 5,000-year-old ancient Indian health science, has mentioned benefits of food for therapeutic purpose. Until just recently, analysis of food was limited to flavour of food and its nutritional value. However, there is growing evidence that other components of food may play an integral role in the link between food and health. Understanding the relationships between foods, physiological functions and diseases have progressed in recent years, particularly over the past decades. Linkages between dietary habits and the quality of life continue to surface on numerous fronts. (Rissanen *et al.,* 2003)

Wildman and Kelley, (2007) reported that the principal reason for the demand of nutraceuticals was the drastic changes in health conditions of the population. People are willing to optimize the health-promoting capabilities of their diets by way of supplementation or by consuming foods that have been formulated or fortified to include health promoting factors.

Bioactive chemical substances in plants such as alkaloids, phenols, flavonoids, glycosides, gums, polysaccharides, peptide glycans, guanidines, steroids, triterpenes, terpenoides, carbohydrates, glycopeptides, aminoacids and inorganic ions are responsible for nutraceutical properties. Various anti-diabetic poly herbal products/ formulations that contain plant metabolites as the active ingredients have been developed. For example, *Alangium salvifolium* tablets extracted from *Alangium salvifolium* and *Gycin max* (Kaushik *et al.,* 2011). *Ipomea* digitata tablets extracted from *ipomea digitata* (Chandira and Jayakar, 2010); Bitter gourd tablets extracted *from Momordica charantia* (Hassan and Khatoon, 2012); diamed powder extracted from *Azardirachta indica*, *Cassia auriculata* and *Momordica charantia* (Pari *et al.,* 2001 and Agrawal *et al.,* 2006) and so on. Also,

polyherbal products extracted from green tea have been documented and are commercially available (Kaur and Talreja, 2014). According to Hui *et al*. (2009), due to the perceived effectiveness and less side effects in clinical experience and relatively low costs of herbs, herbal drugs are becoming more popular as antidiabetic agents.

Jackfruit (*Artocarpus heterophyllus Lam*.) is one of the world's largest edible fruits. The ability of the jackfruit tree to produce higher yield of fruits than any other tree in the Moraceae family (ranging from 70 to 200 kg per tree depending on variety, cultural practices, and environmental conditions), is one of its distinctive characteristics. A fruit's average weight ranges from 3.5 to 10 kg, with some fruits weighing up to 25 kg (Kumar *et al.,* 2002). In jackfruit-growing areas, poor people used to eat this fruit instead of rice at least once a day during the season. As a result, it is sometimes referred to as "Poor man's food" (Rahman *et al.,* 2005).

In 2018, Government of Kerala officially declared Jackfruit as its state official fruit (The Hindu, 2019). The therapeutic use of jackfruit bulbs and seeds for their peculiar qualities have been reported since ancient times. They are rich sources of phytochemicals including phenolic compounds, that offers opportunities for the development of value-added products such as nutraceuticals and various food applications, to enhance health benefits (Umesh *et al.,* 2010). Jackfruit also contains phytonutrients, including lignins, isoflavones and saponins that have wide ranging health benefits. These are also considered as antioxidants, that play a vital role in maintaining human health and preventing disease (Chandrika *et al.,* 2004). Considering its nutritional and health benefits, there is need to promote this fruit for health and prevention of lifestyle diseases. The postprandial glycemic response to raw and ripe jackfruit elicits low glycemic index (Hettiaratchi *et al.,* 2011). The flavonoids present in jackfruit extracts have been identified to be responsible for the non-toxic hypoglycemic action. The functional components of jackfruit help to reduce various diseases such as blood pressure, heart diseases, strokes and bone loss.

Interventions with dietary and consequent modification in lifestyle practices could provide positive impact in the prevention and management of noncommunicable diseases.

. Hence in view of the above, the present study entitled "Development and quality evaluation of a jackfruit based nutri flour" was undertaken with the following objectives.

1.To formulate and standardize a jackfruit based nutri flour comprised of all the edible parts of the raw fruit and

2. To ascertain its physico clinical nutraceutical profile along with in vitro therapeutic efficacy

Review of literature

2. REVIEW OF LITERATURE

In recent years, a new diet-health paradigm has emerged, emphasizing the importance of nutrition. This is because, basic eating habits have changed as a result of new lifestyles. Junk food consumption has risen dramatically, resulting in a slew of ailments linked to poor nutrition. Obesity has now been identified as a global problem. Heart disease is still the leading cause of death in most developing countries, followed by diabetes, cancer, osteoporosis, arthritis, and a variety of other diseases. Clients who are dissatisfied with current pricey medicine's and hightech approach to disease treatment are looking for supplementary or alternative beneficial goods, and the red tape of 'Managed care' makes 'Nutraceuticals' particularly enticing. Our native jackfruit is also reported to possess many medicinal properties. Various jackfruit plant parts, including the bark, wood, leaves, fruit and seeds, exhibit a broad spectrum of antibacterial activity (Swami *et al.* 2012). It has various beneficial nutritional parameters including low glycemic index. Hence, in the present study an effort has been taken to explore the standardisation quality analysis including in vitro therapeutic efficacy of a jackfruit based nutri flour from the different parts of jackfruit cultivars, which is largely consumed by people in Kerala. This chapter comprises the Review of literature classified under the following heads.

2.1. Nutraceutical management of life style disorders

2.2. Nutritional importance of jackfruit

2.3. Nutraceutical implications of jackfruit parts

2.3.1. Antioxidant activity

2.3.2. Anti – cancer property

2.3.3. Anti-microbial activity

2.3.4. Dental Health Promotion

2.3.5. Antidiabetic and hypolipidemic activity

2.4 Need for substitution of refined flour in food formulation

2.4.1. Composite formulation for health

2.4.2. Novel convenient foods based on jack fruit flour

2.4.2.1. Fast dissolving tablets from jackfruit.

2.5. Anti-nutritional factors present in jackfruit

2.5.1. Saponins

2.5.2. Tannins

2.5.3. Phytic acid

2.5.4. Oligosaccharides of the raffinose family

2.5.4.1. Methods for removal of raffinose family oligosaccharides (RFOS)

2.5.4.2. Soaking ang boiling

2.5.4.3.Germination

2.5.4.4. Hydrolysis using α -galactosidase

2.5.4.5. Extrusion and roasting

2.1. NEUTRACEUTICAL MANAGEMENT OF LIFE STYLE DISODERS

"An Ayurvedic proverb says, "When diet is wrong, medicine is of no use; when diet is correct, medicine is of no need".

Food and drug from nature plays quite a significant role in public health care system throughout the world. The development of nutraceutical food products will continue to grow well in the 21st century as the consumer demand for these products are heightened. Consumers are deeply concerned about how their health care is managed, administered and priced. They are frustrated with the expensive, high tech, disease treatment approaches predominant in modern medicine: the consumer is seeking complementary or alternative beneficial products and the red tape of managed care makes nutraceuticals particularly appealing.

The term 'nutraceutical' is a hybrid or contraction of nutrition and pharmaceuticals, it was coined in 1989 by DeFelice and the 'Foundation for Innovation in Medicine'. In 1994 restated and clarified in a press release, its definition as "Any substance that may be

considered a food or part of a food, that provides medical or health benefits, including the prevention and treatment of disease. Such products may range from isolated nutrients, dietary supplements and diets to genetically engineered 'designer' foods, herbal products, and processed foods, such as cereals, soups and beverages. (Defelice *et al.*, 2002).

Natural products, such as cereals, are likely to form the basis of nutraceuticals, as the nutrients in cereals have been shown to reduce the risk of coronary heart diseases, tumour incidence, cancer risk, blood pressure, cholesterol and fat absorption, delaying gastrointestinal emptying and providing gastrointestinal health. (Saika and Deka, 2011).

Whole grains are high in magnesium, which is a cofactor for over 300 enzymes, including those involved in glucose metabolism and insulin production. It has been linked to lowering the risk of certain malignancies, cardiovascular diseases and type 2 diabetes. Lunasin is a novel cancer-prevention, antiinflammatory, and cholesterol-lowering peptide that was discovered in cereals like barley, rye, triticale and wheat (Nakurte *et al.,* 2013).

Oats have the highest concentration of beta glucan, a soluble non-starch polysaccharide, that has been shown to lower the risk of coronary heart diseases. About 3 gm per day of soluble fiber from oat products can achieve a clinically relevant serum cholesterol lowering effect and this reduction is larger in persons with higher baseline blood cholesterol levels (Ripsin *et al.,* 2009).

The functional components of finger millet, such as slowly digesting starch and resistant starch, have given it a boost in popularity. It contains the highest concentration of calcium, antioxidants, and phytochemicals, all of which aid in blood glucose regulation (Wadikar *et al.,* 2007).

Soybeans are high in phytosterols, saponins, phenolic acids, phytic acid, and isoflavones, all of which help to lower the risk of heart diseases and total cholesterol levels. In human ecological observations, the World Cancer Research Fund (2007) found that soybeans have a cancer-preventive impact.

Plantain or banana, a widely grown fruit throughout the world, is the best source of potassium, an essential mineral to maintain normal blood pressure and heart function. It

contains phenolic compounds and flavonoids, as well as dopamine and antioxidants, and it inhibits the angiotensin converting enzyme, which causes blood vessels to constrict and blood pressure to rise (Alothman *et al.,* 2009).

According to Bruni *et al*. (2002) grain amaranthus is a good source of nutrients, a pseudo cereal with higher fibre and protein content than true cereals. It has significant and distinct nutraceutical applications. In non-insulin-dependent diabetes, amaranthus seed powder lowers blood glucose levels and lowers blood serum cholesterol levels (Chaturvedi *et al.,* 2003).

Fenugreek (*Trigonellafoenum-graecum*) is an ancient medicinal plant that has great potential in the natural health products sector. It is known as the vegetarian's primary source of soluble dietary fibre. This dietary fibre has been shown to lessen the risk of cardiovascular diseases and protects against certain malignancies by lowering total and low-density lipoprotein cholesterol. In diabetics, the seed mucilage is more beneficial. The seed powder improves glucose homeostasis by reversing the altered glycolytic and lipogenic enzymes. (Petropoulos, 2002). There was a considerable drop in blood glucose, which resulted in improved glucose tolerance when fenugreek (100g defatted fenugreek powder) was given to NIDDM individuals for 10 days.

Vasanthamani and Savitha (2001), studied the therapeutic effects of fenugreek seed powder. A total of 12 NIDDM subjects were chosen, with six servings as controls. For a period of 15 days, the experimental group were given 25 g of sprouted fenugreek seed powder. When compared to the control group, blood glucose levels in the treated group was significantly lower.

Breadfruit (*Artocarpus altilis*) is one of the low-fat, low-calorie foods with unique nutrients and phytochemical profiles and is particularly rich in dietary fiber, potassium, phosphorous, magnesium, copper, vitamin C, thiamin, riboflavin, niacin, pantothenic acid, B6, and folate. Bioactive compounds or phytochemicals, such as carotenoids and polyphenols, have also been found in large amounts in breadfruit. Fruits rich in fiber helps to control blood sugar in diabetics, reduce their unfavorable blood lipids (a risk CVDs) and

control weight. The daily incorporation of breadfruit to a diet helps in improving its quality and subsequently reduce the risk of development of chronic non-communicable diseases, such as obesity, diabetes, atherosclerosis, hypertension, cancer and neurological disorders including as neural tube defects (Englberger et *al.*, 2007; Lako *et al*., 2007).

The isolated compounds from Breadfruit (*Artocarpus altilis*) exhibit biological activity such as inhibiting platelet aggregation, anti-bacterial activity, anti-fungal properties, inhibition of leukemia cells and also seen to serve as an antitumor agent (Handa *et al.*, 2008).

The evidence of nutraceutical properties of various products in thus a saga, being established by research.

2.2. NUTRITIONAL IMPORTANCE OF JACKFRUIT

The jackfruit tree (*Artocarpus heterophyllus*) of the mulberry family (Moraceae) is believed to have originated in the south western rain forests of India (Boning, 2006), around 300 B.C. The Greek philosopher Theophrastus described the tree as very large with wonderfully sweet and large fruits that were used as food by the sages of India (Srivastava and Singh 2020). The jackfruit tree is well suited to the tropical lowlands, and its fruits are the largest tree-borne fruits, weighing as much as 35 kg and measuring up to 90 cm in length, and 50 cm in diameter.

The word ‘Artocarpus’ is derived from the Greek words *artos* (bread) and *carpos* (fruit) as reported by Bailey (1989). The name “Jackfruit” is derived from the Protuguese word ‘jaca’, which in turn, is derived from the Malayalam language term, ‘chakka’. The fruit is popularly known as, ‘kathal’ or ‘kata-ha’ in Bengali and
in Hindi. The Malayalam name ‘chakka’ was recorded by Hendrikl van Rheede (1678-1703) in the Hortus Malabaricus, vol. iii in Latin.

Tropical fruits are constituents in the daily diets of billions of people. Jackfruit is one the most significant among evergreen trees in tropical areas and countries and is found throughout Asia and Pacific islands, mainly in home gardens. This tree is not considered as an invasive species like other species. (Rahaman *et al.* 2000; Elevitch and Manner, 2006)

The jackfruit is “an underutilized crop” in the tropical-to-subtropical regions where in, most of the fruits 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 (Prem *et al.,* 2015). Jackfruit is widely consumed as a fresh fruit and it has been reported with therapeutic qualities since ancient times. The fruit could actually be a solace for people in different parts of the world facing food insecurity.

The edible bulbs in jackfruit are separated into compartments by latex-like filaments called ‘rags’ or perianth. This waste portion consists about 25% of the total fruit weight. In fresh stages there is high percentage of starch in jackfruit perianth and seed. The starch and dietary fiber content of the flesh increases with the maturity. (Dam and Nguyen, 2013).

The jackfruit is a multi-purpose tree providing food, timber, fuel, fodder, and medicinal and industrial products. The primary economic products from the jackfruits are the fruits, which are used both when mature and immature. The unripe (green) jackfruit is remarkably similar in texture to chicken; thus, jackfruit is an excellent vegetarian substitute for meat. The canned jackfruit is sometimes referred to as “vegetable meat” (Stukin, 2016).

Studies have found that, there is a variation in nutritional composition of jackfruits in different maturity stages and the chemical composition of jackfruit varies depending on the variety. (Haq, 2006., Bhatia *et al.,* 2007, Kumar *et al.,* 2002). Jackfruit *(A. heterophyllus*) contains various nutritional constituents including antioxidants, minerals, vitamins like A, C, E, pyridoxine, riboflavin, folic acid and thiamine; phytochemicals like folates, glucosinolates, carotenoids, flavonoids, phenolic acids, lycopene and selenium. (Chandrika *et al.,* 2004). It also contains free sugar (sucrose), fatty acids, ellagic acid amino acids (such as arginine, cystine, histidine, leucine, lysine, metheonine, theonine, tryptophan, and others) and dietary fibers. Compared with other tropical fruits, jackfruit flesh and seeds contain more protein, calcium, iron, and thiamine (Saxena *et al.,* 2016). Jackfruit has plenty of important minerals. It is rich in magnesium, which is important for the absorption of calcium and helps strengthen the bones and prevents bone-related disorders such as osteoporosis. Iron in jackfruits helps to prevent anemia and aids in proper

blood circulation and copper contained in them can play an important role in thyroid gland metabolism (Liu, 2013).

Samaddar (2009) has reported that the flakes of jackfruits are high in nutritive value, every 100 g of flakes contains 287-323 mg potassium, 30.0-73.2 mg calcium, and 11-19 g carbohydrates. Ripe jackfruit contains minerals such as calcium, magnesium vitamins, and organic acids (Tiwari and Vidyarthi, 2015).

Jack fruit bark from the main trunk contains betullic acid and two new flavone pigments including cycloheterophyllin (C30H30O7) (Chawdhary and Raman, 2000). Heterophylol, a phenolic compound with a novel skeleton, was obtained from *A. heterophyllus* (Chun-Nan and Chai-Ming 2003). The leaves and stem have shown the presence of sapogenins, cycloartenone, cycloartenol, β-sitosterol and tannins; they have shown estrogenic activity (Nath and Chaturvedi 2001), The root contains β-sitosterol, ursolic acid, betulinic acid, and cycloartenone (Dayal and Seshadri, 2002).

Mukprasirt and Sajjaanantakul (2004), reported that raw jackfruit has a lowcalorie content; 100 gm of raw jackfruit bulbs provide 95 calories. The jack fruit bulb is made of soft, fibrous and easily digestible simple sugars like fructose and sucrose.

Jagtap *et al.* (2010) reported that, every 100 g of jack fruit pulp has calories (84 kcal) carbohydrates (18.9 g), protein (1.9 g), fat (0.1 g), moisture (77%), fibre (1.1 g), total mineral matter (0.8 g), calcium (20 mg), phosphorus (30 mg), iron s(500 mg), vitamin A (540 I.U.), thiamin (30 mg) respectively.

Jackfruit contains niacin that is known as vitamin B3 and necessary for energy metabolism, nerve function, and the synthesis of certain hormones; 100g of Jackfruit pulp provides 4mg niacin, when the recommended daily allowances of niacin is16 mg for men and 14 mg for female. (Soobrattee *et al.,* 2012).

Jackfruit seeds constitutes up to 10 to 12 per cent of the total weight of the fruit. Seeds were found to be rich sources of starch (22%) and dietary fiber (3.9%) which are important for health (Faria *et al.,* 2009). Compared to beef and fish, jack fruit seeds have

high protein, along with high carbohydrate and oil content (11.4%) which can help to make it an alternate source for animal diet (Ajay, 2008).

Flavonoids and alkaloids were identified in jackfruit seeds. The analysis rendered the fact that *A. heterophillus* seeds contained alkaloids, quinine, tomatine and nicotin. These alkaloids can be used in the destruction of disease-causing germs (Okoye *et al.,* 2012). The seeds contained myricetine, kaempferol, gossypetine, quercetine and isoliamnetine, are the major type of flavanoids (Okoye, 2016).

The amylose content of jackfruit seed starch was around 24-32%, which is similar to potato starch. Prebiotics are non-digestible food ingredients are present in jackfruit seeds in the form of phenolic compounds and about 6.03 mg/g are extracted as non-reducing sugars (Soong and Barlow, 2004; Nualla *et al*. 2009).

Jackfruit peel, also known as rind or skin, is the outer protective layer of the fruit, which is reportedly rich in cellulose, pectin, protein and starch, forming about 27.75%, 7.52%, 6.27%, and 4%, respectively of the fruit (Sundarraj and Ranganathan, 2017).

Jack fruit rind is composed of hexagonal and conical carpal apices. It contains essential nutrients such as carbohydrates proteins, fiber, fat, vitamins and minerals. (Elevitch and Manner, 2006). According to Feilli, *et al*. (2018) high fiber jack fruit rind powder can be used as food supplement or additive in foods to help preventing constipation.

The proximate composition of raw jack fruit rinds disclosed 0.99 % of ash, 1.71% of crude lipid and 1.54% of crude protein. The crude fiber level was 13.51 % and carbohydrate content was only 5.92%. Jack fruit rinds are potential sources of pectin, with good gelling properties (Koh *et al.,* 2020).

The acetone extract of jack fruit peels showed very high antimicrobial activity against all tested pathogenic bacteria. Highest antimicrobial activity was observed by the acetone extract of jack fruit peels and the zones of inhibition ranged between 20-30 mm. The chemical composition of the major retention peak obtained in GCMS analysis of acetone extracts of the jack fruit peel depicted furanone, furfural and phenolic compounds,

as the prominent retention peaks. The furanone peak retention area in jack fruit peel was 59.47 per cent. Thus, jack fruit rind can assuredly be utilized for its health benefits (Roy and Lingampeta, 2014).

Six carotenoids were detected in jackfruit kernels. The carotenes - β-carotene, α-carotene, β-zeacarotene, α-zeacarotene and β-carotene-5,6-epoxide and a dicarboxylic carotenoid, crocetin, were identified, corresponding theoretically to 141.6 retinol equivalents (RE) per 100 g. Jackfruit is a good source of provitamin A carotenoids as well, though not as good as papaya (Chandrika *et al.,* 2004).

2.3. NUTRACEUTICAL IMPLICATIONS OF JACKFRUIT PARTS

The beneficial effects of fruits and vegetables for prevention of certain diseases are now widely accepted to be due to the presence of bioactive compounds in them (Galaverna *et al.,* 2008). Recent years have seen increased interest on the part of consumers, researchers, and the food industries, into how food products can help maintain health (Vinuda *et al.,* 2010).

Jack fruit is a sweet and delightful fruit with many health benefits. It consists about 29% pulp, 12% seeds and 54% rind (Berry and Kalra, 2000). It provides about 2MJ of energy per kg-wet weight of the ripe perianth (Ahmed *et al.* 2001). Jackfruit contains high levels of proteins, starch, calcium and thiamine. It is also rich in energy, dietary fibre, minerals and vitamin. Even so, it contains no saturated fats or cholesterol, making it a healthy fruit to savour. (Burkill 2007; Ejiofor *et al.,* 2014).

The jackfruit and its derivatives such as wafers, chips, seed flour, peel, and so on could be considered as functional foods, because they have valuable compounds, in different parts of the fruit that display functional and medicinal properties (Swami *et al.,* 2012).

Various jackfruit plant parts, including the bark, wood, leaves, fruits, and seeds, may exhibit a broad spectrum of antibacterial activity. Jackfruit seeds therefore be developed into therapeutic agents, capable of treating infectious diseases and preventing food contamination by food-borne pathogens. Jackfruit seed has antibacterial effects and it

inhibits the growth of *E. coli, F. moniliforme, S. cerevisiae and B. megaterium* (Swami *et al.,* 2012).

The phytochemical components present in the jackfruit are reported to reduce various diseases like high blood pressure, thus preventing heart diseases and strokes, bone loss and degeneration of muscle and nerve functions, this improving the osteo and neuro status (Mushumbusi, 2015).

The jackfruit is a rich source of phenolic compounds and is also rich in phytonutrients such as lignans, isoflavones and saponins, which have anti-cancer and anti-aging properties. These phytonutrients help to eliminate cancer causing free radicals from the body (Ko *et al.,* 2003). One cup of jackfruit can supply the body a very good amount of powerful antioxidants (Umesh *et al.,* 2010). Jackfruit is gluten-free and casein-free, thus offering systemic anti-inflammatory benefits to skin.

The human body does not make vitamin C naturally, but jackfruit is enriched with vitamin C which strengthens the immune systems. Vitamin C is a powerful nutrient which helps to protect against viral and bacterial infections. Vitamin C also helps to strengthen the immune system function, by supporting the function of white blood cells (Mukprasirt and Sajjaanantakul 2004). Vitamin C is vital to the production of collagen, a protein that provides skin with structure and gives it firmness and strength (Babitha *et al.*, 2004).

Potassium present in jackfruit is found to promote the lowering of blood pressure, preventing heart diseases, bone loss, as well as, improving muscle and nerve functions and strokes. Jackfruit contains vitamin B6, which sets off a reduction in homocysteine levels in the blood, thus lowering the risk of heart diseases (Fernando *et al.,* 2001). Jackfruit is enriched with magnesium (27 mg/100 g in young fruit and 54 mg/100 g in seed), which helps to absorb calcium and thus help in strengthening bones and preventing bone-related disorders such as osteoporosis (Fernando *et al.* 2001; Singh *et al.* 2000). It also prevents anemia and also supports proper blood circulation because of the presence of iron (0.5 mg/100 g). Jackfruit contains the micro mineral copper (10.45 mg/kg), which plays an

important role in maintaining thyroid gland metabolism, especially in hormone production and absorption (Gunasena *et al.*, 2006).

2.3.1. Antioxidant activity

Antioxidants are substances that neutralize free radicals or their actions (Sies, 2000). Nature has endowed each cell with adequate protective mechanisms (like superoxide dismutase (SOD), glutathione peroxidase, glutathione reductase, thioredoxin and thiols) against the harmful effects of free radicals. Disulfide bondings are the buffering systems in every cell. Antioxidants regarded as compounds are able to delay, retard, or prevent the oxidation process (Halliwell *et al.*, 2000). The natural antioxidants in fruits and vegetables have gained increasing interest among food scientists, nutrition specialists and consumers, as the compounds are claimed to reduce the risk of chronic diseases and promote human health (Ribeiro *et al.*, 2013).

Jackfruit contains useful antioxidants, which prevents many human diseases. (Devasagayam *et al.*, 2004). Vitamin C (ascorbic acid) is also a water soluble free radical scavenger. The daily recommended dietary allowance of this vitamin is 60 mg, wherein jackfruit contain12 to 14 mg vitamin C per 100 g (Narasimham, 2000).

Munira (2015), observed that *A. heterophyllus* seeds had high antioxidant activity. Chloroformic (CHLF) and and crude ethanolic (CEE) extract of *A. heterophyllus* seeds had high antioxidant activity (attributable to its high phenolic content). Ethyl acetate (EAF) and chloroformic (CHLF) extracts had high radical scavenging activity 1, 1-diphenyl-2picrylhydrazyl (DPPH) and superoxide radical scavenging activities, which indicates that incorporation of the seeds with food is complementary.

2.3.2. Anti-cancer activity

Phyto nutrients in jack fruits like lignans, isoflavones, tannins and saponins all are known for their anti-cancer and anti-aging properties. It helps to prevent different types of cancers such as lung cancer, breast cancer, skin cancer and prostate cancer. This helps in destroying cancer causing free radicals and slows down the degeneration of cells.

A study carried out by Ruiz *et al.* (2015) reported that, jackfruits owned compounds with chemoprotective properties that reduced the mutagenicity of aflatoxin B1 (AFB1) and proliferation of cancer cells. According to Suhartati *et al.* (2012), prenylated flavones, artonins M and E showed significant cytotoxicity against leukemia cells and human oral epidermoid carcinoma.

Zuraidah and Sakinah (2014) observed that, Jackfruit is rich in fiber and a unique sticky latex. Both these components combine together to work as colon cleansers. They help in removing toxins from the digestive tract and help in reducing the risk of colon cancer. Cancer cell binding properties of jacalin, a type of lectin isolated from jackfruit, was discovered in benign and malignant lesions of the breast and thyroid cancer cells

One of the best inhibitors of tyrosinase activity was the *Artrocarpus heterophyllus* extract. In B16 melanoma cells, isolated artocarpanones from jackfruit inhibited both mushroom tyrosinase activity and melanin output. This compound was highly useful in the treatment of hyperpigmentation of human skin. (Arung *et al.,* 2007). The cytotoxic effects on B16 melanoma cells were observed by the isoprenoid substituted flavonoids, derived from the methanolic extracts of jackfruit wood. In vitro, this artocarpin was found to have strong cytotoxic effect against cultured human T47D breast cancer cells. (Arung *et al.,* 2010).

2.3.3. Antimicrobial activity

Antibacterial properties of jackfruit have been evident against 24 different bacterial species. Jacalin, a lectin derived from jack fruit, inhibited DNA viruses such as herpes simplex virus type II (HSV-2), varicella-zoster virus (VZV), and cytomegalovirus (CMV) (Wetprasit *et al.* (2000). Jacalin's unique ability to be highly mitogenic against human CD4 + T cells, has made it as a helpful tool for assessing the immunological state of patients, infected with the human immunodeficiency virus (HIV-1). (Pereira-da-Silva *et al.*, 2006)

Isolated flavonoids in the fruit which included cytcloartomunins, artonins A and B, artocarpanones, hetero flavanones and dihydro isocycloartomanins, inhibited beta glucuronidase, histamine production and possessed antiinflammatory properties. (Wei *et*

al., 2005; Fang and Yen, 2008). Antiviral activity (480µg/ml) was found in a jackfruit extract against human rotaviruses (inhibition rate was 99.2 percent). It was reported that tannins and alkaloids were the key chemicals responsible for the antibacterial activity. (Goncalves *et al.*, 2005).

According to Khan *et al.* (2003), the leaf extract was shown to be effective against *Aspergillus niger, Aspergillus rubrum, Aspergillus versicolor, Aspergillus vitis, Candida albicans, Candida tropicalis, Cladosporium cladosporiods, Penicillium notatum, Trychophyton mentagrophytes* and *Trychophyton tronsurum.* The chitin binding lectin found in the seeds, on the other hand, had proven to stop *Fusarium moniliforme* and *Saccharomyces cervisiae* from growing. (Trindade *et al.*, 2006)

2.3.4. Dental Health Promotion

Latex or resin can be found on the tree's trunk, as well as the fruit of the jackfruit tree. The sticky white latex produced by specific secretory cells called
'laticifers', can be found in all regions of the jackfruit tree. Latex is a multiingredient aqueous emulsion that includes lipids, rubbers, resins, carbohydrates, and proteins, including proteolytic enzymes (Fonseca *et al.*, 2010).

The jackfruit latex extract, which is high in flavonoids and alkaloids, were tested and shown to be comparable to typical antibacterial and antifungal medications. In terms of cost-effectiveness, they confirmed, the important uses of jackfruit latex or resin, or both, as a cementing media, irrigation solution (fluid washing of a body cavity or wound), denture cleaning solution, resin, and potential future dental filling material (Jitendra *et al.*, 2014).

2.3.5. Antidiabetic and hypolipidemic activity

Diabetes, nicknamed "the disease of the twenty-first century," is a threat for modern generations due to its increasing prevalence. Diabetes Mellitus is one of five leading causes of deaths and impairing disease in the developed world. As per WHO, 150 million people were suffering from diabetes worldwide in 2008, the number will be almost five times more than the estimates one decade ago and will be doubled in the year 2030 (Kannan *et al.*,

2012). However, by 2030 the largest increase in prevalence is expected in Asia and Africa. Diabetes is becoming more common in developing countries, as a result of urbanization and lifestyle changes, most notably the ‘Western-style' diets.

Insulin and oral hypoglycemic medications are used to control the pathogenesis of diabetes mellitus and its complications. However, long-term use of most of these drugs resulted in hypoglycemic coma, insulin resistance, hypersensitivity, cholesterol, jaundice, abdominal pain, anorexia, and metallic taste, among other side effects. (Sharma and Kumar, 2011)

The use of herbal medicines in diabetic control has risen in popularity in recent years for a variety of reasons. Natural plant products are also thought to be less toxic and to have fewer side effects than synthetic drugs. Despite the existence of a large number of drugs in the pharmaceutical market, herbal plant remedies are successfully used to treat this disease. (Biworo *et al.,* 2015).

In a streptozotocin (STZ)induced diabetic rat model, an ethyl acetate (EA) fraction of the mature leaves of *A. heterophyllus* showed hypoglycemic and hypolipidemic impact. When a single dose (20 mg/kg) of the ethyl acetate fraction was given to normoglycemic rats, it resulted in a substantial reduction ($P < 0.05$) in fasting blood glucose levels and a significant increase in glucose tolerance ($P < 0.05$) in relation to controls. Chronic administration of the ethyl acetate (EA) fraction of *A. heterophyllus* leaves every day for 5 weeks resulted in substantial reductions in serum glucose, cholesterol, and triglyceride levels in STZ-induced diabetic rats. At the end of the fifth week, the extract-treated diabetic rats had 39 percent lower serum glucose, 23 percent lower serum total cholesterol, 40 percent lower serum TG, and 11 percent higher body weight than the control diabetic rats (Chackrewarthy *et al.,* 2010).

Omar *et al.* (2013) reported the hypoglycemic, hypolipidemic and antioxidative activity of *Artocarpus heterophyllus* (jack fruit) leaf extracts with 70% ethanol n-butanol, water, chloroform, and ethyl acetate extracts. Streptozotocin (STZ) induced diabetic rats were given 70 percent ethanol extract or n-butanol extract, which decreased fasting blood

glucose from 200 to 56 and 79 mg percent, respectively at weekly intervals. Lipid peroxides decreased from 7.3 to 5.4 and 5.9 nmol/l, respectively; glycosylated haemoglobin A1C (percent HbA1C) decreased from 6.8 to 4.5 and 5.0 percent, respectively; and total protein content increased from 2.5 to 6.3 and 5.7 mg percent respectively. As compared to diabetic rats, triglycerides, total cholesterol, low-density lipoprotein cholesterol, VLDL-C, and the LDL/HDL ratio decreased by -37, -19, -23, -37, and -39 percent in the case of 70 percent ethanol extract; and by -31, -14, -17, -31, and -25 percent in the case of n-butanol extract. HDL-C increased by 37% and 11% respectively. Jackfruit ethanolic extract and Jackfruit butanol extract both showed significant improvements in FBG, lipid peroxides, percent HbA1C, TC, LDL-C, and TG levels, as well as insulin, HDL-C, and protein content.

A study conducted by Suchithra and Subramanian (2014) an antidiabetic behaviour of *Artocarpus heterophyllus* rag extract was investigated in high fat fed, low dose STZ induced type 2 diabetic rats. Diabetic rats were given *Artocarpus heterophyllus* rag extract at a dose of 300 mg/kg body weight, daily for 30 days. Fasting blood glucose, plasma insulin and HbA1c were the parameters studied, with metformin (200 mg/kg body weight) serving as the reference drug. Supplementing with the extract reduced elevated glucose, glycosylated haemoglobin, AST, ALT, and ALP levels. Insulin levels were enhanced when the hepatic glycogen content of insulin-resistant diabetic rats was increased. After extract treatment, the activities of glycogen metabolising enzymes were restored to usual. In addition, the extract increased insulin sensitivity, as shown by an intraperitoneal insulin tolerance test. The results showed that *Artocarpus heterophyllus* rags are non-toxic and had potent anti-diabetic properties.

Ayurvedic and traditional medical practitioners recommended hot water extract of mature jack fruit leaves as a treatment for diabetes mellitus. The hypoglycemic effect of the aqueous decoction of jack fruit leaf in both rats and humans was found to be effective. (Fernando *et al.*, 2001). The leaves and stem of the jackfruit showed the presence of sapogenins, cycloartenone, ß-sitosterol and tannins, which helped in lowering fasting blood glucose levels by cortisol inhibition (Chackrewarthy *et al.*, 2010)

Jackfruit seeds contained high amount of resistant starch (RS) (indigestible starch). Resistant starch is categorized into four types (RS1–RS4) and jackfruit seeds are suggested to contain RS1 type. The undigestible starch escapes digestion in the small intestine, and is therefore reported to act like dietary fiber, it also lowers blood glucose levels and improves insulin resistance. (Sajilata *et al.,* 2016).

An experiment conducted by Kannan *et al*. (2012) showed that, the jackfruit extracts could inhibit the glycation of hemoglobin levels (HbA1c). The inhibition is suggested to be caused by the presence of the phytochemical constituents in jackfruit extract, such as ascorbic acid, □-carotene and lycopene.

2.4. NEED FOR SUBSTITUTION OF REFINED FLOUR IN FOOD FORTIFICATION

"Eat healthy and live healthy is one of the essential requirements for long life".

Unfortunately, today's globe has embraced a food consumption system that has a number of negative health consequences. Changes in our lifestyles have compelled humans so much they have very little time to think of eating right.

Globalization and urbanisation have had a significant impact on people's eating patterns, forcing many to consume high-calorie fast foods. Non communicable diseases (NCDs) such as diabetes, cardiovascular diseases, mental health, obesity, hypertension, and some types of cancer have increased, as a result of these bad eating patterns. (Solomons, 2015).

In recent years, the food industry has concentrated its efforts on the creation of new products with features that assist in the prevention of diseases related to nutrition, such as diabetes, obesity, hypertension and cardiovascular issues, as well as supply the necessary nutrients for human nourishment. It has been found that there is a significant correlation between the regular intake of phytochemicals and the prevention of these lifestyle-related diseases. (Gresele *et al.,* 2016)

Chronic diseases were estimated to account for 46 percent of global disease burden in 2001, and this figure is expected to rise to 57 percent by 2020. (WHO, 2002). Most of

these diseases now manifest earlier in life, affecting both the wealthy and the poor in both developing and developed countries.

Noncommunicable diseases (NCDs) kill over 40 million people per year, accounting for roughly 70% of all deaths worldwide. Every year, 17.7 million people die from cardiovascular disorders such as heart attacks and strokes, making it the most dangerous disease on the planet. Cancer claims the lives of around 8.8 million people each year, followed by respiratory diseases, which claim the lives of approximately 3.9 million people each year, and diabetes, which has an annual morbidity rate of 1.6 million people. Among all NCDs, these four types of diseases are the most common causes of death (WHO, 2017)

By 2020, India's population of hypertensive and diabetic patients is predicted to reach 69.9 and 213 million, respectively. Kerala is becoming India's 'Lifestyle disease capital', with high rates of hypertension, diabetes, obesity, and heart disease risk factors comparable to those seen in Western countries (Reddy *et al.,* 2006).

Very recently, there is a shift towards the 'optimal nutrition diet' because of the growing health issues and there has been an increasing awareness of the populace in most nations of the world, about the interplay between nutrition and health. Certain bioactive compounds in foods have various disease-fighting properties, which have made consumers worldwide, become much more interested in the health benefits of foods. (EFSA, 2010).

Consumer awareness of health issues has grown over time. The promotion of healthy diets, nutrition, and lifestyles to reduce the global burden of these diseases is constantly advocated, and one possible way out is the widespread consumption of nutraceuticals, functional foods, and value-added food products, which are readily available and have disease-preventive properties. (Gunther *et al.,* 2004)

According to Chen *et al.* (2017), refined grain flour consumption is widely thought to be linked to negative health outcomes such as an increased risk of cardiovascular diseases (CVD), type 2 diabetes (T2D), hypertension, cancer, and obesity. White flour has been called the "glue of the gut". Maida flour, which is used extensively in the baking

business to create delectable foods, has detrimental effects on our bodies. Maida is made after the fiber-rich bran for wheat flour has been separated. Alloxan is used to bleach the fabric in order to improve its colour and softness. Alloxan is the product of decomposition of uric acid. It consumes and destroys a greater number of pancreatic beta cells. The pancreas is in charge of regulating glucose and sugar in our bodies, and alloxan affects this function, causing diabetes to develop (Steffen *et al.,* 2003).

Maida has got very high glycemic index; as sugar is released into the bloodstream quickly. To counter this, the pancreas generates an insulin surge, which, over time and with increased consumption of processed and refined foods, causes inflammation, insulin resistance, and eventually type II diabetes. About 97 percent of the fibre in wheat is lost when the bran is removed, maida has a lower nutritious value. Many key nutrients are also removed during the refining process (Law *et al.,* 2009).

2.4.1. Composite formulations for health

In 1964, the Food and Agricultural Organization (FAO) pioneered the composite flour technology. Composite flour is a blend of flours, starches, and other components designed to completely or partially replace wheat flour in culinary items. Shittu *et al*. (2017) concurred this concept, because the composite flours utilised binary or ternary mixes of flours from other crops or vegetables, with or without wheat flour.

When compared to wheat flour, the composite flour may provide better overall essential amino acid balance, dietary fibre, antioxidants, and high mineral content, which may aid in the prevention of Protein Energy Malnutrition and degenerative diseases, such as CVDs, obesity, hypertension and various forms of cancer.

Great amount of wheat imports could be reduced in developing countries, if locally sourced flours were incorporated into food items. Thus, governments are putting a greater emphasis on this issue.

The ingredients seen used for the preparation of composite flours are cassava, sweet potato, maize, rice, sorgum, yam, ragi, oats, barley, buck wheat, pulses, chick pea,

cowpea, mung bean, vegetables like pumpkin, bread fruit, fruits like papaya, and jackfruit as reported in literature.

As a result, the nutritional quality of foods made with composite flours is determi ned by the composition of the flours (Ikuomola *et al.,* 2017). The composite flour should be freely available, culturally acceptable, inexpensive and nutritionally and functionally equivalent to wheat flour (Igbabul *et al.*, 2015).

Supplementary foods such as nutri mixes, health drinks, health mixes, and other preparations, when paired with regular diets, have demonstrated to boost health and give the body with targeted nutrients (Sherleker and Udipi, 2006). Supplementation in the form of food formulations is an effective strategy to promote health and prevent malnutrition and noncommunicable illnesses (Sangeetha and Premakumari, 2010).

According to Tilakaratne *et al.* (2015), nutri mix is an instant food powder that delivers good supplementation of key vitamins and minerals, to achieve the recommended dietary intake. Nutri mixes are made to provide high biological value proteins along with producing concentrated sources of specific nutrients. (Karuppasamy *et al.,* 2014).

Subhashree *et al.* (2014) formulated the "amrutham nutri mix" for children using wheat, soya chunks, bengal gram and ground nut, which has provided 391 Kcal of energy, 69.47 g of carbohydrate, 16.14 g of protein, 5.44 g of fat, 191.23 mg of calcium and 8.9 mg of iron.

There has been an increasing interest in using functional gluten-free components to replace refined gluten-free flour, starch and hydrocolloids (Traynham *et al.*, 2007; AlvarezJubete *et al.*, 2010).

Tilakaratne *et al.* (2015) developed a nutri mix fortified with dehydrated muringa leaves and pumpkin powder in various combinations, based on brown rice and mung bean. It was high in vitamin A and had 28 percent protein, 14 percent fibre and 43 percent carbohydrate.

Manjula *et al.* (2017) prepared a herbal health mix with Pennywort leaves to alleviate micronutrient malnutrition. Whole wheat, ragi, bajra, foxtail millet, soy, green grame dal, cocoa powder, sugar, dates, and cardamom were used to make the health mix. The developed health mix was high in protein (12.98 g), vitamin A (156.7 IU), and vitamin C (15.6 mg).

Kadam and Maheswari (2015) formulated a nutri flour for preparing rotti and chapatties using wheat flour, millet flour, soy bean and methi leaves powder. The developed nutri flour had higher amount of protein (15.37 g), carbohydrate (74.2 g) and crude fibre (2.056 g).

Sambavi *et al.* (2015) prepared a nutri flour for baking cookies using 50 per cent of foxtail millet and 50 per cent of wheat flour. The chosen composite flour contained a significant level of protein (14 %), fat (5.7%) and crude fibre (0.07 %). The low-cost nutri mixes made with pearl millet, barley and whey protein concentrates had higher protein content (25.88 g) and carbohydrate (60.98 g) (Zaheeruddin, 2011)

Borkotoky and Sarma (2016), formulated a herbal hypolipidemic health mix with roasted parboiled rice flour, green gram dal, arjuna, cinnamon and fenugreek. The herbal mix (100g) had 74.75 g of carbohydrate, 12.92 g of protein and 7.13 g of dietary fiber. The mix provided antioxidant properties, because it contained vitamin A (29.8 IU), vitamin E (0.57 mg), vitamin C (0.16 mg), selenium (11.2 mg), copper (193.4 µg), zinc (529.2 µg), iron (2531 µg) and manganese (810.7 µg).

A nutritionally superior and low-cost seaweed soup mix powder was developed using vegetables, legumes, cereals and seaweed extracts such as agar and carrageenan. The prepared mix contained 11.3 per cent protein, 2.4 per cent fat, and 64.54 per cent carbohydrate (Jayasingh *et al.,* 2016).

Ndife *et al*. (2011) investigated the sensory qualities of functional loaves made from a blend of whole wheat and soya bean flour. Whole wheat and soybean flour blends were composited at replacement levels of 10,20,30, and 40 percent and whole wheat bread,

served as a control. The sensory evaluation revealed that, there was no significant difference observed between whole wheat bread and the soy bread samples.

Aneena and James (2015), formulated a health mix (Teen Plus) using malted ragi flour, whole cereals, pulses, milk solid and nuts, that provided 398 Kcal of energy, 43.5 g of carbohydrate, 10.65 g of protein, 336 mg of calcium and 6.1 mg of iron. Vitamins such as carotene (9.86 µg), thiamin (0.263 mg), riboflavin (0.241 mg), niacin (3.33 mg) and folic acid (21.63 µg) were also abundant in the combination.

In the making of cookies, a composite flour made from watermelon seed, cassava and wheat was used. The watermelon seed flour was blended with wheat and cassava flour in the following proportions: 0:100, 10:90, 15:85, 20:80, 50:50, and 100:0, 90;10, 85:15, 80:20, 50:50. When compared with other composite flours the result revealed that the blend of watermelon seed flour and cassava in the ratio of 90:10 had a good overall acceptability (Ubbor and Akobundu, 2009). Banu *et al.* (2013) developed a convenient multi whole grain mix for the preparation of a drink and porridge that was formulated using cereals, millets, pulse and nuts.

Mishra and Chandra (2012) formulated a functional biscuit flour made of rice bran and soya flour. Wheat flour was supplemented with soya and rice bran in different proportions of 10, 15, 20, 25 percent level each. The functional biscuits were found to have a good approval rating.

To prevent anaemia, an iron-rich health mix was developed utilising locally accessible iron-rich foods such as garden cress seeds, rice flakes, roasted bengal gram dhal, bajra, samai, and jaggery (Angel and Devi, 2014).

Ranjitha *et al.* (2018) developed nutri enriched cookies fortified with pomegranate peel powder and defatted soybean flour. Consumers considered the formulation with 65% Refined wheat flour + 5% Pomegranate peel powder + 30% Defatted soybean flour, to be nutritionally superior and organoleptically acceptable.

A probiotic fermented food mixture was prepared by Sharon (2010) using banana, defatted soya flour, green gram flour and fruit pulp and it was found that the probiotic mix

provided 9.29 g of protein, 6.45 mg of iron and 68.17 mg of calcium. A probiotic food mix was formulated using locally available ingredients such as Italian millet flour, wheat flour, soya flour, skimmed milk powder and roasted bengal gram dal powder. The protein, fat, crude fibre, carbohydrate, energy, calcium, phosphorus, iron and zinc content of the developed composite probiotic functional mix were found to be 18.10 g, 5.70 g, 3.47g, 58.77 g, 359 Kcal, 107.10 mg, 343.22 mg, 5.66 mg and 2.03 mg per 100 mg respectively (Shilpa *et al.*, 2015)

Bafna *et al.* (2020) formulated a nutrient dense bhakri (a local snack) instant mix using ragi flour, bajra flour, wheat flour, flaxseeds and dry methi leaves with two variations and a basic. The basic instant mix had wheat flour of 96 % and 4 % spices (dry red chilli and garlic powder), but variations I and II contained wheat flour, ragi flour, bajra flour, flaxseeds and dried methi leaves in the ratio of 55:18:18:4:1 and 37:27:27:4:1 respectively.

Malar and Narayanan (2013) developed a nutri mix with high protein (14.2 g), fat (6.6 g), energy (455 Kcal), crude fibre (1.2 g), carbohydrate (76.3 g), calcium (124.0 mg), phosphorus (368.0 mg), and iron content, by combining pearl millet, finger millet, and barnyard millet (6 mg).

Gayatri and Agarwal (2016) prepared a diabetic- friendly antihyperglycemic and antihyperlipidemic nutri mix and incorporated the created nutri mix into highly acceptable of goods such as idly, chapatti, soup, and curry which resulted in highly acceptable results.

Dhanesh *et al.* (2018) developed five value added products by incorporating defatted peanut cake flour (DPF) along with powdered green leafy vegetables (GLV) namely, *Matthi, Seviyan, Pinni, Panjiri and Biscuits*. Results revealed that matthi, seviyan and biscuits were acceptable with a level of incorporation at 10% DPF and 1.5 % GLV, while 15 % DPF and 2% GLV were found to be the acceptable for *pinni and panjiri*.

Yusufu *et al.* (2013) combined sorghum flour, African yam bean flour and mango mesocarp flour to provide supplementary meals. These flours were blended in the following proportion: 5:3:2. Traditional weaning food flour obtained from 100 percent sorghum was

used as the control sample. The result revealed that this complementary food flour formulation had good overall acceptability.

Sowjanya and Manjula (2016), developed an instant nutri mix with dehydrated green leafy vegetables. Ragi, wheat, pepper, dehydrated drum stick leaves and spinach leaves. The dosa prepared from the mix provided energy (310.54 Kcal), carbohydrate (45.47 g), protein (7.73 g), fat (1.46 g) and iron (3.09).

Krishnaja and Ukkuru, 2016 developed a functional food supplement (FFS) using locally available food items, the constituents for the FFS contained barley, ragi, banana, defatted soy flour, drumstick leaves and mushrooms. Fermentation followed by dehydration was the processing technique applied to standardize the FFS. The result of the analysis revealed 48.33 ± 2.08 mg of poly phenols, 5.75 ±
0.25mg of Tannins, 1.2 percent of flavonoids and 93.5 ±3.61 mg of phytates. The energy (378 kcal), protein (16.5 g), carbohydrates (39 g) and dietary fiber content (3.3 g), were more suitable for management of lifestyle diseases.

Lakshmi (2011) prepared a tempeh flour mix using green gram, cowpea, soybean, rice and wheat. The prepared mix provided protein (43.15 g), fat (20.87 g), calcium (331.25 mg), iron (8.03 mg), phosphorus (601.36 mg) and zinc (4.82 mg).

Rajeshwari *et al.* (2016) investigated the effect of partial replacement of wheat flour with different levels of carrot powder (10 and 20%) jackfruit powder (25 and 50%) and aonla powder (10, and 20%) on the color, nutritional and sensory characteristics of the sweet biscuits.

Meka *et al.* (2019) standardized non- wheat, composite flour using yellow maize (YM), soybeans (SB) and jackfruit seed (JF). The control was 80:20, sample A- 75:20:5, sample B- 70:20:10, sample C- 65:20:15, sample D- 60:20:20, and sample E- 55:20:25. The results showed that all the vitamins increased with corresponding increase in the level of yellow maize flour.

Surekha *et al.* (2020) made low glycaemic index noodles from barnyard millet flour by combaining sago flour, pulse flour, bengal gram and dried green leafy vegetables and

found that incorporation of millets boosted the nutritional value. A Foxtail millet based multi grain extruded food product was developed by using foxtail millet flour, rice flour, chick pea flour and flax seed flour. The result revealed that the product had excellent nutritional profile as well as sensory qualities (Geetha *et al*., 2020).

Finger millet and refined wheat flour were combined in a sorghum flourbased functional biscuit, that contained high levels of protein (14 g) and crude fibre (1.88 g) (Kumar *et al.*, 2015). Deshmukh and Yenag (2016) prepared a composite flour bread with the main ingredients being millet and wheat flour. The protein, carbohydrates, vitamins, and minerals in the composite flour bread were all significantly higher amounts.

2.4.2. Novel convenient foods based on jack fruit flour

Kumar *et al.* (2012) used hot air oven drying and freeze-drying procedures to standardize jackfruit powder. The raw jackfruit was sliced, dried in a hot air oven dryer, powdered, and packaged. The nutritional content of freeze-dried jackfruit powder was higher than that of hot air oven dried powder. Feili (2013), developed high fiber jack fruit rind powder that was used as a supplement/additive in foods to help preventing constipation

Pau *et al*. (2018) formulated drum dried jackfruit powder with soy lecithin and gum arabic concentrations. The result revealed that raw jack fruit puree incorporations with 2.65 per cent soy lecithin and 10.28 per cent gum arabic was suitable for the production of good quality jack fruit flour. Subburamu *et al.* (2002) prepared a meal from the jackfruit central core and estimated its carbohydrate (20.5%), crude protein (10.6%), and crude fibre (15.9%) compositions.

Jack fruit seed flour was prepared by blanching and drying of seeds which revealed inactivated anti- nutritional factors. The jack fruit seed flour could be used for making chapathis by mixing with wheat flour (Sharma *et al.*, 2009).

Veena *et al.* (2015) developed noodles from raw jackfruit bulb flour and raw jackfruit seeds, which revealed seed flour and refined flour in different proportion of 40:30:30, 50:25:25, 50:30:20, 50:40:10, 50:10:40 and 50;20;30 these formulations were

extruded. The study reported that when compared to control samples, the treatments had more protein, fiber, and minerals and less energy and carbohydrate.

Tharani (2018) prepared jack fruit rind based papad and crispies with rice flour, jack fruit rind flour and black gram flour respectively in the proportions 50:50;0, 50:40:10, 60:10;10, 70:20:10, 80:10:10, and control 100:0. The study showed that jackfruit rind flour had higher content of crude fiber and dietary fiber, lower carbohydrate and fat content.

Ajisha (2018) developed jackfruit based instant vermicelli payasam mix by using raw jackfruit flour and jackfruit seed flour. The jackfruit-based vermicelli formulated with 60 per cent raw jackfruit flour and 30 per cent jackfruit seed flour was highly acceptable for organoleptic and nutritional qualities.

Chakraborty *et al.* (2013) developed a nutritionally enriched breakfast cereal by utilizing jack fruit seed flour and defatted soy flour using twin- screw extrusion technology. Arpit and John (2015) carried out a study on supplementation of jackfruit seed flour, in the chocolate cake by mixing wheat flour and jackfruit seed flour in different proportions. The incorporation of 10 g jackfruit seed flour per 100 g of wheat flour resulted in an increase in the protein and ash contents and a decrease in the fat content.

Gat and Ananthanarayan (2015) reported that the nutrimental and nutraceutical properties of extrudates improved by the incorporation of jackfruit seed flour (JFSF) into the rice. The nutrimental composition of the extrudate was improved at a concentration of 70:30 (rice: JFSF) with a barrel temperature of 180 °C and a screw speed of 300 rpm. Increase in the total phenolic and flavonoid contents were reported with a decrease in the barrel temperature, and the extrudate obtained at 180 °C and 300 rpm exhibited the highest antioxidant and reducing potential.

Santos *et al.* (2011) developed cereal bars made with 30% and 40% jackfruit seed meal. It showed high fiber contents, better sensory characteristics and nutritive values, similar to those of other bars available in the market

Anila and Divakar (2018) standardized a raw jack fruit based textured vegetable protein. Jackfruit bulb flour, seed flour and gluten in varying proportions were used for the development of TVP.

2.4.2.1. Fast Dissolving Tablets from jackfruit

The oral route of drug delivery is commonly favoured because of its ease of administration. Geriatrics and children alike enjoy fast dissolving tablets (FDTs). When these tablets come into contact with saliva in the mouth, they quickly dissolve and release the medication.

Starch is the primary storage carbohydrate in plants. The global production of starch is 66.5 million tonnes per year (FAOSTAT). The industry's growing demand for starches has sparked interest in new sources of this polysaccharide, including leaves, legume seeds, and fruits. Starch may be used for thickening, gelling, and film formation. (Thomas, 2007)

According to Debijith *et al.* (2009) tablets that uses the Fat dissolving tablets (FDT) technology, dissolve or disintegrate in the mouth without the need for additional water. The Food and Drug Administration (FDA) defines the FDT formulation, as a solid dosage type containing medical substances that disintegrates rapidly, typically within seconds, when put upon the tongue. The use of super disintegrants, which provide instantaneous disintegration of the tablet, after placing on the tongue, releasing the medication into the saliva, is the basic approach in the production of FDT. Super disintegrants are used to quickly dissolve or disintegrate the fast-dissolving tablets. (Mohanachandran *et al.*, 2011)

Mupparaju *et al.* (2019) reported that the cotyledons of jackfruit seeds are moderately high in starch and protein and have medicinal potential. According to the results, the best super disintegrant is the jackfruit seed starch extracted with 0.1 percent sodium hydroxide, which is used in the preparation of fast-dissolving tablets.

Suryadevara *et al.* (2017) reported that there was a model, drug, irbesartan (IRB), an angiotensin II type receptor antagonist, made with the wet granulation technique with IPA (isopropyl alcohol) as granulating fluid was used to create IRB and FDT formulations, containing different concentrations of jackfruit starch extracts and CCS (croscarmellose

sodium). The granules had strong flow properties based on the pre-compression parameters that were evaluated. Using the USP apparatus II and 900 mL of 0.1 N HCl, in vitro dissolution tests were performed, on all prepared matrix tablets. The type of starch used as a super disintegrant, as well as the proportion of super disintegrant, have been found to have a significant impact on the dissolution parameters of different formulations. According to the results of dissolution studies, tablets made with jackfruit seed starch as the disintegrant, were found to be suitable for fast-dissolving tablet preparation.

2.5. ANTI NUTRITIONAL FACTORS PRESENT IN JACKFRUIT

Antinutritional factors are compounds or substances of natural or synthetic origin that interfere with nutrient absorption, reducing nutrient intake, digestion, and consumption, as well as producing other negative effects. Antinutrients are naturally synthesised in plants and are often associated with plant-based, raw, or vegan diets. (Gemede and Ratta, 2014).

Antinutrients are most abundant in grains, beans, legumes, and nuts, but they can also be found in the leaves, roots, and fruits of some plant varieties. Phytates, tannins, lectins, oxalates, and other antinutrients found in plant-based foods are the most common. Antinutrients in vegetables, whole grains, legumes, and nuts are only a problem if a person's diet consists entirely of raw plant foods.

2.5.1. Saponins

Saponins are non-volatile, surface-active secondary metabolites that are widely distributed in nature and are primarily found in plants. Some saponins (steroids, and triterpene glycosides) are edible, while others are poisonous. Saponins with a bitter taste are toxic at high concentrations and can interfere with nutrient absorption, by inhibiting enzymes (metabolic and digestive) and binding to nutrients like zinc. (Gemede and Ratta, 2014).

According to Vincken *et al.* (2007) saponins are secondary compounds derived from plants that are found in more than 100 families of wild and cultivated Magnoliophyta

plants. Magnoliophyta is divided into two major groups: Liliopsida and Magnoliopsida, which contain the majority of saponin-producing species

Saponins are organic compounds that have a variety of biological effects. Saponins have a potent hypocholesterolemic effect in the presence of cholesterol. (Fleck *et al.,* 2019). They can also cause hypoglycemia, as well as affect protein digestion, vitamin and mineral absorption in the gut, and lead to the development of a leaky gut.

2.5.2. Tannin

Tannins are secondary compounds found in the leaves, fruits, and bark of plants. It is a bitter, astringent polyphenolic compound found in plants, that binds or precipitates proteins and other organic compounds such as amino acids and alkaloids. Tannins range in molecular weight from 500 to more than 3000 (Timotheo and Lauer, 2018).

According to Raes *et al.* (2014) tannins reduce essential amino acids by forming reversible and irreversible tannin-protein complexes between the hydroxyl group of tannins and the carbonyl group of proteins. Tannins are heat stable and is believed to be found in food products, inhibiting the activities of trypsin, chymotrypsin, amylase, and lipase, lowering food protein content, and interfering with dietary iron absorption. (Soetan and Oyewol, 2009).

Tannins have been linked to lower feed intake, growth rate, feed production, and protein digestibility in laboratory animals. Microbial enzyme processes, including cellulose and intestinal digestion, can be suppressed if tannin levels in the diet become too high (Mueller, 2001).

2.5.3. Phytic acid

Phytates, also known as phytic acids, which are found naturally in plants. Myo-inositol-1,2, 3,4,5,6-hexakis dihydrogen phosphate, also known as phytate, is found in foods at levels ranging from 0.1 to 6.0 percent (Gupta *et al.,* 2015). Phytic acid is a secondary compound present in all plant-based foods. It is concentrated naturally in plant seeds, primarily in legumes, peanuts, cereals, and oilseeds. (Lott *et al.,* 2000).

Plant-based foods contain more phytic acids than animal-based foods, and vegetarian diets are common in developing countries, contributing to high phytic acid intake. In the small intestine and stomach, phytic acid inhibits the activity of enzymes that are needed for protein degradation. When large amounts of cerealbased foods are eaten, phytic acids impair mineral bioavailability and have a direct impact on children, pregnant and lactating women. (Hassan *et al.,* 2016)

The ability of phytate to lower blood glucose by inactivating amylase enzyme along with, lowering plasma cholesterol and levels of triglycerides and binding to zinc and thereby lowering the ratio of plasma zinc to copper are all possible beneficial effects of phytate. (Shahidi, 2007).

2.5.4. Oligosaccharides of the raffinose family

Raffinose family of oligosaccharides (RFOs), comprising of raffinose, stachyose, and verbascose, are made by adding activated galactose moieties that was donated by galactinol to sucrose. These are a group of nonreducing trisaccharide of sugars that are actively accumulated in plants during drought and dehydration. These oligosaccharides are major components in many food legumes and cause anti-nutritional activity in grain legumes. (Fredrikson *et al.,* 2002)

Raffinose family oligosaccharides (RFOs) (raffinose, stachyose, and verbascose) can cause digestive upsets in addition to indigestible starch. The galactosidase needed to severe the -1-6 linkages between the hexose monomers present in RFOs is not found in the human digestive tract. As a result, RFOs travel to the lower intestine, where they are metabolised by enteric bacteria into hydrogen, methane, and carbon dioxide gas, which are expelled as flatus. (Shimelis and Rakshit, 2007)

Raffinose oligosaccharides, have recently been discovered to have a beneficial impact on the gut microflora and are thus recommended in human diets to avoid cancer in the digestive tract.

Raffinose family oligosaccharides (RFOs) can help to stabilise cell membranes during seed maturation and desiccation, as well as when the seed rehydrates during

germination. Raffinose family oligosaccharides (RFOs) enable cell membranes to enter a vitreous state, which stops diffusion and prevents deleterious reactions in the cell, after seed desiccation, when used in the right ratio with sucrose. This glass-like structure also prevents cell membranes from rupturing due to its rigidity and bulk. (Borejszo and Khan, 2001).

The jackfruit seed contains raffinose series of oligosaccharides which are not hydrolized owing to the lack of galactosidase in the upper gut. When these oligosaccharides come into the large intestine, after fermentation by intestine microflora, it will produce gas and cause flatulence. While flatulence is not dangerous, it is considered a serious issue. A buildup of gas in the rectum can result in pathological symptoms such as headaches, dizziness, and even mental illness. (Mitsou *et al.*, 2010)

2.5.4.1. Methods for removal of raffinose family oligosaccharides (RFOS)

To minimise or remove anti-nutritional factors, toxicants and unwanted components such as enzyme inhibitors and raffinose oligosaccharides, various processing methods such as dehulling, soaking, frying, steam blanching, and autoclaving have been used. Efficiency of α- galactose oligosaccharide removal has improved by extending the soaking time, changing the soaking medium, and raising the processing temperature. In general, soaking for longer periods of time, yields better results. The reduction of oligosaccharides was greater with salt solution soaking than with distilled water soaking.

2.5.4.1.1. Soaking and Boiling

Mulimani *et al.* (2007) reported that, while soaking in distilled water does not result in a substantial reduction in the levels of raffinose family oligosaccharides, decanting soaking water at intervals can increase removal efficiency during the same soaking period.

According to Ibrahim *et al.* (2002), by soaking in alkaline water ($NaHCO_3$ concentration of 0.03%) raffinose family oligosaccharides (RFOs)of cowpea seeds reduced by more than 80% after 16 hours.

An experiment conducted by Kon (2003) reported that, the rate of water uptake and the percentage of oligosaccharides extracted from small white californian beans increased as the temperature of the soaking water was raised. Beans soaked in water at 20 degrees Celsius took 16 hours to achieve saturation, and only 15% of the stachyose and raffinose content of the beans were extracted into the soaking water during that time. Beans soaked in 90°C water, took just 50 minutes to achieve saturation, resulting in the extraction of 57% of the stachyose and raffinose from the beans.

At 60°C and above, the inter and intracellular membranes begin to break down, making the bean more permeable to water ingestion and solute diffusion. It was not investigated whether the mechanical disruption of these membranes caused by milling the beans into flour increases the extraction rate of RFO in a similar way.

In a study conducted by Iyer *et al.* (2006), raffinose and stachyose levels were reduced by 25-40% and 30-40%, respectively, after soaking the whole great northern, kidney, and pinto beans in water at 22°C for 18 hours. Raffinose was reduced by 80-90 percent and stachyose was reduced by 70-80 percent after boiling the three beans for 90 minutes.

Barampama and Simard (2004) found that soaking *phaseolus vulgaris* seeds for 12 hours and then boiling for an hour resulted in a 60% reduction in raffinose and a 70% reduction in stachyose, while boiling for 90 minutes resulted in a 50% reduction in raffinose and a 50% reduction in stachyose. Raffinose was reduced by 35 percent and stachyose was reduced by 30 percent after soaking for 12 hours.

Han and Baik, (2006) reported that by applying ultrasound or high hydrostatic pressure to different legumes while they were being soaked, 33.3 percent raffinose and 46.6 percent stachyose were separated from soybeans after 3 hours of soaking. Using ultrasound during the 3-hour soaking time, increased raffinose removal to 55.7 percent while reducing stachyose removal to 28.6%.

Song and Bhagya (2006) found that RFOs were reduced by 9.8% when pinto beans were soaked and then cooked for 90 minutes, while RFOs were reduced by
57.6%, when pinto beans were soaked and then cooked for 90 minutes.

2.5.4.1.2. Germination

The removal of oligosaccharides from the raffinose family can be accomplished by germination. Fialho *et al.,* 2008 investigated the effects of germination on the oligosaccharide and cyanide content of lima beans. After two days of germination, raffinose was degraded to a safe amount. The quality of raffinose family oligosaccharides in soybean seeds changed during germination (Guimaraes *et al.,* 2001).

Through de novo synthesis, activation of intrinsic phytase, or both by germination/malting boosted endogenous phytase activity in cereals, legumes, and oil seeds. Endogenous phytase activity was lower in tropical cereals like maize and sorghum than in rye, wheat, triticale, buckwheat, and barley. (Eagli *et al.,* 2002). The rate of phytate hydrolysis varied by species and cultivars, as well as germination stage, pH, moisture content, temperature (optimal range 45-570°C), phytate solubility, and the presence of inhibitors (Sandberg, 2002).

El- Hag *et al*. (2001) found during 10-day germination that, there was about 50 per cent reduction in trypsin inhibitor activity in kidney bean (P. vulgaris). According to Ramakrishnan *et al.* (2006), the raw dry Indian bean showed a very strong trypsin inhibitory activity, that gradually declined by 51per cent over the 12hour soaking phase, before reaching a level of 17 per cent of the basal level of dry seeds at 32 hours germination. Sangronis and Machado (2007) reported that after 5 days of germination, trypsin inhibitor levels in white beans, black beans, and pigeon beans were reduced by 52.5, 25.6, and 41.0 percent, respectively. The reserved compounds present in the cotyledons were used for the embryo's development and growth; hence germination is mostly a catabolic process.

According to Lopez Amoros *et al.* (2006), antioxidant activity in beans and peas increased during germination, and antioxidant activity in soybean, adzuki bean, and mung

bean increased after germination. The rise in phenolics was detected in these legumes, which could be attributable to the biochemical metabolism of seeds during germination. (Lin and Lu, 2003).

2.5.4.1.3. Hydrolysis using α -galactosidase

Alpha- galactosidase is an exoglycosidase that degrades terminal -1, 6linked-d-galactose residues from simple galactose-containing oligosaccharides like melibiose, raffinose, stachyose, verbascose, and ajugose, as well as more complex polysaccharides like galactomanns (Kapnoor and Mulimani, 2010).

The ability of endogenous alpha-galactosidase to remove specific compounds, such as raffinose oligosaccharides, is dependent on the quantity of endogenous alpha-galactosidases, which varies between beans. When soaking and heating treatment were combined, enzyme removal of phytate in white beans was successful up to 80% reduction at 60^0C (Gurtas *et al.*, 2001). Shivam and Mishra (2010) reported that the breakdown of oligosaccharides into mono- and disaccharides resulted in a decrease in raffinose family oligosaccharides after therapy with α -galactosidase. Sucrose content increased due to the hydrolysis of α -galactosidic linkages between sugar molecules. In a study conducted by Guimaraes *et al.* (2001), soymilk incubated with α - galactosidase for 8 hours at 30 degrees Celsius, reduced raffinose by 73.3 percent and stachyose by 40.6 percent.

Matella *et al.* (2015) reported that incubation of black, red, and navy beans with -galactosidase for 1 hour at 23°C reduced RFOs more effectively (30% and 50% reduction) than soaking the beans for 5 hours at 23°C (1 percent and 35 percent reduction).They also proposed a method for removing RFOs from legume flours in a commercial setting The process entailed extracting soluble sugars from ground beans with ethanol, treating the sugars with galactosidase to hydrolyse the RFOs, recovering the ethanol, and adding the reduced-RFO sugars to the bean slurry before drying and milling.

Anila and Divakar (2019) reported that when the enzyme ‘galactosidase' was mixed separately with the flour of jackfruit seed and jackfruit bulb in a ratio of 1:100, with the moisture level ranging from 25 to 200 percent (dough to batter stage), the amount of

Raffinose decreased as the moisture content increased (25100 percent). Later when, the material was slightly raised before being reduced (125 percent, 150 percent, 175 percent, 200 percent), in comparison to the control (0.97 g g-1), the overall amount of oligosaccharides decreased.

2.5.4.1.4. Extrusion and Roasting

Extrusion cooking exposes a substance to a high temperature, high pressure setting, which can induce beneficial chemical changes in the material. With a moisture content of 21.44 percent and a temperature of 157°C, extrusion of a high starch fraction of pinto bean flour resulted in a 43 percent decrease in raffinose and a 22 percent decrease in stachyose concentration. (Borejszo and Khan 2001).

According to El-Hady and Habiba (2003) the extrusion process reduced total phenolics and tannins. Extrusion processing of the raw kidney bean flour had a stronger influence on tannin removal than soaking followed by extrusion. Korus *et al.* (2007) reported that extrusion caused a reduction in the total phenolic content for several bean varieties, but caused an increase in total phenolics. Overall, literature suggests that extrusion causes slight reduction, usually less than 25 per cent, in phenolic contents of beans.

RFOs were completely removed from hyacinth beans after 2 minutes of dry roasting. A non-enzymatic browning reaction, sugar oxidation, or pyrolysis were thought to be the causes of RFO reduction. However, this procedure denaturizes a significant portion of the bean proteins, which could be suitable for certain applications (Revilleza *et al.*, 2009).

Fasina *et al.* (2001) heated various legume seeds to a surface temperature of 140°C by infrared heating and then soaking for 24 hours, which reduced raffinose concentration from 75.7 percent to 84.4 percent, compared to soaking alone, which reduced it from 20.8 percent to 67.1 percent. The authors also observed small increases in the rate of water absorption for the infrared-treated seeds, which they attributed to cracking

of the seeds allowing water access to the inner regions of the seeds, as well as higher leaching rates of RFOs and other solutes.

In the present study an effort has been taken to explore the quality evaluation of a jackfruit based nutri flour comprised of the most of the edible parts of jackfruit. Though the different parts of jackfruit cultivars have been used widely, there is no affirming data to recommend these jackfruit cultivars to the diabetic population.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled “Development and quality evaluation of a jackfruit based nutri flour” was conducted as four experiments and the methodology adopted is discussed under the following heads.

3.1. Determination of Glycemic Index of jackfruit parts

3.2. Development of nutri flour

3.3. Quality evaluation of nutri flour

3.4. Quality improvement of nutri flour

3.5. Assessment of in vitro therapeutic efficacy of nutri flour

3.1. DETERMINATION OF GLYCAEMIC INDEX OF JACKFRUIT PARTS

3.1.1. Selection and collection of jackfruits

Artocarpus heterophyllus Lam., commonly known as jackfruit, is a medium sized evergreen tree that bears high yields of the “largest” known edible fruit. This fruit is the gigantic syncarp and is known as the largest fruit of the world.

Jackfruit cultivars “*koozha*” and “*varikka*” were selected for the study. Raw jackfruits were harvested from the trees grown in the Instructional farm, College of Agriculture vellayani. The raw fruits were taken with 12-week maturity, along with the manifestations, such as flattening of spines, colour change from green to pale green, hollow sound and last leaf in the stalk turning **yellow.**

3.1.2. Cleaning and recording weight

Whole weight of jackfruits cv *koozha* and cv *varikka*, were taken. As the fruits were big in size, they were cut into big pieces; the bulbs, perigones, seeds, rind, core and testa were separated out. Jackfruit parts were first cleaned under running water and were then cleaned with distilled water. The percentage components, fresh weight, dry weight, processing loss and dry matter percentage, were recorded.

Fresh weight

Fresh weight of the jackfruit parts were noted independently by taking the fresh weight of the parts separately (bulbs, seeds, perigones, testa, rind and core) before dehydration.

Dry weight

Dry weight of each of the jackfruit parts were noted independently after dehydration at 65^0c.

Percentage composition

Percentage composition of fresh weight jackfruit parts was calculated by the formula

$$\text{Percentage components} = \frac{Fresh\ weight\ of\ jackfruit\ parts}{whole\ weight\ of\ fruit} \times 100$$

Yield ratio of components

Yield ratio of components of jackfruit parts was calculated by the formula

$$\text{Yield ratio of components} = \frac{\text{Dry weight of jackfruit parts}}{\text{Whole weight of fruit}} \text{ X } 100$$

Moisture percentage

Moisture percentage of the jackfruit parts were calculated by the formula

$$\text{Moisture percentage} = \frac{Fresh\ weight - Dry\ weight}{Fresh\ weight\ of\ parts} \text{ X } 100$$

Processing loss

Processing loss is an economic characteristic to understand the actual edible entity produced from the raw material after the wastage is accounted. Processing loss of jackfruit was calculated by the formula

$$\text{Processing loss} = \frac{\text{Whole weight of fruit - Dry weight of each part}}{\text{Whole weight of fruit}} \times 100$$

Dry matter percentage

Dry matter percentage of jackfruit parts were calculated by the formula

$$\text{Dry matter percentage} = \frac{\text{Dry weight of fruit parts}}{\text{Fresh weight fruit parts}} \times 100$$

3.1.3. Glycemic index (GI) and Glycemic load (GL) of jackfruit parts

Different carbohydrate (CHO) foods produce different blood glucose response. Jenkins *et al.* (1981) developed the concept of GI to classify CHO. The GI classifies foods based on the postprandial glycemic response, following consumption of that food. Post-prandial glycemia is influenced by both the amount and the type of carbohydrates in the foods. The nature of carbohydrates is best described by their glycemic indices (GIs) (WHO, 2010).

By convenient sampling, ten healthy adult volunteers, comprising 5 females and 5 males in the age group of 18 to 45years and BMI below 25 kgm^2, who were non-diabetic, non-smokers and not on any medication were selected. The subjects were requested to maintain their usual daily food intake and activity throughout the study period. The purpose and protocol of the study were explained to the subjects and a written consent was collected from them (Appendix. 1). They were asked to assemble on a fixed day with empty stomach in the early morning. Then fifty grams of glucose was diluted in 150 ml of water and given

to them for drinking. The blood glucose levels at fasting state and thereafter, followed by administration of glucose, at 30, 60, 90 and 120 minutes were determined. The study was carried out from the following day with the same volunteers. They were fed with the separated parts of bulbs, perigones, seeds, rind, core and testa on consecutive days. These parts were cooked with minimum embellishments and their quantity to feed was arrived at after determining the carbohydrate content. The blood glucose levels were also determined as given above and recorded. Blood glucose curve and the incremental area under the curve (IAUC) were calculated by the trapezoidal rule (Gibaldi and Perrier, 1982).

Calculation of Glycemic Index (GI)

Glycemic index was calculated by dividing the IAUC of the test food by the IAUC of the reference food multiplied by 100 for each individual using the following formula (Wolever *et al.,* 2003).

$$GI = \frac{\text{Incremental area of the test food}}{\text{Incremental area of the glucose}} \times 100$$

The average GI of the ten individuals was taken as the GI of a test food.

Classification of foods based on GI

The glycemic index of the food is generally categorized into the following three on the basis of their GI values.

- High GI (70-100) Carbohydrates which break down quickly during digestion, releasing blood sugar rapidly into the blood stream causing marked fluctuation in blood sugar levels.

- Medium GI (56-69) Carbohydrates which breakdown moderately during digestion, releasing blood sugar moderately into the blood stream.

• Low GI (0-55) Carbohydrates which break down slowly during digestion, releasing blood sugar gradually into the blood stream, keeping blood sugar levels steady (Dona *et al.* (2010).

Glycemic load (GL)

Glycemic load accounts for how much of carbohydrate is in the food and how each gram of carbohydrate in the food raises blood glucose levels. Glycemic load is classified as: low (< 10), intermediate (11-19) and high (> 20).

$$\text{Glycemic load (GL)} = \frac{\text{GI x available carbohydrate(g)}}{100}$$

Available carbohydrate = total carbohydrate - dietary fiber (Das *et al.*, 2007).

3.1.3.1. Statistical Design and details of treatments

Experimental design: Completely randomized design (CRD), One way ANOVA.

Number of Treatments - 12

Number of Respondents - 10

Cultivars

T_1 - T_6 - cv *Koozha ;* T_7 - T_{12} - cv *Varikka*

Edible Portion

T1 & T7 - Bulbs

T2 & T8 - Seeds

T3 & T9 - Perigones

T4 & T10 - Testa

T5 & T11 - Rind

T6 & T12 - Core

3.2. DEVELOPMENT OF NUTRI- FLOUR

Nutri- flour formulations were made based on the results of experiment 3.1.

3.2.1. Preliminary processing.

The bulbs, perigones, seeds, rind, core and testa were separated from the jackfruit and weight of each fruit parts were recorded. As the fruits contain sticky latex, small quantity of vegetable oil was applied on hands before separating the bulbs. The white arils or seed coat were peeled off manually. The spermoderm layer was also removed manually. All parts were washed under tap water to remove dust and dirt. The raw material was cut in dimensions of 2.5 x 1 cm. All jackfruit parts were subjected to thermal treatment to inactivate antinutritional factors present in it. Then the blanched slices were dried at 65^0 C in the electric drier for 6-7 hours. Proper care was given to avoid the cross contamination from other foreign particles.
After drying, the dry weight of each part of jackfruit was recorded.

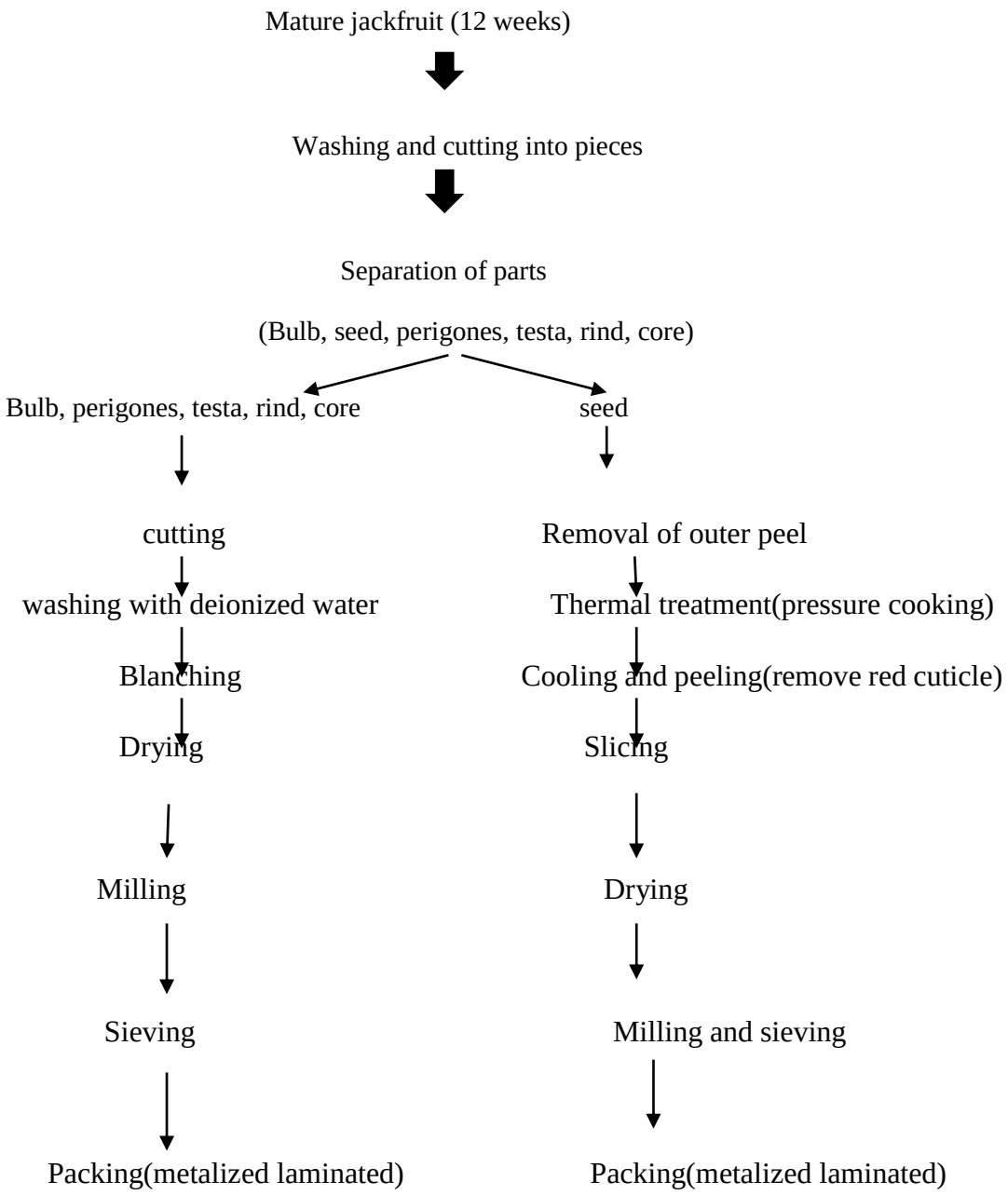
Milling and packing

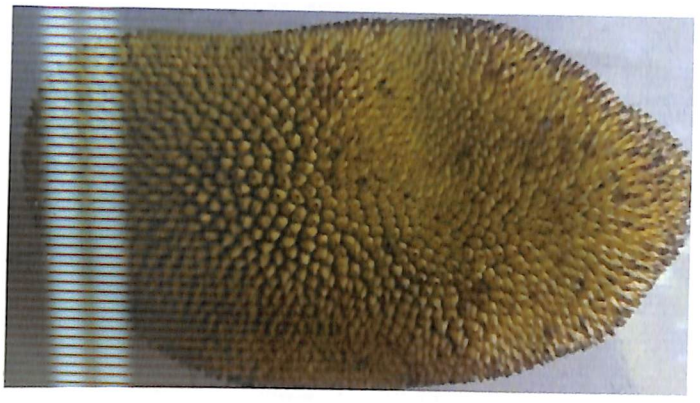
The dried jackfruit parts were milled into fine flours separately. The flours were sieved through a 0.05 mm sieve and packed in metalised laminated and highdensity polyethylene (HDPE) covers for further analysis.

3.2.2. Formulations for the nutri flour

Totally, the twelve different parts of jackfruit cultivars (*koozha* and *varikka*) were used for preparing jackfruit-based nutri flour. The bulbs, perigones, seeds, rind, core and testa of each cultivars were used. Nutri- flour formulations were made based on the results of experiment 3.1. (GI and GL values). The major component (50-60%) of flour was contributed from the fruit parts with low glycaemic index and 40 percent was formed by other components in different proportions. The flours of all jackfruit parts were processed separately after pre-treatments and combined into ten formulations (F_1 to F_{10}), the control formulation (F_{11}) comprised of 50% *Koozha* jackfruit bulb flour and 50% *Varikka* jackfruit bulb flour was also used for comparison given in Table. 27.

Figure.1. Flow diagram for preparation of jackfruit flour



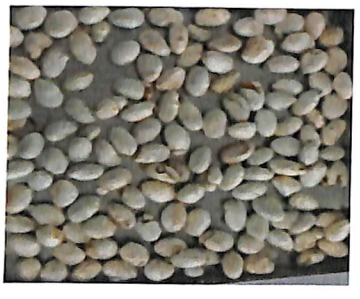


Jackfruit bulbs

Fresh

Dried

Jackfruit seeds



Fresh

Dried

Jackfruit Perigones

Plate 1. Jackfruit parts

Jackfruit Testa

Fresh

Dried

Jackfruit Rind

Fresh

Dried

Jackfruit Core

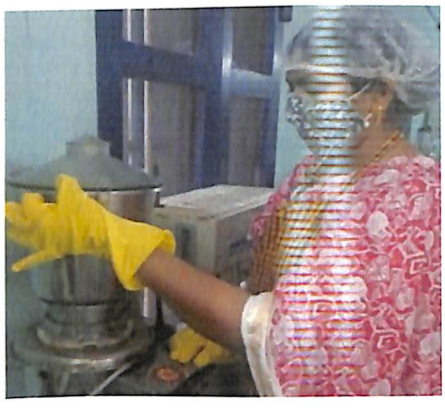
Fresh

Dried

Plate 2. Jackfruit parts

Blanching

Drying



Milling

Packing

Plate 3. Processing of nutri flour

3.2.3. Acceptability of the nutri flour combinations

The formulations were packed separately and each of them were utilized for product preparation.

Selection of judges for acceptability studies

Organoleptic evaluation was performed by semi trained panelists after considering their performance test for recognition of basic tastes and aroma. The panel comprised of ten members aged between 20-35 years as suggested by Jellinek (1985).

Preparation of the product

The formulations were evaluated for their organoleptic qualities by processing them into three commonly consumed popular breakfast dishes like “puttu”, “ada” and “oratti”.

Preparation of ‘Puttu’

Nutri flour ‘puttu’ was prepared using 100g of nutri flour, 70 ml of water and 2g of salt; Nutri flour was mixed with salt and water was added in batches and blended thoroughly, to make a moist flour with crumbly texture. The nutri flour puttu was steamed with layers of grated coconut which totalled 1 table spoon.

Preparation of ‘Ada’

Hundred grams of nutri flour, 2g of salt and 95 ml of hot water was mixed in a bowl and knead into a soft dough. A portion of dough was spread on flamed banana leaf and flattened. A table spoon of grated coconut was placed in the center of the dough. The banana leaf was then folded and steamed for 10 minutes.

Preparation of ‘Oratti’

Hundred grams of jackfruit-based nutri flour was mixed with 1 table spoon of grated coconut, ½ teaspoon cumin seeds, 15 gm chopped onions, 1 gm green chilli and 120 ml water. Oratti was made on a hot greased tawa by spreading the dough manually into rounds.

Preparation of score card

Score cards were prepared on a 9-point hedonic rating. The score card for sensory evaluation comprised of the sensory attributes – appearance, colour, aroma, taste, texture and overall acceptability. These were rated as scores ranging from 19 as described by Sudha *et al.* (2011).

The 9-point hedonic rating was performed for evaluating the most acceptable formulations from the three products; 9 representing "like extremely" and 1 representing "dislike extremely" and this is given into Appendix 2.

Organoleptic evaluation

Organoleptic quality is one of the most important criteria that determines the acceptability of any food product by the consumer. The sensory properties of the developed jackfruit-based nutri flour powder was carried out in the morning (10 AM) using score cards based on a nine-point hedonic rating scale by a panel of selected 10 judges. The quality attributes namely appearance, colour, aroma, texture, taste and overall acceptability were evaluated.

3.2.4. Selection of the most acceptable variation in each treatment

The best formulation of nutri flour composition was selected based on the acceptability scores by applying using Kruskal- Wallis test.

3.3. QUALITY EVALUATION OF THE NUTRI FLOUR

Quality aspects such as functional properties, chemical constitution, nutritional profile, nutraceutical composition and shelf-life studies were assessed in the best treatment.

3.3.1. Functional properties of the nutri flour

Functional properties are the fundamental physico- chemical properties that reflect the complex interaction between the composition, structure, molecular conformation and physico-chemical properties of food components, together with the nature of environment,

in which these are associated and measured (Kinsella, 1976). Functional properties such as swelling power, solubility, water absorption capacity and bulk density were estimated.

Swelling power

Swelling power and solubility were carried out in the temperature range of 55-95^{0}C using the method of Leach *et al.* (1959). 0.1 g of samples were accurately weighed and quantitatively transferred into a clear dried test tube and weighed (W1); 10 cm^3 of distilled water was added to the test tube and the mixture was mixed thoroughly with a variwhirl mixer for 30 seconds. The resultant slurries were heated at a temperature that varied between 55^{0}C and 95^{0}C for 30 minutes in a water bath (using temperature regulated water bath). The mixture was cooled to room temperature and centrifuged (5000 rpm, for15min). The residue obtained (after centrifuge) with water was retained and test tube was weighed (W2).

$$\text{Swelling power (g)} = \frac{W_2 - W_1}{\text{Weight of sample}}$$

Solubility

A known volume of nutri flour (1gm) and distilled water (10ml) was heated at 80^{0}C.The resulting product mixture was centrifuged and the supernatant was taken into a pre- weighed petri dish and evaporated for 2h at 130^0 C and then weighed. The residue obtained after drying of supernatant represented the amount of flour solubilized in water (Oladele and Aina, 2011). Formula used for calculating solubility was

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

Water absorption capacity

One gram sample was mixed with 10ml of distilled water for 30 minutes. The contents were allowed to stand at 30^0C in a water bath for 30 minutes and then centrifuged at 3000-5000rpm for 20-30 minutes. After centrifuging, the volume of the supernatant was recorded, which was used for determination of water absorption and the result was expressed as g/g sample (Rosario and Flores,1981). Formula used for calculating water absorption capacity was

$$\text{Water absorption capacity (\%)} = \frac{\text{Weight of water absorbed (g)}}{\text{Weight of dry sample}} \times 100$$

Bulk density

Ten ml capacity graduated cylinder was filled with the sample. This was done by gently tapping the bottom of the cylinder on the laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Formula used for calculating bulk density was

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (ml)}}$$

3.3.2. Chemical and nutritional profile of nutri flour

In the present study macro and micro nutrients, present in nutri flour was determined. Levels of total carbohydrate, protein, dietary fibre and moisture were estimated. Total minerals, calcium, phosphorus, sodium, potassium, iron, magnesium, copper and zinc were also ascertained. Nutraceutical composition of phenol, phytic acid, tannin, β carotene, antioxidants were also estimated. Shelf-life studies were conducted through sensory and microbial profile.

Proximate Composition

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

Total carbohydrate

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 carbohydrate of nutri flour was 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).

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 also provide energy for the body.

Nutri flour (0.3g) was digested with 6ml of Con: H_2SO_4 after adding 0.4g of $CUSO_4$ and 3.5g K_2SO_4 in a digestion flask until colour of the sample was converted to green. After digestion, it was diluted with water and 25ml of 40 percent NaOH was added into it. This distillate was collected in 20 per cent boric acid containing mixed indicator and then titrated with 0.2N HCl. The nitrogen content obtained was multiplied with a factor of 6.25 to get the protein content and expressed in percentage (AOAC, 2000).

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 nutri flour was determined according to AACC method (2000). Two grams of nutri flour was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. The filtration was repeated through muslin cloth followed by washing with sulphuric acid, water and alcohol in a sequential manner. The residue was transferred to a pre- weighed washing dish. The residue was then ignited for 30 minutes in a muffle.

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) and expressed in g $100g^{-1}$. This method measures the weight lost by foods due to evaporation of water. About 5 g of the sample was weighed into 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 desiccator and weighed, the process was repeated at 30 minutes intervals until the difference between two consecutive weights was less than one milli gram.

Mineral content

Total Minerals

Five grams of the sample was 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 55^0+100^0C till grey ash was formed. The contents were cooled in desiccator and weighed. The process of heating in the muffle furnace, cooling and weighing was repeated at 30 minutes intervals, till constant weight was achieved (Sadasivam and Manickam, 1992).

Wet digestion method was used for analysing minerals like P, Ca, Cu, Fe, Ma, K, Na, and Zn. The biological materials were oxidized with diacid (HNO_3HClO_4 mixture in the ratio of 4:1). The acids were partially removed by volatilization whereas the soluble mineral constituents remained dissolved in nitric acid.

Potassium

The method suggested by Jackson and Herrington (1973) was followed for analysing the potassium content of nutri flour using the flame photometer.

One gram of the digested solution was made up to 25 ml and read directly in a flame photometer. The potassium content was expressed in mg per 100 gm of the sample.

Calcium

Calcium was estimated by titration method with EDTA as suggested by Hesse (1971). The calcium content in nutri flour was estimated using Ethylene Diamine Tetra Acetic Acid (EDTA) titration method, after wet digestion of the samples using di - acid mixture and expressed as mg 100 g^{-1}

Phosphorus

The phosphorus content in nutri flour was estimated by Spectronic 20 (AOAC, 2005).

Determination of phosphorus was carried out by measuring calorimetrically the blue colour formed when the ash solution was treated with ammonium molybdate and thus phosphomolybdate formed was reduced.

Sodium

Sodium is an element important for fluid distribution, maintaining blood pressure, cellular work and electrical activity in the body.

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

Iron

Iron was estimated by atomic absorption spectrophotometric method, using the diacid extract prepared from the sample (Page *et al.,* 1992) and the result was expressed in mg per 100 grams of sample.

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.

Manganese

The manganese content was estimated by using atomic absorption spectrophotometer by Dithizone method (AOAC, 2005).

Copper

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).

Zinc

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

3.3.3 Nutraceutical composition

Phenols

The phenols of nutri flour were estimated by using the method described by Sadasivam and Manickam (1992).

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.

Phytic acid

The estimation of phytic acid is based on the principle that the phytate is extracted with trichloroacetic acid and precipitated as ferric salt. The iron content of the precipitate is determined calorimetrically and the phytate phosphorus content was calculated from this value assuming a constant 4 Fe: 6 P molecular ratios in the precipitate (Sadasivam and Manickam, 1992).

Tannin

Tannin like compounds reduce phosphotungstomolybdic acid in alkaline solution to produce a highly coloured solution, the intensity of which is proportional to the amount of tannins (Sadasivam and Manickam, 1992). A blank was prepared with water instead of the sample.

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. Standard curve of tannic acid was used to estimate water soluble tannins and it was expressed as gram per g^{-1} of dry weight.

β carotene

β carotene was estimated by the method of Sadasivam and Manickam (2008), 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.

Antioxidants

Total antioxidant activity was determined using 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. 0.1 ml of 0.02 M Fe Cl_2 in 3.5% (w/v) and HCl were added to the reaction mixture, after 3 minutes and the absorbance of red colour was measured at
500 nm. The inhibition of lipid peroxidation in % was calculated as; inhibition % = [(A0 – A1)/A0 X 100]

3.3.4. Shelf-life Studies of nutri flour

The selected nutri flour formulation was packed in metalized laminated pouches and was stored for a period of six months at ambient conditions. For comparison, plain jackfruit bulb flour (control) was also packed in a similar package and analysed for moisture content. Quality evaluation of the product and microbial profile was conducted at monthly intervals.

Moisture

Moisture content was estimated by the method of AOAC (1990).

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 v) medium were used for microbial analysis. Ten grams of the flour 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}, 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 dish 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 flour was expressed as cfu/g of the product.

Sensory profile

Judges were selected for acceptability studies as described in 3.2.3. The treatments were rated by ranking the scores of various characteristics namely appearance, colour, flavour, texture and overall acceptability using score cards based on 9-point hedonic scale (Appendix.2). The scores of the sensory panel were analysed and ranks recorded. Their quality was analysed initially and repeatedly on a monthly basis up to six months.

3.4. QUALITY IMPROVEMENT OF NUTRI FLOUR

The main deleterious effect of jackfruit consumption is its low digestibility and flatulence factors, caused by the presence of oligosaccharides.

Oligosaccharides

Jackfruit seed contains several oligosaccharides such as raffinose and stachyose, which can cause flatulence for humans, and these substances also create a darker color during flour processing (Setiawan, 2016). In this study, HPLC method was used for estimating oligosaccharide content of the jackfruit based nutri flour. The level of stachyose, glucose, mannose, rhamnose and arabinnise were ascertained being the prominent member of the oligosaccharide family.

3.4.1. Treatment with *Saccharomyces cerevisiae*

As a part of reducing the antinutrients in jackfruit, fermentation with *Saccharomyces cerevisiae* was adopted.

To reduce the level of oligosaccharides, flours were made into batter and subjected to fermentation with *Saccharomyces cerevisiae* @ 5g/kg for 8 hrs (Krishnaja, 2014 and Anila, 2018). The level of oligosaccharides were then compared with that of control.

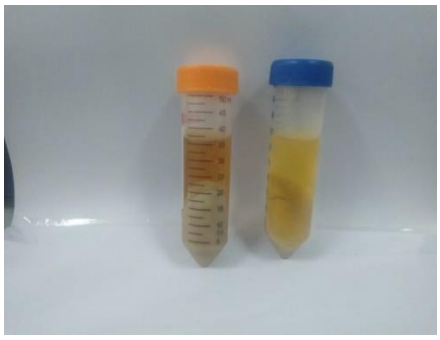
Quality comparison of untreated and treated flour

The treated and untreated flour was tested for the breakdown of oligosaccharides.

HPLC estimation of Oligosaccharides

The breakdown of Oligosaccharides presents in the jackfruit based nutri flour (untreated and yeast treated) were analysed through High-performance liquid chromatography (HPLC) analysis.

The reference sugars were: stachyose (purity 98%), D-(+)-glucose (purity > 99.5%), fructose (purity 98%) and D-(+)-galactose (purity > 99%), rhamnose (purity 98%) and D-arabinose (purity 99%); which were procured from Sigma – Aldrich Chemie GmbH (Aldrich Division; Steinheim, Federal Republic of Germany). HPLC-grade water.



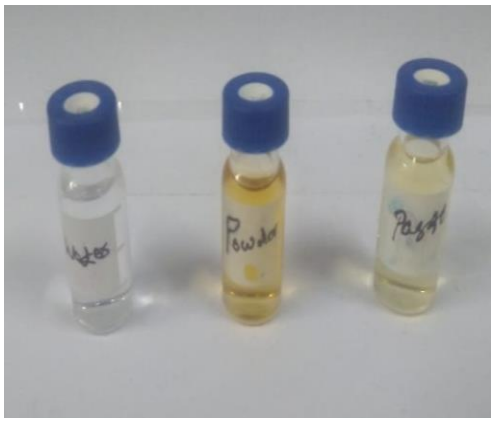


Plate 4. HPLC instrumentation setup for analysing of oligosaccharides

Extraction of sample and HPLC analysis

One gram each of untreated and treated nutri flour were weighed into a container having 10 mL of Milli Q water. The mixture was vortexed for 5 min, followed by centrifugation at 4°C at 10,000 rpm for 15 minutes. The supernatant was then passed through a 0.2 µm nylon membrane filter. Sample aliquots of 10 µl, were injected for HPLC analysis.

Sugars were identified by comparing the retention times shown in the peaks of the chromatographed samples with those of authentic sugar samples. Calibration curves were prepared for each sugar in concentrations ranging from 1 to 10 mg/mL. Quantification of the sugars present in the untreated and treated nutri flour was obtained from the measured peak areas and the corresponding standard curves.

The analysis was performed on a prominence UFLC system containing LC20AD system controller, Rezex RHM-Monosaccharide H+ (300 ×7.8mm), a column oven (CTO-20A), an auto sampler injector (SIL-20AC HT) and a RID detector (RID 10A). The mobile phase used was 100% milli Q water with a run time of 20min. The injection volume was 10µL, and the flow rate was kept at 0.8mL/min. The column was maintained at 80°C. Sample peaks were identified by comparing with retention times of standard peaks. LC Lab solutions software was used for data acquisition and analysis (plate 4).

Invitro Starch digestibility (IVSD) of flour

Starch digestibility was estimated as suggested by Satterlee *et al.* (1979). One gram of the sample in 100 ml water was gelatinised and boiled for one-hour and filtered. One ml of the gelatinised solution was taken and one ml of enzyme solution of saliva diluted with equal quantity of water was added. The mixture was incubated at 37^0c for 1-2 hours. The reaction was stopped by adding one ml of sodium hydroxide and later glucose was estimated by the method of Somoygi (1952).

$$\text{IVSD} = \frac{\text{mg of glucose (Nelson's method)}}{\text{Mg of starch}} \times 100$$

3.5. ASSESSMENT OF INVITRO THERAPEUTIC EFFICACY OF NUTRI FLOUR

Medicinal plants or their extracts have been used by humans since time immemorial for different ailments and have provided valuable drugs such as analgesics (morphine), antitussives (codeine), antihypertensives (reserpine), cardiotonic (digoxin), antineoplastics etc. In the present study invitro therapeutic efficacy of jackfruit nutri flour for its anti-diabetic, hypolipidemic and hepatoprotective activity of nutri flours were analysed.

3.5.1. Extraction procedurs Extraction with Petroleum Ether

The jackfruit-based nutri flour was placed in a 'thimble' made of strong filter paper in a chamber of soxhlet (2000ml). The powder was extracted for 72-hrs at 55℃ petroleum ether as the solvent. After completion of extraction petroleum ether was filtered, dry mass was concentrated, extract was air dried to remove all traces of the solvent and the percentage yield was calculated.

Extraction with Ethanol

The nutri flour was subjected to solvent extraction using Soxhlet apparatus. The solvent was heated using the isomantle and evaporated. For ethanol extraction the temperature used was 78℃. The extraction was done for 18-20 hrs and after completion of extraction, the solution was evaporated to dryness under reduced pressure and controlled temperature by using rotary evaporator

Extraction with Distilled water

The nutri flour after extraction with ethanol was placed in a stopper container with the distilled water (1176ml) and chloroform (24ml) and allowed to stand at room temperature for a period of 7 days with frequent agitation until the soluble matter was dissolved. Then the mixture was strained and the combined liquids were clarified by filtration. At last, the solution was dried using a rotary evaporator. The extracts were

concentrated under reduced pressure (bath temperature 50□C). The dried extracts were stored in air tight containers in the refrigerator.

3.5.1.1. Anti-diabetic activity of nutri flour

The α-glucosidase and α- amylase enzyme inhibition activity was used for analysing anti-diabetic activity of the nutri flour (Shai *et al.*, 2011).

3.5.1.1.a. In vitro α- Amylase inhibition Assay

The α- amylase inhibitory activity was determined according to the method described by Jyothi and Sreelakshmi (2011). The total assay mixture containing 200□L of 0.02 M sodium phosphate buffer (pH 6.9 with 0.006 M NaCl) containing

0.5 mg/mL of □- amylase enzyme in different concentrations (in µg) of the test sample were pre-incubated at 37ºC for 10 min. After the pre-incubation, 200 µL of a 1% starch solution in 0.02 M sodium phosphate buffer (pH 6.9) was added to each tube and incubated at room temperature for 5 mins. The reaction was stopped using 1.0 mL of di nitro salicylic acid (DNSA) reagent. The test tubes were incubated in water bath, with boiling water for 5 min and then cooled to room temperature. The volume of the reaction mixture was made up to 10mL by adding distilled water, and the absorbance was measured at 540 nm using UV-Visible spectrophotometer. The control samples were also prepared accordingly without any plant extracts and were compared with the test samples containing various concentrations of plant extracts prepared with different solvents of DMSO. The result was expressed as % inhibition, which was calculated using the formula;

Inhibition activity (%) = (B-A/B-C) ×100

A- Absorbance of the Test sample

B- Absorbance of the Control with starch and alpha amylase

C- Absorbance of the Control with starch and without alpha amylase

3.5.1.1.b. In vitro α- Glucosidase Inhibition Assay

The effect of the sample for α-glucosidase activity was determined according to the method described by Shai *et al.* (2011) with suitable modification.

400 µL of α-glucosidase (0.067 U/mL) was preincubated with different concentrations of the sample for 30 min. Then 200 µL of 3.0 mM (PNPG) was used as substrate and dissolved in 0.1M sodium phosphate buffer (pH 6.9) which was then added to start the reaction. The reaction mixture was incubated at 37°C for

30 min and stopped by adding 2 mL of 0.1 M Na_2CO_3. The α-glucosidase activity was determined by measuring the yellow-colored para- nitro phenol released from

PNPG at 400 nm. The results were expressed as percentage of inhibition. The same procedure was done with acarbose (1mg/ml stock) which was used as standard.

Inhibitory activity (%) = (B-T/B-C) ×100

B - Absorbance of blank.

T - Absorbance in the presence of test substance.

C - Absorbance of control.

3.5.2. Hypolipidemic activity of nutri flour

The petroleum, ethanol and distilled water extract of nutri flours were tested *in-vitro* for the hypolipidemic activity. The activity of HMG-CoA was assayed and the decrease in absorption of NADPH and NADP was measured at 340 nm. Fenofibrate was used as standard (Zhang *et al.,* 2006).

$$\% \text{ of inhibition} = \frac{\text{Control value} - \text{test value}}{\text{Control value}} \times 100$$

3.5.3. Hepatoprotective activity

The hepatoprotective activity of the test samples were evaluated using

$HepG_2$ cell lines. HepG2 cells were cultured in a growth media (DMEM + 10% FBS) at a density

of 5×10^4 cells/well in a 96-well tissue culture plate and incubated overnight. Post incubation, cells were treated with varying concentrations of the test samples (25, 50, 100 µg/ml) and incubated for 24 hrs, thereafter; IC_{50} concentration of H_2O_2 was estimated (30 µg was added and allowed for further 24 hrs incubation. Post incubation, the treated cells were washed with PBS and incubated with MTT containing growth media. Finally, the medium was removed, and the formazan crystals were dissolved using 150 µl DMSO (100%). The optical density was then measured at 570 nm. Untreated cells were kept as control and percentage cell viability in treated cells were calculated. (Mosmann, 1986).

% of Cell viability = (Treated / control) x100

3.5.3.1. Focus Formation Assay

Cell viability was assessed by Focus formation assay.

Cells were seeded in 6 well plate and supplied with sufficient medium for nourishing. After 24hr of incubation, the medium was removed and washed with PBS. The cells were treated with 3ml test compounds and incubated for 24hrs. After 24hrs of incubation, cells were washed with PBS. Cells were fixed with 4% Paraformaldehyde and stained with 0.5% crystal violet for 15 min. Colonies were observed under microscope.

3.6. STATISTICAL ANALYSIS

The generated data were subjected to statistical analysis using Complete Randomized Design (CRD). One way analysis of variance (ANOVA) at 0.05% significance level and independent sample 't' test were used to calculate significant difference in the treatment means and for organoleptic analysis, the different preferences as indicated by scores were evaluated by Kruskal- Wallis test to get the mean rank value for all treatments.

Results

4. RESULTS

The results pertaining to the study entitled “Development and quality evaluation of a jackfruit based nutri flour” are detailed in this chapter under the following headings:

4.1. Determination of glycemic index of jackfruit parts

4.2. Development of nutri flour

4.3. Quality evaluation of nutri flour

4.4. Quality improvement of nutri flour

4.5. Assessment of in vitro therapeutic efficacy of nutri flour

4.1. DETERMINATION OF GLYCEMIC INDEX OF JACKFRUIT PARTS

4.1.1. Selection and collection of jackfruits

With increasing demand for food, current agriculture is focusing on agroprocessing to utilize maximum, out of the plant resources. Jackfruit (*Artocarpus heterophyllus Lam.)* is one of the largest edible fruits grown worldwide. A distinguishing feature of jackfruit tree is its ability to produce a higher yield of fruits, than any other trees in the Moraceae family, producing 70 - 200 kg of fruits per tree, depending on variety, cultural practices, and environmental factors. There are two cultivars of jackfruits that are predominant in kerala; the *koozha* and *varikka*. Varikka has a slightly hard inner flesh when ripe, while the inner flesh of ripe *koozha* fruit is very soft and is almost dissolving.

The consumption of fresh jackfruit as well as the processing of this fruit results in high amounts of wastes, from its skin, rind, and even seeds. The process of separating the fruitlets from the rind is a laborious process and it is seen wasted to a great extent, due to lack of post-harvest technological interventions.

A bulb-based flour is already commercialized, but this study aimed to develop and evaluate the quality of a jackfruit based nutri flour with all the edible parts of the two cultivars, *koozha* and *varikka*, namely its bulbs, seeds, perigones, testa, rind and core. Raw

jackfruits (12 weeks maturity) of cv *koozha* and cv *varikka* were collected from Instructional farm College of Agriculture, Vellayani. The bulbs, perigones, seeds, rind, core and testa were separated.

4.1.2. Cleaning and recording weight

An average weight of a jackfruit is about 3.5 to 10 kg and sometimes a fruit may reach up to 25 kg (Kumar *et al.*, 2002). Weight of whole jackfruits of cv *koozha* and cv *varikka*, were noted. As the fruits are big in size, they were cut into big pieces; and the bulbs, perigones, seeds, rind, core and testa were separated out. Jackfruit parts were cleaned with distilled water. The details of fresh and dry weight, percentage composition, yield, moisture percentage, processing loss and dry matter percentage of the various edible portions of jackfruit were recorded and are presented in the Tables from 1 to 18.

Table.1. Yield and processing loss of *koozha* jack fruit bulbs

Sample No	(1) Whole weight of fruit (kg)	(2) Fresh weight of bulb (Kg)	(3) Percentage composition	(4) Dry weight of bulb (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss (%)
1	11.54	4.60	39.87	2.15	18.63	42.13	81.36
2	15.87	6.42	40.46	3.05	19.21	41.08	80.78
3	18.06	7.97	44.12	3.40	18.82	57.34	81.17
4	13.16	5.98	45.42	2.52	19.14	57.02	80.85
5	19.87	8.98	45.19	4.78	24.05	46.77	75.94
6	21.5	11.94	55.53	5.23	24.32	56.19	75.67
Mean	16.66	7.64	45.09	3.52	20.69	50.08	79.29

Table.2. Yield and processing loss of *varikka j*ack fruit bulbs

Sample No	(1) Whole weight of fruit	(2) Fresh weight of bulb (Kg)	(3) Percentage composition	(4) Dry weight of bulb (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of bulb (%)
1	17.40	7.85	45.12	3.72	21.37	52.61	76.32
2	12.83	5.20	40.55	1.42	11.06	72.69	88.93
3	18.75	8.24	43.94	3.92	20.90	52.42	79.03
4	20.12	9.15	45.47	2.43	12.07	87.92	87.92
5	10.54	4.07	38.65	1.12	10.62	72.48	89.37
6	20.36	9.42	46.26	2.51	12.32	73.35	87.67
Mean	16.66	7.32	43.33	2.52	25.24	68.57	84.87

Drying removes moisture content, as a result the whole product shrinks and decreases in size and weight, thus requiring less space for storage. Many foods lose volume or weight as they are processed. The yield of dried products is directly related to how much water is in the orginal product.

As seen in table 1 percentage composition of fresh *koozha* jackfruit bulbs alone ranged from 39. 87 to 55.53 per cent. Yield ratio of jackfruit bulb ranged between 18.63 to 24.32 per cent. Owing to the loss of moisture, the moisture content of *koozha* bulbs was in the range 41.08 per cent to 57.34 percentage. The resulting processing loss was worked out to be in the range of 75.67 to 81.36 percentage.

The percentage composition of *varikka* jack fruit bulb was found to be in the similar range of 38.65 per centage to 46.26 percentage. When the yield ratio of *varikka* bulbs was analyzed, it was found to be in the range of 10.62 to 21.37 per cent. On analyzing the moisture content of fresh *varikka* jackfruits, it was found to be in the range of 52.42 to 87.92 percentage. Processing loss occurs in fruits and vegetables due to removal of inedible portion and moisture loss. The processing loss of dried bulbs was also similar to that of *koozha* jackfruits, ranging from 76.32 to 89.37 per centage.

Table.3. Dry matter percentage of jackfruit bulbs

Sample No	Dry matter (%) of *koozha*	Dry matter (%) of *varikka*
1	46.73	47.38
2	47.50	27.30
3	42.65	47.57
4	42.14	26.55
5	53.22	27.51
6	43.80	26.64
Average	46.0	33.82
t_{cal}	**2.62***	
t critical	**2.22**	
Sig	**0.025**	

*Significant @ 5% level.

"Dry matter" represents the percentage of nutrients present excluding water content. Dry matter content of a foodstuff is important because it reveals the actual amounts of various nutrients available to the food. Table 3. shows that the dry matter percentage of *koozha* bulbs ranged from 42.14 to 53.22 per cent; while that of *varikka* bulbs ranged between 26.55 to 47.57 per cent. Dry matter percentage corresponding to *koozha* and *varikka* jackfruit bulbs were compared using 't' test assuming equal variance of treatment means. Results revealed a significant difference between the mean values of dry matter of *koozha* and *varikka* (t_{cal} > t critical (0.05). Also, it is clear that dry matter content is higher for *koozha* cultivar than *varikka* cultivars.

Table.4. Yield and processing loss of *koozha* jackfruit seed

Sample No	(1) Whole weight of fruits (Kg)	(2) Fresh weight of seed (Kg)	(3) Percentage composition	(4) Dry weight of seed (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of seed (%)
1	11.54	2.27	19.67	0.98	8.52	56.65	91.47
2	15.87	3.90	20.8	2.47	15.56	36.66	84.43
3	18.06	4.27	26.90	2.15	11.90	49.64	88.09
4	13.16	3.37	25.63	1.52	11.50	54.89	88.44
5	19.87	5.98	30.12	2.83	14.24	52.67	85.75
6	21.5	6.92	32.18	3.52	16.37	49.13	83.62
Mean	16.66	4.45	25.88	2.24	13.01	49.94	86.96

Table.5. Yield and processing loss of *varikka* jackfruit seed

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of seed (Kg)	(3) Percentage composition	(4) Dry weight of seed (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of seed (%)
1	17.40	4.20	24.13	2.10	12.06	50.00	87.93
2	12.83	3.08	59.23	1.23	9.58	60.06	90.41
3	18.75	4.92	27.27	2.72	14.50	44.71	85.49
4	20.12	5.42	59.26	2.3	11.43	57.56	88.56
5	10.54	2.10	19.92	0.97	9.25	53.52	90.74
6	20.36	5.48	26.91	2.41	11.83	56.02	88.16
Mean	16.66	4.2	36.12	1.95	11.4	53.64	88.54

The seeds make up around 10 to 15% of a jackfruit (Ocloo *et al.*, 2010). Moisture content of *koozha* jackfruit seed ranged from 36.66 to 56.65. Table 4 reveals the yield and processing loss of *koozha* jackfruit seeds. In this study it was found that, seeds formed 19.67 to 32.18 per cent of the whole fruits and yield ratio varied between 8.52 to 16.37 per cent. Processing loss with respect to dried seed ranged from 83.62 to 91.47 per centage.

Fresh seeds of *varikka* formed 19.92 to 59.26 percentage of whole fruit. While dry seeds were found to weigh between 0.97 to 2.10 kilogram. Moisture content of *varikka* seeds varied 9.25 to 12.06 per cent. The processing loss was in the range of 85.49 to 90.74 per cent. The processing loss was varying much among the cultivars.

Table.6. Dry matter percentage of jack fruit seed

Sample No	Dry matter (%) of *koozha*	Dry matter (%) of *varikka*
1	43.34	50.00
2	63.33	39.93
3	50.35	55.28
4	45.10	42.43
5	47.32	46.47
6	50.86	43.97
Average	50.05	46.34
t_{cal}	**1.002***	
t critical	**2.22**	
Sig	**0.33**	

*Significant @ 5% level.

Table 6. reveals the dry matter percentage of *koozha* and *varikka* jackfruit seeds; which were compared using 't' test, assuming equal variance to treatment means. Results revealed there was no significant difference between the mean dry matter content of *koozha* and *varikka* seeds (t_{cal} < t critical (0.05).

Table.7. Yield and processing loss of perigones of *koozha* jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) fresh weight of perigones (Kg)	(3) Percentage composition	(4) Dry weight of perigones (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of perigones (%)
1	11.54	0.63	5.50	0.27	2.40	56.22	97.59
2	15.87	0.73	4.64	0.32	2.04	55.96	97.95
3	18.06	0.90	5.01	0.53	2.96	40.88	97.03
4	13.16	0.69	5.30	0.29	2.21	58.16	97.78
5	19.87	0.99	5.00	0.57	2.87	42.51	97.12
6	21.5	1.72	8.00	0.76	3.5	55.69	96.45
Mean	16.66	0.94	5.57	0.46	2.66	51.57	97.32

Table 8. Yield and processing loss of perigones of *varikka* jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of perigones (Kg)	(3) Percentage composition	(4) Dry weight of perigones (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of perigones (%)
1	17.40	0.88	5.10	0.40	2.32	54.50	97.67
2	12.83	0.64	5.02	0.30	2.35	53.17	97.64
3	18.75	0.93	4.98	0.47	2.53	49.14	97.46
4	20.12	0.99	4.94	0.41	2.04	58.55	97.95
5	10.54	0.68	6.52	0.33	3.16	51.45	96.83
6	20.36	0.99	4.89	0.42	2.0	57.83	97.93
Mean	16.66	0.85	5.24	0.39	2.4	54.10	97.58

The edible bulbs in jackfruit are separated into compartments by latex-like filaments called 'rags' or perianth. This portion consists about 25% of a total fruit weight (Dam and Nguyen, 2013). In this study it was showed that the contribution of perigones to the whole weight of jackfruit *koozha* ranged from 0.63 to 1.72%, while that of *varikka* perigones ranged from 0.64 % to 0.99 %. On comparing the yield ratio of perigones among the two cultivars, from *koozha* was in the range of 2.04 to 3.5 % and that was *varikka* of 2.0 % to 3.16 %. Moisture content of *koozha* perigones were in the range of 40.88 to 58.16%, while in the case of *varikka* perigones it ranged from 49.14 to 58.55 %. The processing loss of jackfruit perigones is presented in Table 7 and 8, it can be seen that both cultivars had above 95% of processing loss with respect to dried perigones.

Table 9. Dry matter percentage of jack fruit perigones

Sample No	Dry matter (%) of *koozha*	Dry matter (%) of *varikka*
1	45.49	43.77
2	46.82	44.03
3	50.85	59.11
4	41.44	41.83
5	48.54	57.48
6	42.16	44.30
Average	48.42	45.88
t_{cal}	**0.72***	
t critical	**2.22**	
Sig	**0.48**	

*Significant @ 5% level.

Table 9. shows the dry matter percentage of perigones of both cultivars. Dry matter of Jackfruit *koozha* ranged between 41.44 to 50.85 per cent; While the *varikka* perigones had varied between 41.83 to 59.11 per cent. Dry matter percentage of *koozha* and *varikka* jackfruit perigones were compared using 't' test and the results revealed that there was no significant difference between the mean values of dry matter corresponds to *koozha* and *varikka* perigones (t_{cal} < t critical (0.05).

Table.10. Yield and processing loss of seed testa of *koozha* jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of testa (Kg)	(3) Percentage composition	(4) Dry weight of testa (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of testa (%)
1	11.54	0.18	1.57	0.15	1.29	91.75	98.70
2	15.87	0.16	1.03	0.48	3.02	70.73	96.97
3	18.06	0.19	1.07	0.82	4.54	57.73	95.45
4	13.16	0.14	1.04	0.30	2.27	78.87	97.72
5	19.87	0.20	1.03	0.94	4.73	54.36	95.26
6	21.5	0.22	1.03	0.10	0.48	53.36	99.51
Mean	16.66	0.18	1.12	0.46	2.72	67.8	97.26

Table 11. Yield and processing loss of seed testa of *varikka* jackfruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of testa (Kg)	(3) Percentage composition	(4) Dry weight of testa (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of testa (%)
1	17.40	0.18	1.07	0.07	0.43	59.35	99.56
2	12.83	0.12	0.93	0.02	0.16	82.5	99.83
3	18.75	0.19	1.05	0.08	0.47	55.05	99.52
4	20.12	0.21	1.06	0.09	0.44	55.34	99.52
5	10.54	0.07	6.64	0.01	0.10	84.28	99.89
6	20.36	0.21	1.07	0.09	0.48	55.04	99.51
Mean	16.66	0.16	1.97	0.06	0.34	65.26	99.63

Analyzing the percentage composition of seed testa of *koozha* cultivars, it was found to range from 1.03 to 7.10 per centage while *varikka's* percentage composition ranged from 0.07 to 0.21 %. The yield ratio of seed testa was in the range of 0.15 to 0.94 % in *koozha* and 0.01 to 0.09% to *varikka*. The moisture content of *koozha* jackfruit testa was in the range of 53.36 to 91.75%; while the moisture content of testa of *varikka* jackfruit ranged from 55.04 to 84.28% The processing loss from drying of jackfruit *koozha* testa was in the range of 95.26 to 99.51%, in the case of *varikka* cultivars it was found to vary between 99.51 to 99.89%.

Table12. Dry matter percentage of jackfruit seed testa

Sample No	Dry matter (%) of *koozha*	Dry matter (%) of *varikka*
1	18.29	40.64
2	29.26	17.5
3	42.26	44.94
4	21.12	44.65
5	45.63	15.71
6	46.63	44.95
Average	33.86	34.73
t_{cal}	**-0.11***	
t critical	**2.22**	
Sig	**0.91**	

*Significant @ 5% level.

Table 12. reveals the dry matter percentage of *koozha* and *varikka* jackfruit seed testa, which were compared using 't' test assuming equal variance to treatment means. Results revealed that there was no significant difference between the mean value of dry matter of *koozha* and *varikka* testa (tcal < t critical (0.05). Dry matter percentage of *koozha* testa was range in 18.29 to 46.63 while that of *varikka* testa was seen to vary between 15.71 to 44.95 per cent.

Table.13. Yield and processing loss of rind of *koozha* jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of rind (Kg)	(3) Percentage composition	(4) Dry weight of rind (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of rind (%)
1	11.54	1.12	9.70	0.65	5.63	41.96	95.66
2	15.87	1.78	11.21	0.75	4.72	57.86	95.27
3	18.06	2.52	13.95	1.05	5.81	58.33	94.18
4	13.16	1.35	10.25	0.74	5.66	44.81	94.33
5	19.87	2.92	14.69	1.34	6.74	54.10	93.25
6	21.5	3.83	17.81	1.92	8.9	49.86	91.06
Mean	16.66	3.86	12.93	1.07	6.24	51.15	93.95

Table.14. Yield and processing loss of rind of *varikka* jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of rind (Kg)	(3) Percentage composition	(4) Dry weight of rind (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of rind (%)
1	17.40	1.80	10.36	0.81	4.67	54.77	95.32
2	12.83	1.26	9.81	0.73	5.75	41.42	94.24
3	18.75	2.12	11.30	0.97	5.2	54.00	94.8
4	20.12	2.96	14.73	1.35	6.70	54.39	93.29
5	10.54	0.99	9.46	0.34	3.28	65.33	96.71
6	20.36	3.05	14.98	1.44	7.07	52.78	92.92
Mean	16.66	3.48	11.77	0.94	5.44	53.78	94.54

Fresh rind formed 9.70 to 17.81% of the whole *koozha* fruit. The corresponding range of dried rind form was 4.72 to 6.74 %. In the case of *varikka*, the fresh rind formed 9.81 to 14.98% and their dried form constituted 3.25 to 6.70 %. Moisture percentage of *koozha* jackfruit was in the range of 41.96 to 58.33 per cent and that of *varikka* was between 41.42 to 65.33 %. The processing loss was above 90 % in both the cultivars

Table 15. Dry matter percentage of jackfruit rind

Sample No	Dry matter (%) of *koozha*	Dry matter (%) of *varikka*
1	58.03	45.22
2	42.13	58.57
3	41.66	45.99
4	55.18	45.60
5	45.89	34.66
6	50.13	47.21
t_{cal}	**).72***	
t critical	**2.22**	
Sig	**0.48**	

*Significant @ 5% level.

Dry matter percentage of *koozha* and *varikka* rind results showed there was no significant difference between the mean value of dry matter of *koozha* and *varikka* rind (t_{cal} < t critical (0.05). Dry matter percentage of *koozha* jackfruit was in the range of 41.66 to 58.03 per cent and that of *varikka* 34.66 to 58.57 %.

Table.16. Yield and processing loss of core of koozha jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of core (Kg)	(3) Percentage composition	(4) Dry weight of core (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of core (%)
1	11.54	0.82	7.14	0.38	3.33	53.33	96.66
2	15.87	0.98	6.22	0.48	3.04	51.01	96.95
3	18.06	1.08	5.97	0.62	3.46	42.12	96.53
4	13.16	0.89	6.81	0.42	3.19	53.06	96.80
5	19.87	1.21	6.11	0.68	3.44	43.47	96.55
6	21.5	1.86	8.65	0.94	4.40	49.03	95.59
Mean	16.66	1.14	6.81	0.59	3.47	48.67	96.51

Table.17. Yield and processing loss of core of *varikka* jack fruit

Sample No	(1) Whole weight of fruit (Kg)	(2) Fresh weight of core (Kg)	(3) Percentage composition	(4) Dry weight of core (Kg)	(5) Yield ratio of component	(6) Moisture (%)	(7) Processing loss of core (%)
1	17.40	1.20	6.92	0.63	3.66	46.83	96.33
2	12.83	0.97	7.61	0.52	4.08	46.42	95.91
3	18.75	1.10	5.8	0.58	3.11	46.90	96.88
4	20.12	1.22	6.06	0.63	3.13	48.36	96.86
5	10.54	0.89	8.49	0.47	4.53	46.65	95.46
6	20.36	1.28	6.28	0.63	3.13	52.19	96.86
Mean	16.66	1.11	6.86	0.58	3.60	47.89	96.38

With respect to the core of *koozha* cultivars their fresh weight formed 5.97 to 8.65 of the whole fruit, as for *varikka* the range was between 5.8 to 8.49 %. When the product was dried their percentage components ranged from 3.04 to 4.40% in the case of *koozha* and 3.11 to 4.53% for *varikka* cultivars. Moisture content of core was in the higher side for *koozha* cultivars, many of the treatment were found to have a moisture content above 50%, while *varikka* was found have moisture content below 50%. Processing loss of core was similar in both the cultivars.

Table.18. Dry matter percentage of jack fruit Core

Sample No	**Dry matter (%) of *koozha***	**Dry matter (%) of *varikka***
1	53.16	46.66
2	53.57	48.98
3	53.09	57.87
4	51.63	46.93
5	53.34	56.52
6	49.92	50.96
Average	51.32	52.45
t_{cal}	**-0.59***	
t critical	**2.22**	
Sig	**0.59**	

*Significant @ 5% level.

Table 18. shows the dry matter percentage of *koozha* and *varikka* jackfruit cores which was compared using 't' test assuming equal variance to treatment means. Results revealed there was no significant difference between the mean values of dry matter correspond to *koozha* and *varikka* core (t_{cal} < t critical (0.05).

4.1.3. Glycemic index (GI) and Glycemic load (GL) of jackfruit parts

4.1.3.1. Carbohydrate content of test fruit parts

Foods that contain complex carbohydrates are digested and absorbed at a slower rate, resulting in lower blood glucose. Hence, these foods may have metabolic benefits in relation to diabetic control (Ludwig, 2000) Fruits consist mainly of complex carbohydrates which are known to have additional nutritional value specifically in terms of micronutrients (Fatema *et al.,* 2003). Table 21 reveals the content of carbohydrates of jackfruit parts.

Table 19. Carbohydrate content in jackfruit parts (per 100g)

Fruit parts	**carbohydrate content (100 g)**
T_1	14.74±0.06
T_2	17.26±0.145
T_3	4.95±0.140
T_4	3.70±0.107
T_5	2.82±0.100
T_6	5.59±0.228
T_7	19.79±0.162
T_8	10.98±0.030
T_9	2.78±0.095
T_{10}	3.41±0.171
T_{11}	4.53±0.098
T_{12}	2.73±0.210
CD	**0.413****
SE(m)	**0.141**

** Significant at 0.05 level of significance.

T_1 - T_6 - cv *Koozha*

T_7 - T_{12} - cv *Varikka*

T_1 & T_7 - Bulb, T_2 & T_8 - Seed, T_3 & T_9 - Perigones, T_4 & T_{10} - Testa, T_5 & T_{11}- Rind, T_6 & T_{12} - Core.

Table 19 shows the carbohydrate content of different parts with respect to bulbs, seeds, perigones, testa, rind and core of *koozha* and *varikka* cultivars. The result show that *varikka* bulb had the highest carbohydrate content (19.79g/100g) followed by *koozha* seed (17.26g) *koozha* bulb (14.74g/100g) and *varikka* seed (10.98 g/100g). The lowest carbohydrate content was seen in *varikka* core (2.73g/100g) followed by *varikka* perigones (2.78g/100g), *koozha* rind (2.82g/100g), *varikka* testa (3.41g/100g) and *koozha* testa (3.70). When *koozha* core recorded 5.59g/100g *varikka* are recorded only 2.73g. The carbohydrate content in *varikka* bulb was significantly different from the other parts

Table 20. Comparison in Carbohydrate content of *koozha* and *varikka* parts

Carbohydrate (100 g) in jackfruit				**"t" values (0.05)**	**Sig**
Koozha		*Varikka*			
T_1	14.74	T_7	19.79	-10.78	0.0085*
T_2	17.26	T_8	10.98	7.02	0.0196*
T_3	4.95	T_9	2.78	3.33	0.0793
T_4	3.70	T_{10}	3.41	3.48	0.0733
T_5	2.82	T_{11}	4.53	-3.63	0.0681
T_6	5.59	T_{12}	2.73	8.43	0.0138*

From Table 20 it is revealed that there was a significant difference ($p<0.05$) in the carbohydrate content of *koozha* and *varikka* bulbs, when compared using 't' test. The carbohydrate content was significantly low in *koozha* bulb. In the case of seeds, there was a significant difference between both cultivars. *Koozha* seed (17.26g/100g) had higher carbohydrate content compared to *varikka* seed (10.98g/100g). Carbohydrate content of perigones, testa and rind of both cultivars had no significant difference ($p >0.05$) among the cultivars; while core of the fruit showed significant difference; among the cultivars *koozha* core (5.59g/100g) had higher carbohydrate content than *varikka* core (2.73g/100g).

4.1.3.2. Dietary fiber of jackfruit parts

Dietary fibre is the non-digestible component of plant matter in the diet that is resistant to enzymatic digestion in humans. It consists of cellulose, non-cellulosic

polysaccharides such as hemicellulose, pectic compounds, gums, mucilages, and lignin- a non-carbohydrate component. Fibre-rich foods such as cereals, nuts, fruits, and vegetables are beneficial to health, its consumption has been linked to a lower risk of a variety of ailments. Higher Dietary fibre consumption has been associated to a lower risk of cardiovascular disease, diabetes, obesity, and intestinal disease (Divyashree *et al.,* 2017).

Table 21. Dietary fiber content in jackfruit parts

Fruit parts	**Fiber (100 g) in jackfruit**
T_1	3.33±0.087
T_2	2.22±0.170
T_3	2.97±0.127
T_4	1.73±0.070
T_5	6.69±0.114
T_6	2.95±0.087
T_7	1.76±0.130
T_8	1.90±0.110
T_9	2.48±0.117
T_{10}	1.70±0.061
T_{11}	5.78±0.078
T_{12}	2.41±0.061
CD	**0.311****
SE(m)	**0.106**

** Significant at 0.05 level of significance.

T_1 - T_6 - cv *Koozha*

T_7 - T_{12} - cv *Varikka*

T_1 & T_7 - Bulb, T_2 & T_8 - Seed, T_3 & T_9 - Perigones, T_4 & T_{10} - Testa, T_5 & T_{11}- Rind, T_6 & T_{12} - Core.

Table 21. reveals the dietary fiber content of different parts of jackfruit cultivars (*koozha* and *varikka*) viz bulbs, seeds, perigones, testa, rind and core. The result show that jackfruit *koozha* rind (6.69g/100g) had higher dietary fiber followed by *varikka* rind

(5.78g). Fiber content of *koozha* perigones (2.97g/100g), was on par with *koozha* core (2.95g/100g), similarly, fiber content in *varikka* perigones (2.48) and *varikka* core (2.41g/100g) were on par. The lowest fiber content was reported in *varikka* testa (1.70g/100g) followed by *koozha* testa (1.73g/100g), *varikka* bulb (1.76g/100g) and varikka seed (1.90g). Dietary fiber was higher in *koozha* cultivars compared with *varkka* cultivars.

Table 22. Comparison in fiber content of *koozha* and *varikka* parts

Dietary fiber (g/100g) in jackfruit				**"t" values (0.05)**	**Significance**
Koozha		*Varikka*			
T_1	3.33	T_7	1.76	3.4410	0.0751
T_2	2.22	T_8	1.90	2.9669	0.0973
T_3	2.97	T_9	2.48	5.1687	0.0655
T_4	1.73	T_{10}	1.70	3.000	0.0955
T_5	6.69	T_{11}	5.78	2.6154	0.1204
T_6	2.95	T_{12}	2.41	2.5507	0.1254

From table 22. shows the comparison of dietary fiber of the bulb, seed, perigones, testa, rind and core among the two cultivars, which showed no significant difference ($p>0.05$) when they were compared using 't' test. The fiber content was lowest in seed *testa* (1.70 and 1.73g/100g) in *varikka* and *koozha* respectively. *koozha* rind had the highest fiber content (6.69g/100g) than *varikka* rind (5.78g/100g).

4.1.3.3. The blood glucose level of subjects after ingestion of jackfruit parts

Fruits are well known to have extra nutritional value. However, the response in blood glucose level varies with different fruits. Fatema *et al.* (2003) reported that it is important to know the composition of fruits and their biological responses in order to rationalise the advice of including fruits in the diet of diabetic patients. Studies have revealed that tropical fruits may produce higher responses of postprandial blood glucose than temperate fruits Therefore, this experimental study was carried out to determine the

mean blood glucose at different time points, after consuming different parts of jackfruit cv *koozha* and cv *varikka* bulbs, seeds, perigones, testa, rind and core. The values obtained are presented in Table 23

Table.23. Glycemic response of subjects after injection of jackfruit parts (N=10)

Serum glucose (mmol/L)					
Jackfruits	0 (min)	30 (min)	60 (min)	90 (min)	120 (min)
Jackfruit *koozha*					
T_1	5.01±0.07	$5.9±0.06^{b}$	$5.1±0.10^{e}$	$5.2± 0.11^{de}$	$5.8± 0.03^{a}$
T_2	5.0±0.07	$5.4±0.08^{c}$	$5.6±0.08^{b}$	$6.04± 0.04^{a}$	$5.1±0.07^{bc}$
T_3	4.8±0.05	$5.08±0.05^{de}$	$5.1±0.06^{de}$	$5.3±0.06^{d}$	$5.1± 0.02^{bc}$
T_4	4.9±0.06	$5.03±0.04^{e}$	$5.1±0.06^{de}$	$5.1±0.14^{de}$	$5.04± 0.11^{cd}$
T_5	4.8±0.05	$5 ±0.04^{e}$	$5.03±0.04^{e}$	$4.8±0.09^{f}$	$4.6±0.03^{e}$
T_6	5.0±0.07	$5.2±0.06^{cd}$	$5.5±0.10^{bc}$	$5.3±0.14^{d}$	$5.2± 0.05^{bc}$
T_7	5.02±0.07	$6.1±0.06^{b}$	$5.2±0.14^{de}$	$6.06± 0.02^{a}$	$5.2± 0.08^{bc}$
T_8	5.01±0.07	$6.08±0.04^{b}$	$5.8±0.15^{b}$	$5.8± 0.05^{ab}$	$5.7±0.02^{a}$
T_9	4.9±0.06	$5.06±0.06^{e}$	$5.1±0.04^{de}$	$5.8±0.05^{ab}$	$5.6± 0.03^{a}$
T_{10}	4.9±0.07	$5.08±0.07^{e}$	$5.1±0.07^{e}$	$4.9± 0.12^{ef}$	$5.6 ±0.04^{a}$
T_{11}	4.9±0.06	$5.07±0.06^{e}$	$5±0.05^{e}$	$5.2± 0.12^{de}$	$4.8 ±0.11^{de}$
T_{12}	5.01±0.07	$5.1±0.06^{cd}$	$5.3±0.12^{cd}$	$5.6± 0.12^{bc}$	$4.9± 0.08^{d}$
Glucose	4.9±0.11	$6.8 ±0.11^{a}$	$6.07±0.11^{a}$	$6.12±0.06^{a}$	$5.9± 0.02^{a}$
CD	0.206	0.1902**	0.272**	0.2718**	0.204**

** Significant at 0.05 level of significance.

T_1 - T_6 - cv *Koozha*

T_7 - T_{12} - cv *Varikka* T_1 & T_7 - Bulb, T_2 & T_8 - Seed, T_3 & T_9 - Perigones, T_4 & T_{10} - Testa, T_5 & T_{11}- Rind, T_6 & T_{12} - Core.

Table 23. shows that there was no significant difference in initial blood glucose response of each subject in the group ($p > 0.05$) but the difference was significant in most of the other time durations. Significantly different patterns of blood glucose response was observed during 30 to 120 minutes of the dietary regime ($p<0.05$). Jackfruit *koozha* bulbs reached peak blood glucose values at 30 minutes (5.9 ± 0.06), while in the case of *varikka* bulb, it reached its peak value in 90 minutes (6.06 ± 0.02). *Koozha* seed reached its peak value at 90 minutes (6.04 ±0.04), *varikka* seed reached in 30 minutes (6.08 ±0.04). Peak value of *koozha* and *varikka* perigones was attained in 90 minutes (5.3 ±0.06 and (5.8 ± 0.05) respectively. *Koozha* seed testa reached peak value in 60 and 90 minutes (5.1±0.06 and 5.1±0.14) while *varikka* seed testa reached into 120 minutes (5.6±0.04). Peak value of 5.03±0.04 was reached in 60 minutes in the case of *koozha* rind, while for the *varikka* rind the peak value was obtained in 30 minutes (5.07±0.06). The peak value of 5.5±0.10 in 60 minutes was observed for *koozha* core, while the peak for *varikka* core was observed in the 90 minutes (5.6 ± 0.02).

Area under the curve (AUC)

Net incremental AUC (net AUC) includes all incremental area below the curve, (Wolever and Brand-Miller, 2004). Table 24. Shows the AUC of the test fruit ranged between 111.82 mmol.min/L and 171.13 mmol.min/L. Among different jackfruit parts, the mean AUC was highest for *varikka* seed (171.13±0.80) and followed by *varikka* bulb (167.49±1.04) and *koozha* seed (167.31±1.31) while the lowest was obtained in *koozha* rind (111.82±0.88) which was on par with T_4 and T_{10} (Rinds of *varikka and koozha*) (133.79±0.48).

Table.24. The Area Under Study (AUC) of jackfruit parts under study

Test fruits	AUC (mmol.min/L)
T_1	158.69 ± 0.87^{d}
T_2	167.31 ± 1.31^{c}
T_3	119.76 ± 0.71^{f}
T_4	114.22 ± 0.61^{gh}
T_5	111.82 ± 0.88^{h}
T_6	131.77 ± 0.77^{e}
T_7	167.49 ± 1.04^{c}
T_8	171.13 ± 0.80^{b}
T_9	121.86 ± 0.68^{f}
T_{10}	114.22 ± 0.83^{gh}
T_{11}	116.75 ± 0.76^{g}
T_{12}	133.79 ± 0.48^{e}
Glucose	245.23 ± 2.04^{a}
CD	2.771**

** Significant at 0.05 level of significance.

T_1 - T_6 - cv *Koozha*

T_7 - T_{12} - cv *Varikka*

T_1 & T_7 - Bulb, T_2 & T_8 - Seed, T_3 & T_9 - Perigones, T_4 & T_{10} - Testa, T_5 & T_{11}- Rind, T_6 & T_{12} - Core.

Glycemic Index (GI)

Glycemic index is an important tool used in treating people with diabetes and in weight loss programs. Low glycemic index foods, by virtue of slow digestion and absorption of their carbohydrates, produce a more gradual rise in blood sugar and insulin levels and are increasingly associated with health benefits. Low glycemic index foods have thus been shown to improve the glucose tolerance in both healthy and diabetic subjects.

Mendosa (2003) gave a special classification of foods based on their respective glycemic index and glycemic load values as follows (GI: High > 70, Medium 56-69 and low < 55; GL: High > 20, Medium 11-19 and low < 10). Table 25. reveals that the jackfruit

variety *koozha* rind had the lowest glycemic index value (45.26±0.52), which was on par with *koozha* testa (46.24±0.57), *varikka* testa, (46.53±0.63) *varikka* rind (47.27±0.62). The highest glycemic index value was reported for *varikka* seed (69.31±0.99) followed by *varikka* bulb (67.82±0.90), *koozha* seed (67.74±0.87) and *koozha* bulb (63.29±1.21).

Table.25. Glycemic Index of jackfruit parts under study

Jackfruit parts	GI
T_1	63.29 ± 1.21^{b}
T_2	67.74 ± 0.87^{a}
T_3	48.52 ± 0.75^{de}
T_4	46.24 ± 0.57^{f}
T_5	45.26 ± 0.52^{f}
T_6	53.37 ± 0.76^{c}
T_7	67.82 ± 0.90^{a}
T_8	69.31 ± 0.99^{a}
T_9	49.37 ± 0.62^{d}
T_{10}	46.53 ± 0.63^{ef}
T_{11}	47.27 ± 0.62^{def}
T_{12}	54.19 ± 0.69^{c}
Glucose	100
CD	2.216**

** Significant at 0.05 level of significance.

T_1 - T_6 - cv *Koozha*

T_7 - T_{12} - cv *Varikka*

T_1 & T_7 - Bulb, T_2 & T_8 - Seed, T_3 & T_9 - Perigones, T_4 & T_{10}- Testa, T_5 & T_{11}- Rind, T_6 & T_{12} - Core.

Glycemic load (GL)

The glycemic load (GL) can be defined as the product of the glycemic index **(**GI) of a food and the amount of carbohydrate in a serving (Foster-Powell *et al.*, 2002). Table 26

shows that, out of the 12 jack fruit parts of *koozha* and *varikka* cultivars, lower glycemic load was reported for *varikka* core (1.29±0.01), followed by *koozha* rind (1.30±0.06) and, *varikka* perigones (1.44±0.02), and *koozha* testa (1.66±0.02). The highest value was obtained for *koozha* seed (12.42±0.16), which was on par with *varikka* seeds (11.81±0.17) and *koozha* bulbs (11±0.21).

Based on the value of glycemic index and glycemic load the formulations for nutri flour were formulated after preliminary trials.

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Table.26. Glycemic Load of jackfruit parts under study

Test fruits	GL
T_1	11 ± 0.21^{ab}
T_2	12.42 ± 0.16^{a}
T_3	2.19 ± 0.03^{e}
T_4	1.66 ± 0.02^{e}
T_5	1.30 ± 0.06^{e}
T_6	2.81 ± 0.04^{e}
T_7	8.27 ± 0.11^{bc}
T_8	11.81 ± 0.17^{ab}
T_9	1.44 ± 0.02^{e}
T_{10}	6.45 ± 4.79^{e}
T_{11}	2.12 ± 0.02^{cd}
T_{12}	1.29 ± 0.01^{de}
Glucose	50
CD	3.893**

** Significant at 0.05 level of significance.

T_1 - T_6 - cv *Koozha*

T_7 - T_{12} - cv *Varikka*

T_1 & T_7 - Bulb, T_2 & T_8 - Seed, T_3 & T_9 - Perigones, T_4 & T_{10} - Testa, T_5 & T_{11}- Rind, T_6 & T_{12} - Core.

4.2. DEVELOPMENT OF NUTRI- FLOUR

4.2.1. Formulations of nutri flour

Different parts of the jack fruit cultivars (*koozha* and *varikka*) were used for preparing the jackfruit-based nutri flour. The bulbs, perigones, seeds, rind, core and testa of each cultivar were used. Nutri- flour formulations were made based on the results of glycemic index. The order of glycemic index of jackfruit parts were observed as KJRF> KJTF >VJTF >VJRF > KJPF > VJPF >KJCF >VJCF > KJBF >KJSF > VJBF >VJSF. The major component (50-60%) of flour was contributed from the fruit parts with lower glycemic index and 40 per cent of the mix was formulated by other components in different proportions. The flours of all jackfruit parts were processed separately after pre-treatments and these processed raw materials were mixed into 10 different formulations. The different formulations are depicted in Table. 27.

The formulation of food products was intended to enhance the nutritional quality of food products with acceptable, organoleptic qualities and which are low cost effective to fulfil consumer demands. Formulated composite flours have better nutritional value concerning elements of minerals, vitamins, fibres and proteins than flour milled from any specific cereal alone, it could provide a balance of many nutrients (Shanti *et al.,* 2015).

The sensory evaluation of freshly prepared products namely ‘puttu’, ‘ada’ and ‘oratti’ from the jackfruit based nutri flour was conducted, by a panel of 10 judges using a nine-point hedonic scale comprising of 6 sensory parameters such as appearance, colour, flavor, texture, taste and overall acceptability. Acceptability of the combinations based on the mean scores obtained are presented in Table. 28 to 30.

There has been tremendous role of organoleptic evaluation over the years; in partnership with research and development, as well as marketing departments. It helps in the formulation of profitable strategies. Now a days, chemical and physical properties of products decides the sensory attributes, that are ascertained by combining data obtained from organoleptic evaluation with instrumental testing. Organoleptic evaluation is used to estimate shelf life of the food products as sensory characteristics of the products depreciate

Treatments	Formulations(100g)												
	Jackfruit parts with low GI					Jackfruit parts with high GI							
	KJRF	KJTF	VJTF	VJRF	KJPF	VJPF	KJCF	VJCF	KJBF	KJSF	VJBF	VJSF	
F1	**20**	**10**	**9**	**8**	**8.5**	**7.5**	**7.5**	**7**	6	6	5.5	5	100
F2	**20**	**10**	**9**	**8**	**8.5**	**10**	**8**	**6**	8	5	3.5	4	100
F3	**20**	**10**	**9**	**8**	**8.5**	**7**	**8**	**6**	10	6	5.5	2	100
F4	**20**	**10**	**9**	**8**	**8.5**	**5**	**5.5**	**5**	9	5	6	9	100
F5	**20**	**10**	**9**	**8**	**8.5**	**4.5**	**4**	**3.5**	4.5	8	8	12	100
F6	**20**	**10**	**9**	**8**	**8.5**	**6.5**	**7**	**7**	8	4	10	2	100
F7	**20**	**10**	**9**	**8**	**8.5**	**7.5**	**10**	**9**	6	7	3	2	100
F8	**20**	**10**	**9**	**8**	**8.5**	**7**	**6**	**5.5**	7	8	6	5	100
F9	**20**	**10**	**9**	**8**	**8.5**	**2**	**2.5**	**2**	12	7	12	7	100
F10	**20**	**10**	**9**	**8**	**8.5**	**5**	**4.5**	**3**	7	12	7	6	100
Control	100 % jackfruit bulb flour (50% KJBF+50% VJBF)												

(KJRF- *Koozha* Jackfruit Rind Flour, KJTF- *Koozha* Jackfruit Testa Flour, VJTF - *Varikka* Jackfruit Testa Flour, VJRF - *Varikka* Jackfruit Rind Flour, KJPF - *Koozha* Jackfruit Perigones Flour, VJPF- *Varikka* Jackfruit Perigones Flour, KJCF - *Koozha* Jackfruit Core Flour, VJCF - *Varikka* Jackfruit Core Flour, KJBF - *Koozha* Jackfruit Bulb Flour, KJSF- *Koozha* Jackfruit Seed Flour, VJBF- *Varikka* Jackfruit Bulb Flour, VJSF - *Varikka* Jackfruit Seed Flour), **(*Bolded numerals indicate jackfruit parts with lower glycemic index)***

ahead of microbial quality. It explores new technologies for product development and understanding consumer behavior
(Sharif *et al.,* 2017).

4.2.2. Organoleptic evaluation of 'Puttu' prepared with nutri flour

The appearance of a food influences its craving and acceptance, before the product ever touches the lips. The organoleptic evaluation revealed that (Table. 28) the mean rank value for appearance of jack fruit nutri flour based "puttu" ranged between 9.70 – 83.65. The mean rank values were analyzed and it was observed that F_{10} obtained the first rank (83.65) after control (98.80). While F_1 got least mean rank value of 9.70. F_3 (29.94) was on par with F_4 (29.96).

The mean rank value for colour of jack fruit nutri flour based – 'puttu" ranged between 17.90 – 85.10. The highest mean rank value was obtained by F_8 (85.10) followed by F_9 (82.65) and lowest by F_2 (17.90). There was a significant difference between the mean rank scores of colour.

From the organoleptic analysis of flavour it was noticed that F_9 obtained the maximum mean rank value (81.90) after control F_{11} (102); while F_2 obtained the minimum mean rank value 17.10.

The highest mean score value for texture was noticed in F_8 (77.80) after control F_{11} (100.66) followed by F_9 (77.61), F_{10} (75.94), F_7 (70.60). The minimum texture rank value was noticed in F_1 (17.77).

F_9 had the highest mean rank score for taste (90.05) and over all acceptability (93). Statistical analysis of the data revealed that there was significant difference between the mean rank scores of the different quality attributes of the jack fruit nutri flour based puttu at 5% level.

Table 28. Mean scores for organoleptic evaluation of "Puttu "prepared with jackfruit-based nutri flour

Treatment	Appearance		Colour		Flavour		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
F_1	9.70	4.3	33.83	5.2	34.22	6.2	17.77	4.4	31.65	3.5	15.66	3.4
F_2	14.72	4.7	17.90	4	17.10	5.2	18.66	4.1	27.25	3.3	23.40	3.5
F_3	29.94	5.1	24.50	4.4	28.40	5.8	31.60	4.7	24.45	3.1	21.50	3.4
F_4	29.96	5.2	31.83	4.7	25.85	5.7	30.60	4.6	49.40	4.2	41.65	4.2
F_5	45.00	5.7	34.38	5.2	47.35	6.6	34.30	4.9	41.40	3.8	46.70	4.5
F_6	54.70	6.2	30.16	4.3	34.72	5.4	50.00	5.6	69.70	5	49.65	4.7
F_7	64.70	6.7	67.00	5.7	66.83	6.8	70.60	6.9	50.50	4.2	54.45	4.9
F_8	72.35	7.1	**85.10**	**7.4**	74.18	7.3	**77.80**	**7.4**	48.15	4.1	71.85	5.8
F_9	81.66	7.4	82.65	7.1	**81.90**	**7.8**	77.61	7.2	**90.05**	**6**	**93**	**7.3**
F_{10}	**83.65**	**7.7**	72.60	6.3	78.77	7.5	75.94	6.9	73.95	5.1	80.70	6.4
Control (F_{11})	98.80	8.2	99.50	8.6	102.00	8.5	100.66	8.2	104	7.3	102.5	8.3
K W Value	92.81		87.88		81.47		82.10		69.76		86.47	
λ^2 (0.05)	18.31											

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

4.2.3. Organoleptic evaluation of 'Ada' prepared with nutri flour

As shown in Table 29, the organoleptic evaluation of the mean rank value for appearance of jack fruit-based "Ada" ranged between 21.80 – 82.25. The highest mean rank score was obtained by F_{10} (82.25) which was on par with F_9 (79.35) and F_8 (76.95) while the lowest was obtained by F_2 (21.80).

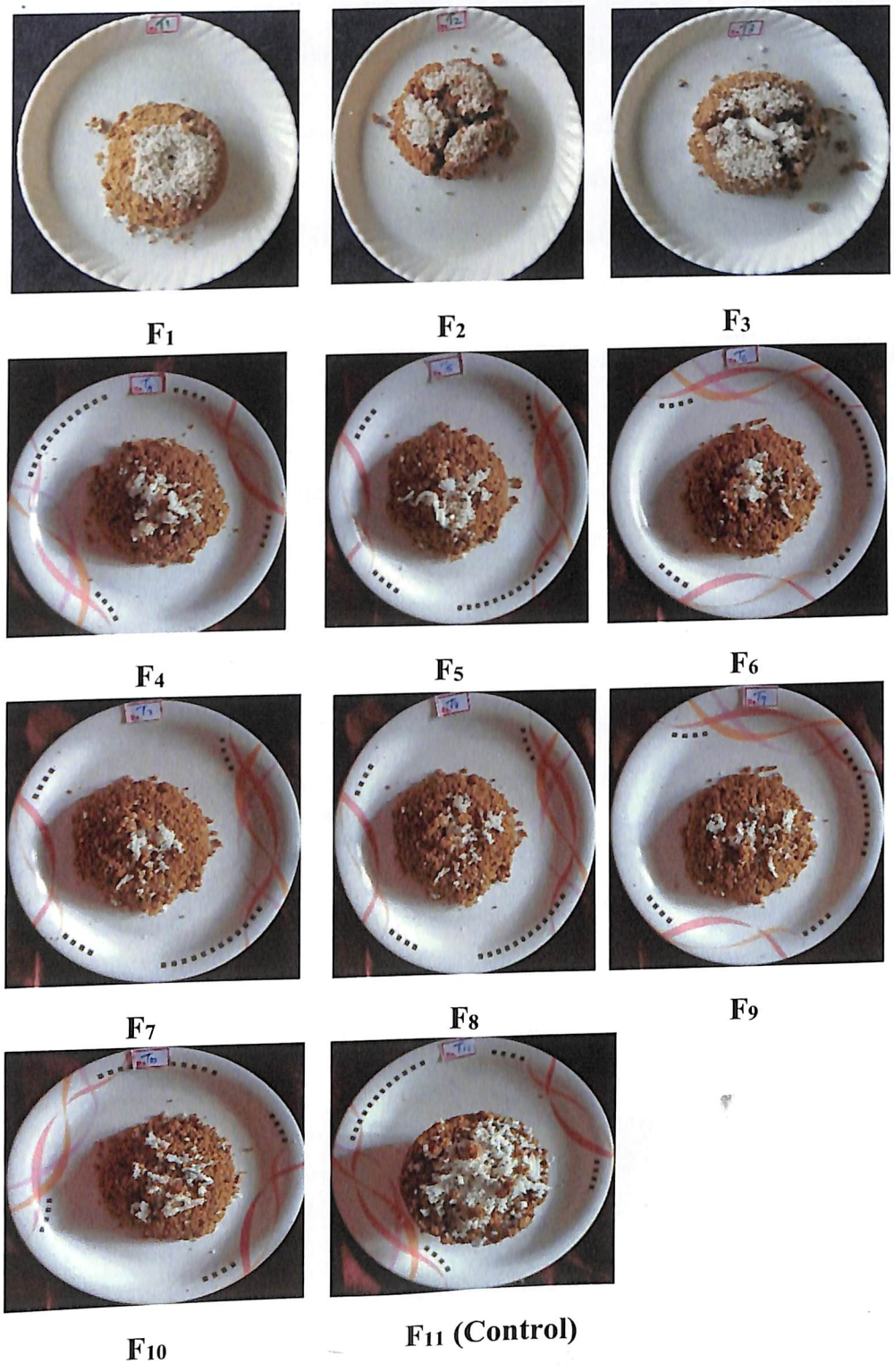


Plate 5. Organoleptic evaluation of "Puttu" formulation

The highest mean rank value for colour was obtained by F_9 (88.05) after control F_{11} (101.80); while F_2 obtained the least mean rank value (20.10).

Considering the flavour of jackfruit based "ada" (Table.31) the maximum mean score was obtained by F_{10} (81.65) after control F11 (96.38). The least score was obtained by F_3 (15.20) followed by F_2 (21.05), F_4 (29.38), and F_1 (30.60) respectively.

The maximum mean rank value for texture was observed in F_8 (87.90) which was on par with F_9 (84.80) and F_{10} (78.35) while the minimum mean rank was (16.60) was obtained by F_2.

The maximum mean rank value for taste and overall acceptability were obtained F_9 (88.75 and 87.60) and lowest mean rank value for taste was obtained by F_3 (20.15) followed by F_2 (23.65), F_5 (25.15) and F_1 (28.20).

The lowest overall acceptability was observed by F_3 (12.30). Statistical analysis of the data revealed that there was significant difference between the mean rank scores of the different quality attributes of the jack fruit based "ada" at 5% level.

Table 29. Mean scores for organoleptic evaluation of "Ada" prepared with jackfruit-based nutri flour

Treatment	Appearance		Colour		Flavour		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
F_1	35.40	5.8	53.15	5.5	30.60	6.4	24.10	4.6	28.20	3.6	14.90	3.5
F_2	21.80	5.3	20.10	4	21.05	5.8	16.60	4.2	23.65	3.4	18.55	3.8
F_3	24.40	5.4	28.80	4.4	15.20	5.4	30.60	4.9	20.15	3.1	12.30	3.2
F_4	32.80	5.7	34.95	4.7	29.38	6.1	28.50	4.8	48.15	4.5	44.10	4.7
F_5	35.10	5.8	46.40	5.2	47.90	6.9	37.00	5.2	25.15	3.4	50.40	5.1
F_6	51.95	6.4	27.30	4.3	43.83	6.3	54.80	6.2	69.50	5.4	47.20	4.9
F_7	68.75	7	68.40	6.3	65.75	7.1	59.72	6.6	54.60	4.8	61.90	5.9
F_8	76.95	7.3	54.22	5.7	80.16	8	**87.90**	**7.7**	71.70	5.6	79.30	7.2
F_9	79.35	7.4	**88.05**	**7.4**	80.15	7.9	84.80	7.4	**88.75**	**6.4**	**87.60**	**7.7**
F10	**82.25**	**7.5**	81.75	7.1	**81.65**	**8.1**	78.35	7.1	79.45	5.9	84.00	7.5
Control(F_{11})	100	8.2	101.80	8.4	96.38	8.7	102.44	8.7	101.20	7.3	101.10	8.6
K W Value	76.94		76.09		83.73		90.22		83.70		97.277	
$\lambda^2(0.05)$	18.31											

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

4.2.3. Organoleptic evaluation of 'Oratti' prepared with nutri flour

The organoleptic evaluation revealed that table 30, the mean rank value for appearance of jackfruit nutri flour based "oratti" ranged between 22.85 to 86.05. The maximum mean rank value was obtained by F_9 (86.05) followed by F_8 (83.45) and F_{10} (79.10) while the minimum mean rank value was fetched by F_3 (22.85), which was on par with F_1 (22.88) and F_5 (27.80).

In case of colour maximum mean score was observed for F_9 (91.50) after control F_{11} (103.77). The minimum score was observed in F_6 (24.80), followed by F_2 (25.60), F_3 (30.45), F_4 (33.10).

The highest mean rank value for flavour was obtained by F_9 (88.85) and the lowest mean rank value of 16.15 was obtained by F_6.

From the organoleptic analysis it was observed that the higher value for texture was obtained by F_9 (92.30) after control F_{11} (97.10) and least value for F_2 (12.65). Among all the parameters used for organoleptic analysis, taste is the most desirable characteristic for acceptability. The mean rank values for taste of the eleven treatments of "ada" ranged between 13.90 to 102.10. The highest mean rank score (87) for taste was obtained by F_9 after control F_{11} (102.10) while lowest mean rank value was obtained for F_2 (13.90).

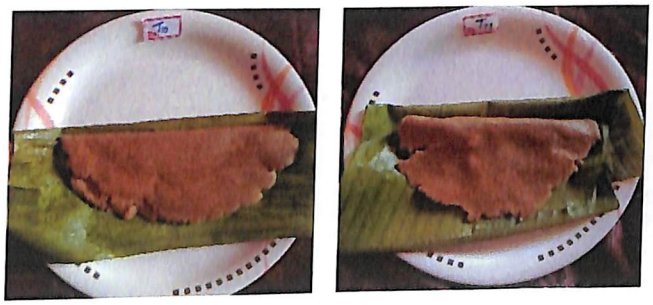
Overall acceptability of the eleven treatments is clearly depicted in table 32. Among the eleven treatments F_9 obtained the maximum mean rank value of 89.90 after the control F_{11} (101.60). Least mean rank value of 9.65 and lesser acceptability was noted for F_3. Result of tests indicates that there was significant difference in the mean rank scores obtained for the eleven treatments F_1 to F_{11}.

Statistical analysis by applying of Kruskal-Wallis test revealed that there was a significant difference between the appearance, colour, flavour, texture, taste and overall acceptability of products like '*puttu', 'ada'* and '*oratti'*.

F_1 F_2 F_3

F_4 F_5 F_6

F_7 F_8 F_9



F_{10} F_{11} (Control)

Plate 6. Organoleptic evaluation of "Ada" formulation

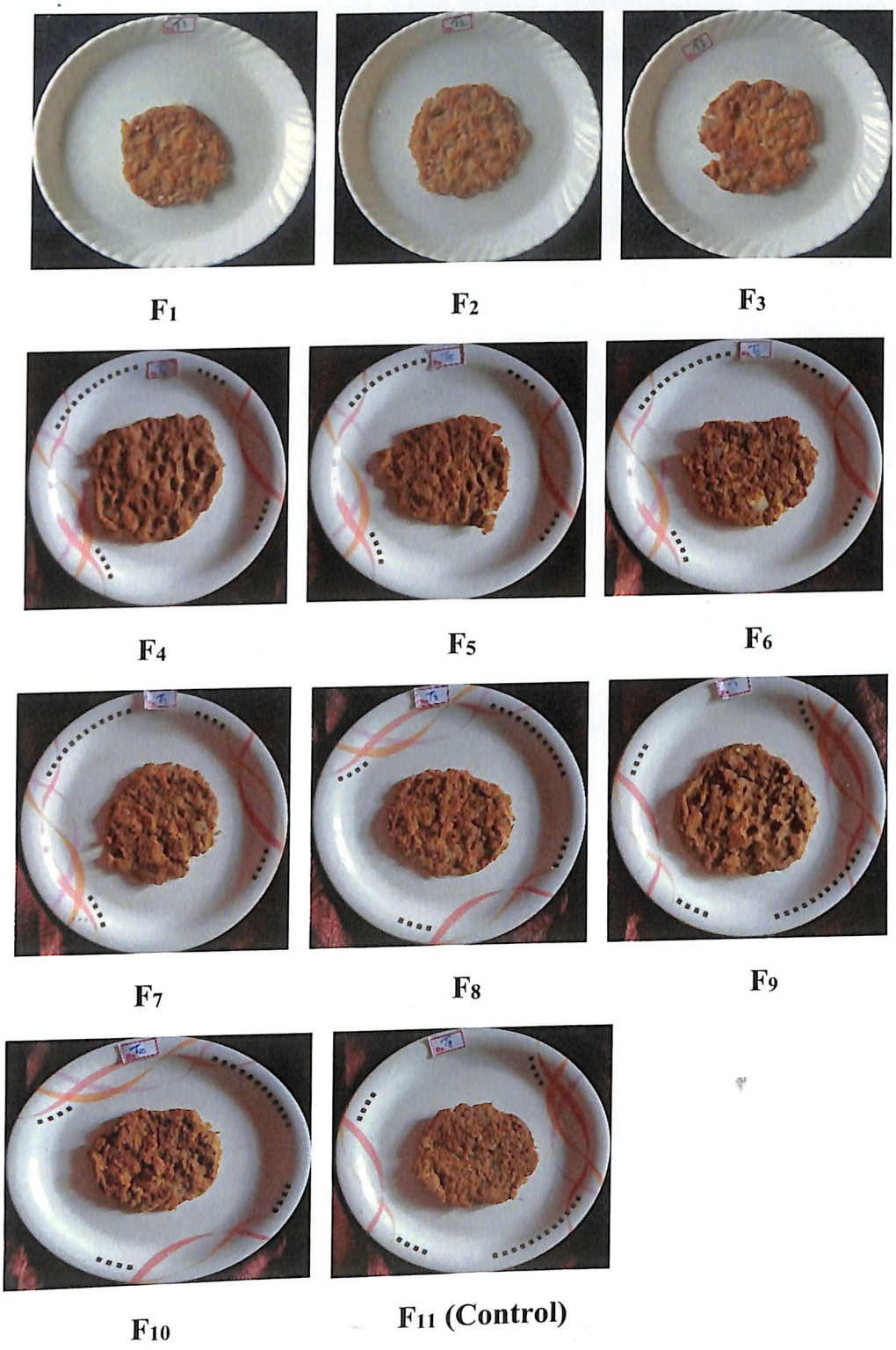


Plate 7. Organoleptic evaluation of "Oratti" formulation

On the basis of analysis of mean scores F_9 was selected as the best combination. Among the three products based on comparative scores of each parameter '*oratti'* was found to be more acceptable.

Table 30. Mean scores for organoleptic evaluation of "Oratti" prepared with jackfruit-based nutri flour

Treatment	Appearance		Colour		Flavour		Texture		Taste		OAA	
	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS	MRV	MS
F_1	22.88	5.4	49.90	5.6	40.30	6.6	19.75	5.1	26.60	4.1	26.55	4.3
F_2	32.75	5.7	25.60	4.6	19.00	5.5	12.65	4.7	13.90	3.2	31.20	4.6
F_3	22.85	5.3	30.45	4.8	33.66	6.2	25.40	5.4	23.40	3.9	9.65	3.2
F_4	35.65	5.8	33.10	4.9	16.15	5.3	29.60	5.6	46.00	5.6	33.90	4.7
F_5	27.80	5.5	42.25	5.3	37.40	6.4	40.05	6.2	21.80	3.8	49.50	5.5
F_6	54.80	6.6	24.80	4.5	31.05	5.8	61.10	7.2	62.70	5.8	43.80	5.2
F_7	64.30	6.9	63.81	6.5	74.25	7.5	57.95	6.9	66.10	5.2	71.40	7
F_8	83.45	7.8	63.40	6.2	78.55	7.7	79.55	8.1	81.90	6.3	79.20	7.6
F_9	**86.05**	**7.9**	**91.50**	**7.6**	**88.85**	**8.2**	**92.30**	**8.3**	**87.00**	**6.6**	**89.90**	**8.2**
F_{10}	79.10	7.6	85.90	7.3	82.85	7.9	85.10	7.8	76.00	6.1	77.18	7.9
Control(F_{11})	92.15	8.2	103.77	8.5	93.00	8.4	97.10	8.6	102.10	7.6	101.60	8.8
K W Value	77.78		77.99		91.64		98.67		93.25		87.80	
λ^2 (0.05)	18.31											

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

4.3. Quality evaluation of the nutri flour

Quality aspects with respects to functional properties, chemical constitution, nutritional profile, nutraceutical composition and shelf-life studies were assessed for the best formulation of nutri flour and the results are depicted in Table 31 to 37.

4.3.1. Functional properties of nutri flour

The F_9 flour formulation comprising of KJRF (20), KJTF (10), VJTF (9), VJRF (8), KJPF (8.5), VJPF (2), KJCF (2.5), VJCF (2), KJBF (12), KJSF (7), VJBF (12), VJSF (7) was analyzed for functional properties such as swelling power, solubility, water absorption capacity and bulk density.

Functional properties are affected by the complex interaction between the physical and chemical components of food along with their association with environment. These properties are essential to ascertain the activity of food components in specific conditions (Siddiq *et al.*, 2013).

In this study, the functional properties of jackfruit based nutri flour was analyzed and the results were compared with *koozha* and *varikka* bulb flour and is depicted in Table 33.

Table.31. Functional properties of jackfruit flour

Treatments	Functional qualities			
	Swelling power (g)	Solubility (%)	Water absorption capacity (%)	Bulk density (g/ml)
JNF	7.65^{b}	1.48^{b}	4.36^{b}	1.04^{a}
KJBF	7.89^{b}	1.83^{a}	4.95^{b}	1.23^{a}
VJBF	8.18^{a}	1.86^{a}	5.23^{a}	1.34^{a}
CD (0.05)	0.351*	0.172*	0.449*	NS

(Results represent mean values of three replication)

* significant @ 5%

Koozha jackfruit bulb flour (KJBF) Jackfruit based nutri flour (JNF)

Varikka jackfruit bulb flour (VJBF)

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

Swelling power

As revealed in table.31, the swelling power varied from 7.65 to 8.18g among the jackfruit flours. There was no significant variation in the swelling power of *koozha* jackfruit bulb flour (KJBF) (7.89g) and nutri flour (JNF) (7.65g). Varikka jackfruit flour (8.18g) showed that higher swelling power among treatments.

Solubility

The value of solubility varied between 1.48 to 1.86 per cent, the highest solubility was observed in *varikka* jackfruit bulb flour (VJBF) - 1.86 per cent which was on par with 1.83 for *koozha* jackfruit bulb flour (KJBF). Significant differences were ($p <0.05\%$) seen between the solubility of nutri flour and *varikka* jackfruit bulb flour (VJBF).

Water absorption capacity

The analysis revealed that jackfruit-based *Varikka* jackfruit bulb flour (VJBF) had higher water absorption capacity (5.23 %) than *koozha* jackfruit bulb flour (KJBF) (4.95 %) and nutri flour (JNF) (4.36%).

Bulk density

Bulk density is one of the most common and simple measurements in food analysis, which can be used for the analysis of solid foods. Volumes of different food products can be compared with this parameter. The bulk density of *varikka* jackfruit bulb flour (VJBF) was highest with a score of 1.34g/ml which was followed by 1.23g/ml for *koozha* jackfruit bulb flour (KJBF) and 1.04 per cent for nutri bulb (JNF). Though there was slight difference among treatments, this was statistically not significant.

4.3.2. Chemical and nutritional profile of nutri flour

In recent times, newer functions, beyond the mere supply of energy and nutrients have been assigned to nutrition, as a result food component with biological activities have been discovered. They have emerged as substantial contributors to the health-promoting effects of fruits, vegetables, nuts, seeds and wholegrain cereals, and the consumption of these foods has become an integral part of nutrition campaigns. The knowledge about optimal food sources requires data about the distribution and amounts of bioactive compounds in foods (Ritchie *et al.,* 2006).

Proximate composition

Protein, carbohydrate energy and minerals are referred to as proximate principles. Proximate and nutrient analysis of edible fruits and vegetables plays a crucial role in assessing their nutritional significance (Pandey *et al.,* 2006). The proximate composition of developed nutri flour was assessed with respect carbohydrate, protein, dietary fibre, and moisture and was compared with control.

Table. 32. Proximate composition of jackfruit flours (per 100g)

Treatments	Proximate composition			
	Carbohydrate (g)	Protein (g)	Dietary fibre (g)	Moisture (%)
JNF	31.59[a]	7.03[a]	13.58[a]	0.96[b]
KJBF	14.74[c]	5.84[b]	1.95[b]	1.28[a]
VJBF	19.79[b]	3.65[c]	1.61[b]	1.39[a]
CD	5.47*	1.80*	2.28*	NS

(Results represent mean values of three replication)

Koozha jackfruit bulb flour (KJBF) Jackfruit based nutri flour (JNF)

Varikka jackfruit bulb flour (VJBF)

Total Carbohydrate

Viscosity, sweetness, coating ability, bulk, consistency, solubility, body, texture, and browning capacity are all factors affected by carbohydrates. Chemical structural differences are particularly noticeable in diverse carbohydrates and are associated with various functional purposes.

Nutri flour had a carbohydrate content of 31.59 g/100g. This was compared with the carbohydrate content of KJBF and VJBF, which were 14.74 g and 19.79g respectively.

Protein

Proteins have a crucial role in foods by providing taste, texture, and flavour, which are important characteristics for food selection, in addition to their biological purpose in sustaining the functions of living organisms. Proteins have been investigated in a variety of industrial applications due to their varied functioning and complex molecular structure. Some examples include the adhesives, protein plastics, gels, coatings, additives and biomaterials.

As shown in Table 32, protein content was seen to vary between 3.65 to 7.03g, there was a significant difference ($p < 0.05\%$) observed between the treatments. The protein content was significantly high in nutri flour (7.03g/100g). Protein content of *koozha* jackfruit bulb (KJFB) was 5.84g and the lowest in *varikka* jackfruit bulb flour (VJBF) 7.03g.

Dietary fibre

Dietary fibres are the edible parts of plant or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. The importance of food fibres has led to the development of a large and potential market for fibre-rich products and ingredients. In recent years, there is a trend to find new sources of dietary fibre that can be used in the food industry Supplementation has been used to enhance fibre content of foods.

The dietary fibre was higher in nutri flour (13.58g/100g), and this content showed significant variation with the values of dietary fiber in *koozha* jackfruit bulb (KJBF) (1.95g/100g) and *varikka* jackfruit bulb (VJBF) (1.61g/100g).

Moisture

Moisture content of the food material is an important factor considered before consumption, because moisture content affects the physical and chemical aspects of a food that relates to freshness and stability for long-term storage. The moisture content determines the actual quality of the food before consumption and subsequent processing.

The statistical analysis revealed that there was no significant variation in the moisture content of jackfruit flours. The moisture content of nutri flour was 0.96 per cent, *koozha* jackfruit bulb flour (KJBF) 1.28 per cent, *varikka* jackfruit bulb flour 1.39 per cent.

Minerals

Total minerals

Total minerals are a measure of the total amount of minerals present within a food and it is also a measure of the amount of specific inorganic components present within a food. Minerals are elements present in the earth and food also, that are necessary for life. Minerals are required for heart and brain function, as well as hormone and enzyme production. The result reveals that, there was a significant variation ($p<0.5\%$) in the total mineral content of nutri flour with that of developed by jackfruit flours. The highest total mineral content was observed in nutri flour (0.98g) and lowest was in VJBF (0.84g).

Calcium

Calcium is a mineral found in many foods, which is essential for all living organisms especially for cell physiology. The body needs calcium to maintain strong bones and to carry out many important functions. The calcium content of nutri flour as compared with jackfruit bulb flours is depicted in Table 33. Higher calcium content was observed for nutri flour (114.32mg) followed by KJFB (106.42mg). Lowest content was noted in VJBF

(72.4mg). Significant difference

($p < 0.05\%$) seen between the calcium content of jackfruit flours.

Table 33. Mineral content of jackfruit flour per 100 g

Treatments	Mineral content								
	Total minerals (g)	Calcium (mg)	Phosphorus (mg)	Sodium (mg)	Potassium (mg)	Iron (mg)	Manganese (mg)	Copper (mg)	Zinc (mg)
JNF	0.98[a]	114.32[a]	47.92[a]	10.21[a]	418.10[a]	1.67[a]	1.59[a]	0.457[a]	0.923[a]
KJBF	0.91[b]	106.42 [b]	43.65 [b]	8.71[b]	373.52[b]	1.35[b]	0.88[c]	0.190[b]	0.523[c]
VJBF	0.84[c]	72.4[c]	30.28[c]	7.67[c]	354.11[c]	0.96[c]	0.95[b]	0.150[c]	0.827[b]
CD	0.065*	5.895*	2.619*	1.34*	15.12*	0.54*	0.178*	0.156*	0.130*

(Results represent mean values of three replication)

Koozha jackfruit bulb flour (KJBF)

Varikka jackfruit bulb flour (VJBF)

Jackfruit based nutri flour (JNF)

Phosphorus

Phosphorus is found in a wide variety of foods, but its bioavailability depends on the type of food source. Plant-based foods have a lower bioavailability of 20% to 50%, because phosphorus in these foods is a component of phytates, which the body does not absorb as easily. The results emphasize that there was significant differences ($p<5\%$) in phosphorus content of jackfruit flours. The highest phosphorus was recorded in nutri flour (114.32mg) and lowest was obtained in *varikka* jackfruit bulb (VJFB) 30.28mg.

Sodium

Sodium is both an electrolyte and mineral. Electrolytes carry an electric charge when dissolved in body fluids such as blood. Most of the body's sodium is located in blood and in the fluid around cells. Sodium helps the body to keep fluids in a normal balance. Sodium plays a key role in normal nerve and muscle function. The comparison of sodium content with bulb flours elucidated that nutri flour had the higher sodium content of 10.21mg, followed by *koozha* jackfruit bulb flour (KJBF) of 8.71mg. The least score was obtained for *varikka* jackfruit bulb flour (VJBF) with 7.67mg. A significant variation was seen in the sodium content between treatments.

Potassium

The analysis revealed that there was significant variation in the potassium content between treatments. Higher potassium content was noted for nutri flour (418.10mg) and lower amount was noted in *varikka* jackfruit flour (354.11mg).

Iron

Iron is a component of enzymes involved in the synthesis of collagen and some neurotransmitters. Iron also is needed for proper immune function. It is very necessary for normal growth and development of human body. As shown in Table. 33, iron content was found to be higher in nutri flour (1.67 µg/100g) followed by *koozha* jackfruit bulb flour (KJBF) - 1.35 µg/100g and was lowest in *varikka* jackfruit bulb flour (VJBF) - 0.96 µg/100g.Significant variation ($p<5\%$) was observed between the treatments.

Manganese

Manganese is a critical component in dozens of proteins and enzymes. The statistical analysis revealed that there was no significant variation in the manganese content of jackfruit flours. The highest manganese was recorded in nutri flour (1.59 mg) followed by *varikka* jackfruit bulb flour (VJBF) - 0.95 mg and lowest was seen in *koozha* jackfruit bulb flour (KJBF) - 0.88 mg.

Copper

Copper is an essential trace element; it is required for the synthesis and release of life-sustaining proteins and enzymes. The results emphasize that there were significant differences (p<5%) in copper content of jackfruit flours. The highest copper was recorded in nutri flour (0.457 mg) and lowest content was noted in *varikka* jackfruit bulb (VJFB) - 0.150 mg.

Zinc

Zinc plays a role in cell division, cell growth, wound healing, and the breakdown of carbohydrates Zinc is also needed for the senses of smell and taste. As revealed in Table 33, there was a significant difference in the zinc content of jackfruit flours (p <0.05%). Nutri flour had the highest zinc content of 0.92 mg followed by KJBF 0.827mg and lowest in VJBF 0.523mg.

4.3.3. Nutraceutical composition of nutri flour

Table.34. depicts the nutraceutical composition of the flour with respect to phenols, phytic acid, tannin, β carotene and antioxidants of the jackfruit flours.

Table. 34. Nutraceutical composition of jackfruit flour per 100g

Treatments	Nutraceutical components				
	Phenol (mg)	Phytic acid (mg)	Tannin (mg)	β carotene (µg)	Antioxidants (µg)
JNF	3.03[a]	167.66[a]	19.45[a]	65.98[a]	35.85[a]
KJBF	1.28[b]	145.66[b]	13.98[c]	54.50[b]	33.20[b]
VJBF	1.11[b]	144.66[b]	14.61[b]	40.55[c]	31.23[c]
CD	0.359*	19.74*	3.66*	6.27*	1.77*

(Results represent mean values of three replication)

Koozha jackfruit bulb flour (KJBF)

Jackfruit based nutri flour (JNF)

Varikka jackfruit bulb flour (VJBF)

Phenols

Naturally occurring phenols refer to the functional group phenol that is found in natural products. Statistical analysis of phenols showed that nutri flour (3.03mg) had higher phenol content followed by *koozha* jackfruit bulb flour (1.28mg) and was lowest was observed in *varikka* jackfruit bulb flour (1.11mg). There was no significant difference ($p>0.5\%$) in the phenol content of *koozha* jackfruit bulb flour (KJBF) and *varikka* jackfruit bulb flour. But significant variation ($p<0.5\%$) was observed between nutri flour and jackfruit flours.

Phytic acid

Phytic acid functions as a phosphorus store, energy store, a source of cations and a source of myo-inositol (a cell wall precursor). Phytic acid is the principal storage form of phosphorus in plant seeds. Analysis revealed that, there was significant difference in the phytic acid content of the jackfruit flours. Phytic acid was found to be higher in nutri flour (167.66mg) and lower in *varikka* jackfruit bulb flour (144.6mg). Phytic acid content of *Koozha* jackfruit bulb was - 145.66mg, the content in *koozha* and *varikka* bulb flours were on par at 5%.

Tannins

Tannins are complex chemical substances that are derived from phenolic acids and it is a class of astringent, polyphenolic biomolecules that bind to and precipitate proteins and various other organic compounds including amino acids and alkaloids. Tannin content of nutri flour was 19.45mg, while that of *varikka* jackfruit flour (VJBF) was 14.61mg and *koozha* jackfruit flour (KJBF) was 13.

98mg/100g. Significant difference ($p<5\%$) was observed between the treatments.

β carotene

β-Carotene is an organic, strongly colored red-orange pigment abundant in plants, and fruits. Plant carotenoids are the primary dietary source of provitamin A, β-carotene best-known as provitamin A carotenoid. As revealed in Table 34, there was a significant

difference in the β carotene of jackfruit flours (p <0.05%). β carotene varied between 40.55µg to 65.98 µg, the highest β carotene was observed in nutri flour - 65.98µg and the lowest was observed in *varikka* jackfruit bulb flour (VJBF) - 40.55 µg; β carotene of *koozha* jackfruit bulb flour (KJBF) was 54.50 µg. **Antioxidants**

Antioxidants are molecules that relieve oxidative stress by preventing the formation and oxidation of free radicals. The antioxidant content varied between 31.23µg to 35.85µg and there was significant difference (p <0.05%) between the treatments. Antioxidants were significantly high in nutri flour (35.85µg) followed by *koozha* jackfruit bulb (KJFB) 33.20 µg and the lowest content was observed in *varikka* jackfruit bulb flour (VJBF) 31.23µg.

Shelf-life Studies of nutri flour

Shelf-life studies play a critical role in the development of new products. The most important function of shelf-life evaluation of food is safety, followed by quality including physical, chemical, and sensorial properties. The shelf life of a product is the period of time during which the stipulated quality of the items remains acceptable under expected storage and display conditions. Shelf life of the food depends on four main factors like formulations, processing, packaging and storage. (Azanha and Faria, 2005). Product quality affects exposure to light and heat, gas transport, mechanical stresses, and contamination by microorganisms.

The shelf life of the jackfruit-based flours was analysed with respect to moisture content, sensory profile and microbial growth, initially and up to a period of six months. Storage studies in general provide a detailed picture of the storage atmosphere, packaging material and other related factors about the product's quality.

Moisture content of stored jackfruit flours

Moisture content is one of the most commonly measured properties of food materials, it influences the physical properties of a substance, including weight, density,

viscosity and conductivity. It is generally determined by weight loss upon drying. For estimating the moisture content of the jackfruit flours (JNF and JFBF), they were packed in metallic laminated pouches, sealed air tight and stored in ambient conditions. The moisture content was analyzed at regular intervals up to 6 months and the results are shown in Table. 35.

The initial moisture content of JFBF packed in laminated pouches was (1.32 %) and that of JNF was 1.28% moisture content increased significantly throughout storage period. Moisture content had gradually increased and reached 2.33% by the end of six months for JFBF and 2.28 % in JNF. A significant difference in moisture content observed during the periodic analysis.

The initial moisture content of JNF packed in laminated pouches was (1.28 %), after that the content significantly increased throughout the storage period. The moisture content of JNF packed in metallic laminated pouches increased from 1.28 to 2.28. A significant difference was observed between the periodic analysis.

The percentage increase in moisture content was higher in JFBF (1.01%) than JNF (1.00%).

Table. 35. Moisture content of packed jackfruit bulb flour and nutri flour in metalized pouches

Storage period	Moisture (%)	
	JFBF	JNF
Initial	1.32	1.28
1st month	1.61	1.56
2nd month	1.87	1.85
3rd month	2.14	2.12
4th month	2.28	2.25
5th month	2.31	2.26
6th month	2.33	2.28
Increase (%)	1.01	1.00
CD	0.068	0.063

(Results represent mean values of three replication)

Jack fruit bulb flour (JFBF)

Jackfruit based nutri flour (JNF)

Microbial profile of stored jackfruit flours

Microbiological quality is a major concern in the food industry because of the acute risk to health posed by bacteria, mold, and yeast. Microbial analysis of the nutri flour standardised in this study was conducted to determine the keeping quality. Jackfruits parts were subjected to pretreatments like blanching and boiling to ensure absence of pathogenic microorganisms. The microbial analyses were conducted at monthly intervals and the details are presented in Table.36.

The analysis revealed that there were no bacterial colonies found in $1x10^{-6}$ and $1x10^{-7}$ dilution up to 4 months of storage in jackfruit bulb flours and nutri flours. After fifth month of storage 2 and 1.33 bacterial colonies in jack fruit bulb and 1.66 and 1.00 colonies in nurtri flour, were observed in 10^{-6} and 10^{-7} dilution respectively. After sixth month of storage 2.66 and 2.33 bacterial colonies in jack bulb flour and 2 and 1.66 colonies were found in nutri flour at the dilutions of 10^{-6} and 10^{-7} respectively.

The results further revealed that there was no fungal growth in both jackfruit bulb flours and nutri flours initially as well in the first and second month. After 3 months, the fungal growth was seen to increase from 1.66 to 4 cfu/ml in jack fruit bulb flour and 1.33 to 3.66 cfu/ml in nutri flour at 10^{-4} dilution and between 1.33 to

3.33 cfu/ml observed in jackfruit bulb flour and 1.00 to 3 cfu/ml in nutri flour at10^{5} dilution. There were no coliforms found during the six-month storage period.

Table. 36. Colony count of microbes on agar plate into 10^{-6} and 10^{-7} dilution

Storage periods	Bacteria (cfu/ml)				Fungi (cfu/ml)			
	10^{-6}		10^{-7}		10^{-4}		10^{-5}	
	JFBF	JNF	JFBF	JNF	JFBF	JNF	JFBF	JNF
Initial	ND	ND	ND	ND	ND	ND	ND	ND
After1month	ND	ND	ND	ND	ND	ND	ND	ND
After 2 month	ND	ND	ND	ND	ND	ND	ND	ND
After 3 month	ND	ND	ND	ND	1.66	1.33	1.33	1.00
After 4 month	ND	ND	ND	ND	2.0	2.33	1.66	1.33
After 5 month	2.0	1.66	1.33	1.0	3.33	3.00	2.66	2.0
After 6 month	2.66	2.0	2.33	1.66	4.00	3.66	3.33	3.0

(Results represent mean values of three replicates), CFU/ml- Colonies forming unit/ml), (ND - No colonies detected)

Jack fruit bulb flour (JFBF), Jackfruit based nutri flour (JNF)

Organoleptic Qualities of selected jackfruit-based nutri flour and jackfruit bulb flour –during storage

Organoleptic evaluation of a food product during storage is important as far as food manufacturers are concerned. Sensory profile is the most important criterion for a new food product in the market. Organoleptic evaluation of food products undergoes a variety of changes during storage, including chemical, microbiological, enzymatic, and physical alterations. Taste, colour, flavour, texture, and appearance are all altered, as a result of these factors. Organoleptic evaluation is used to track these changes, and thus the expiry date can be calculated by compiling chemical and sensory parameters.

Table.37 showed that initially the mean score for appearance in JFBF and JNF was 8.25 7.96 respectively. A gradual reduction in the mean scores were observed from first month to after six months of storage, the score was reduced to 8 in JFBF and 7.43 in JNF. With respect to colour, JFBF had a higher score of 8.52 than JNF (7.64) during the initial period, which on storage decreased to 8.15 to 7.21 after six months of storage. The mean score for flavour of JFBF and JNF were 8.44 and 8.26 initially, which gradually reduced to 7.25 and 7.32 respectively after six months of storage. Initially the mean score for texture of JFBF was 8.63 and JNF 8.32, after 6 months it also got reduced to 7.54 and 7.22 respectively. With regard to taste, JFBF had a higher score of 7.66 than JNF (6.66), the mean rank value decreased from 6.20 to 5.32 after six-month storage. The overall acceptability was higher in JFBF (7.21) than JNF (6.82) respectively after six months of storage.

Table. 37. Mean scores of organoleptic qualities of jackfruit-based nutri flour and jackfruit bulb flour on storage

Quality attributes	Storage period in months													
	Initial		1		2		3		4		5		6	
	JFBF	JNF	JFBF	JNF	JFBF	JNF	JFBF	JNF	JFBF	JNF	JFBF	JNF	JFBF	JNF
Appearance	8.25	7.96	8.25	7.94	8.25	7.68	8.20	7.57	8.13	7.42	8.08	7.52	8.00	7.43
Colour	8.52	7.64	8.43	7.58	8.44	7.45	8.41	7.41	8.36	7.32	8.24	7.27	8.15	7.21
Flavor	8.44	8.26	8.24	8.22	8.21	7.96	7.85	7.92	7.80	7.76	7.75	7.64	7.25	7.32
Texture	8.63	8.32	8.62	8.30	8.28	8.10	8.12	8.00	8.04	7.65	7.94	7.42	7.54	7.22
taste	7.66	6.66	7.43	6.42	7.38	6.20	7.24	6.13	7.11	5.94	6.85	5.64	6.20	5.32
OAA	8.85	8.28	8.36	8.16	7.92	7.86	7.95	7.66	7.63	7.42	7.54	6.98	7.21	6.82
Total score	50.35	47.12	49.33	46.62	48.48	45.25	47.77	44.69	47.07	43.51	46.4	42.47	44.35	41.32

(Values are expressed as mean values of ten replicates

4.4. QUALITY IMPROVEMENT OF NUTRI FLOUR

Flour quality is not a static entity, which is dependent on methods of testing and also parameters evaluated. Flour is a biological material and when obtained from different sources can vary considerably in its protein quality, protein quantity, ash, moisture, enzymatic activity, color, and physical properties. In the present study, oligosaccharide contents and invitro starch digestibility were evaluated in this regard.

Oligosaccharides

Oligosaccharide is a carbohydrate comprised of few saccharides, *i.e.*, about three to ten monosaccharide units. Most types of oligosaccharides are indigestible, so they move through small intestine to large intestine, where bacteria finally break them down. Oligosaccharides help prevent constipation, but they could also cause bloating and gas.

4.4.1. Treatment with *Saccharomyces cerevisiae*

To reduce the level of oligosaccharides, nutri flour was made into batter and subjected to fermentation with *Saccharomyces cerevisiae* @ 5g/kg for 8hrs (Anila, 2018).

Reduction of oligosaccharide content in nutri flour

The oligosaccharide (Stachyose) and sugar content in untreated and treated (*Saccharomyces cerevisiae)* nutri flours were analysed by the analytical tool - HPLC and the results are presented in Table. 38 to 40.

Table. 38. Quantification of Oligosaccharide (stachyose) content in untreated and yeast treated nutri flour (@ 8 hours)

Treatments	Retention Time (min)	Area (AU)	Concentration (ppm)	Percentage of stachyose
Standard (Stachyose)	6.93	-	-	-
F_1 (control)	6.93	594387	14172.6	9.76
F_2 (8 hours) after treatment	6.93	258785	6182.116	1.54

In HPLC analysis, the retention time of standard stachyose was 6.93. Retention time recorded in the untreated nutri flour and nutri flour with 8 hrs fermentation was also 6.93 min. Stachyose percentage in untreated nutri flour was computed as 9.76 % and that in treated nutri flour was 1.54%. Nutri flour treated with *Saccharomyces cerevisiae* was found to be lower in oligosaccharides compared to control.

Table. 39. Quantification of monosaccharide contents in untreated and yeast treated nutri flour

Treatments	Retention Time (min)	Area (AU)	Concentration (ppm)	Percentage of monosaccharides
Standard (Glucose)	10.13	-	-	-
F_1 (control)	10.13	1011340	10577	9.76
F_2 (8 hours) after treatment	10.13	29571	9.118	1.54
Standard (fructose)	10.89	-	-	-
F_1 (control)	10.89	1791793	10658	7.28
F_2 (8 hours) after treatment	10.89	48726	0.6421	Nil
Standard (Galactose)	10.67	-	-	-
F_1 (control)	10.67	1542684	10725	6.52
F_2 (8 hours) after treatment	10.67	26418	0.4584	Nil

Analysis of monosaccharide levels were also taken up. Table.39 shows the monosaccharides such as glucose, fructose and galactose content in untreated and treated flour samples with (*Saccharomyces cerevisiae)* as observed in HPLC assay. The retention time of standard glucose was 10.13min, which was similar in both treated and un treated nutri flour (10.13). Glucose percentage in untreated nutri flour was 9.76% and that in treated was 1.54%.

The percentage of fructose, in treated and untreated nutri flour was 7.28%, and nil, before and after treatment respectively.

The retention time of standard galactose, treated and untreated nutri flour was found to be 10.67min. The level of galactose was compared with treated and un treated nutri flour. The result showed that percentage of galactose was high in un treated nutri flour (6.52 %) and was nil in treated flour.

Table.40. Quantification of Rhamnose and Arabinose content in untreated and yeast treated nutri flour (@ 8 hours)

Treatments	Retention Time (min)	Area (AU)	Concentration (ppm)	Percentage of Oligosaccharides
Standard (Rhamnose)	11.53	-	-	-
F_1 (control)	11.53	22935	0.127	0.00003
F_2 (8 hours) after treatment	11.53	NIL	Nil	Nil
Standard (Arabinose)	11.37	-	-	-
F_1 (control)	11.37	7908	0.287	0.0001
F_2 (8 hours) after treatment	11.37	Nil	Nil	Nil

The content of rhamnose and arabinose, treated with *Saccharomyces cerevisiae* and untreated nutri flour as observed after HPLC assay are tabulated in Table. 40. In HPLC analysis the retention time of standard rhamnose was 11.53 min. Retention time recorded in both untreated and treated nutri flours were also same. Percentage of rhamnose was found in very minute quantities in un treated nutri flour (0.00003%) and for treated flour it was totally absent.

The retention time of standard arabinose, treated and untreated nutri flour was found to be 11.37min. The result showed that percentage of arabinose was absent in treated nutri flour and in un treated flour arabinose content was found in negligible amount of 0.0001%.

4.4.2. *In vitro* starch digestibility

In vitro digestion is to simulate the digestive process in human beings. Since digestion of food in humans is a very complex process, perfect simulations are not yet possible. Enzymes are present in digestive fluids as well as in the brush border of the small intestine (Smith and Morton, 2001). Starch digestion (SD) is characterized by the rate and the duration of postprandial glycemic response. Starch can be undigested, rapidly digested or slowly digested. Starch granule characteristics, state, size, processing methods and presence of other ingredients all influence starch digestibility.

Table.41. *In vitro* starch digestibility of nutri flours

Treatments		
	Untreated nutri flour (F_1)	Yeast treated nutri flour @ 8 hours (F_2)
Invitro starch digestibility (%)	54.84	82.81
Mean difference	27.97	
t value	1)3.35	
Significance	0.001	
	S	

In vitro starch digestibility of un treated nutri flour and yeast treated nutri flours (*Saccharomyces cerevisiae*) were statistically compared by applying independent 't' test and is presented in table 41. Invitro starch digestibility was significantly high in yeast treated nutri flour (82.81 per cent) when than untreated nutri flour (54.84 per cent).

4.5. ASSESSMENT OF IN VITRO THERAPEUTIC EFFICACY OF NUTRI FLOUR

There are various approaches available to alleviate and treat diseases and use of medical nutrition therapy (MNT) is considered an important one in this regard. Medication along with MNT plays a synergistic role in the management of various diseases. Jackfruit shows many therapeutic qualities; it boosts immunity and lowers blood sugar levels. Jackfruit, which is rich in protein, Vitamin A, C, potassium, antioxidant properties, high fibre content and low glycemic index makes it a healthy snack for diabetic patients and also other decreased conditions. In the present study, using in vitro methods, anti-diabetic, hypolipidemic and hepatoprotective activity of nutri flours were analysed and the results are depicted in Table. 42 to 45.

4.5.1. Anti-diabetic activity

Morbidity due to diabetes, is on the rise; medicinal plants are widely used for the treatment and prevention of diabetes. The medicinal plants or natural products involve retarding the absorption of glucose by inhibiting the carbohydratehydrolyzing enzymes, such as *α*-glycosidase and, *α*- amylase. More ever they are mostly safe and have no side effects (Olubomehin *et al.,* 2013).

The successful prevention of the onset of diabetes consists in controlling postprandial hyperglycemia by the inhibition of α-glucosidase and α-amylase activities, resulting in aggressive delay of carbohydrate digestion to absorbable monosaccharides. In the present study, anti-diabetic activity was investigated through α-glucosidase and α-amylase inhibitory activity, after extracting the bioactives with different solvents such as petroleum ether, ethanol and distilled water from the jackfruit-based nutri flours and compared with the control sample acarbose (*α*-glycosidase and α -amylase inhibitors).

4.5.1.a. α -amylase inhibitory assay

Table 43. shows the percentage inhibition at 100, 50, 25, 12.5 and 6.25 µg/mL concentrations of nutri flour extracts, that showed a concentration dependent reduction in

percentage inhibition. Thus, the petroleum ether extraction of nutri flour at concentration of 100 µg/mL showed a maximum inhibition of 47.17% on the activity α -amylase, with an IC_{50} value 40.86 µg/mL and the standard acarbose showed the inhibitory activity of 94.41% on the activity α -amylase with an IC_{50} value 78.12µg/mL The lowest inhibition was exhibited at the concentration of 6.25 µg/mL (20.35±0.446). The ethanolic extracts of nutri flour at the concentration of 100 µg/mL showed 26.69% inhibitory activity on α -amylase with an IC_{50} value

28.56µg/mL, and at concentration of 6.25 µg/mL it exhibited very low α -amylase inhibitory activity of 8.27%. The extraction with distilled water did not show αamylase inhibitory activity. Petroleum ether extracts of nutri flour showed appreciable α-amylase inhibitory effects when compared with acarbose.

Table.42. α -amylase inhibitory assay of nutri flour with Acarbose (standard)

Sample	**Concentration (µg/L)**	**OD at 540nm**	**% of Inhibition**	**IC_{50} (µg/L)**
Blank	-	0.980	-	
Control	-	0.031	-	
Acarbose (standard)	6.25	0.645	34.18±0.599	78.12
	12.5	0.543	45.48±0.540	
	25	0.282	74.39±0.436	
	50	0.115	90.14±0.605	
	100	0.076	94.41±0.507	

Table.43. α -Amylase inhibitory assay of nutri flour in different solvents

Sample	Concentration (µg/L)	OD at 540nm	% of Inhibition	IC_{50} (µg/L)
Blank	-	0.708	-	
Control	-	0.014	-	
PE	6.25	0.562	20.35±0.446	40.86
	12.5	0.525	25.91±0.248	
	25	0.510	27.66±0.418	
	50	0.473	42.59±0.660	
	100	0.450	47.17±0.459	
ETOH	6.25	1.21	8.27±0.557	28.56
	12.5	1.18	13.68±0.841	
	25	1.12	18.24±0.526	
	50	1.04	21.50±0.426	
	100	0.92	26.69±0.692	
DW	6.25	1.21	-	-
	12.5	1.16	-	
	25	1.05	-	
	50	0.997	-	
	100	0.988	-	

– PE – Petroleum ether, ETOH – Ethanol, DW- Distilled water

4.5.1.b. α -Glucosidase inhibitory assay

Table 44. shows the invitro α -Glucosidase inhibitory assay of acarbose. The percentage inhibition at 100, 50, 25, 12.5 and 6.25 µg/mL concentrations of acarbose showed a concentration dependent reduction in percentage inhibition.

Acarbose (at a concentrations 100 µg/mL) showed 97.42% inhibitory effects on the activity α -Glucosidase with an IC_{50} value of 80.33 µg/mL.

The petroleum ether extracts of nutri flour (at a concentration 100 µg/mL) exhibited 63.93% of α -Glucosidase inhibitory activity with an IC_{50} values 43.82 µg/ml. The ethanol extracts of nutri flour (at a concentration 100 µg/mL) exhibited 45.62% of α-Glucosidase inhibitory activity with an IC_{50} values 32.05 µg/mL. The distilled water extract of nutri flour α -Glucosidase showed the lowest inhibitory activity compared to petroleum ether and ethanolic extracts. At the concentration of 100 µg/mL they exhibited 13.85% of α -Glucosidase inhibitory activity with an

IC_{50} values 22.15 µg/mL (Table.45) Both petroleum ether and ethanol extracts of nutri flour showed appreciable α -Glucosidase inhibitory effects.

Table.44. α -Glucosidase inhibitory assay of nutri flour with Acarbose (standard)

Sample	Concentration (µg/L)	OD at 400nm	% of Inhibition	IC_{50} (µg/L)
Blank	-	0.704	-	
Control	-	0.026	-	
Acarbose (standard)	6.25	0.567	20.33±0.486	80.33
	12.5	0.442	37.09±1.191	
	25	0.208	73.75±0.792	
	50	0.050	95.73±0.468	
	100	0.042	97.42±0.482	

Table.45. α -Glucosidase inhibitory assay of nutri flour in different solvents

Sample	Concentration (µg)	OD at 400nm	% of Inhibition	IC_{50} (µg/L)
Blank	-	0.66	-	
Control	-	0.06	-	
PE	6.25	0.59	22.54±0.560	43.82
	12.5	0.58	33.31±0.525	
	25	0.57	44.52±0.363	
	50	0.56	56.61±0.692	
	100	0.54	63.93±0.729	
ETOH	6.25	0.62	15.56±0.536	32.05
	12.5	0.61	26.81±0.465	
	25	0.56	36.22±0.736	
	50	0.52	43.02±0.983	
	100	0.51	45.62±0.644	
DW	6.25	0.68	0.84±0.186	22.15
	12.5	0.63	3.38±0.450	
	25	0.62	6.12±0.343	
	50	0.61	7.98±0.490	
	100	0.57	13.85±0.591	

PE – Petroleum ether, ETOH – Ethanol, DW- Distilled water

4.5.2. Hypolipidemic activity of nutri flour

In an *in-vitro* hypolipidemic activity study of different fractions of nutri flour in petroleum ether, ethanol and water extracts were separately examined for inhibition of *β*-hydroxy-*β*-methyl glutaryl coenzyme A reductase (HMG-CoA reductase).

Table 46 depicts the *in-vitro* hypolipidemic effects of jackfruit based nutri flour extracts on the activity of HMG-CoA reductase; the key limiting enzyme of cholesterol

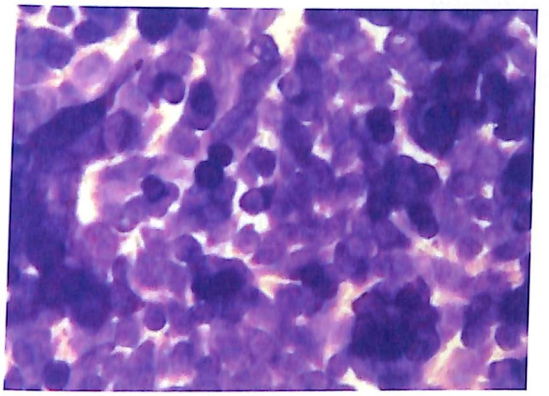
biosynthesis. Results revealed that the nutri flour extracts in petroleum ether recorded higher inhibition percentages of this enzyme than other fractions
(78.06%) comparable to fenofibrate drug (93.51%). The ethanol extracts of nutri flour exhibited 43.17% of inhibition. The lowest inhibition percentage was observed in nutri flour extract in distilled water 39.53%.

Table.46. Hypolipidemic activity of nutri flour

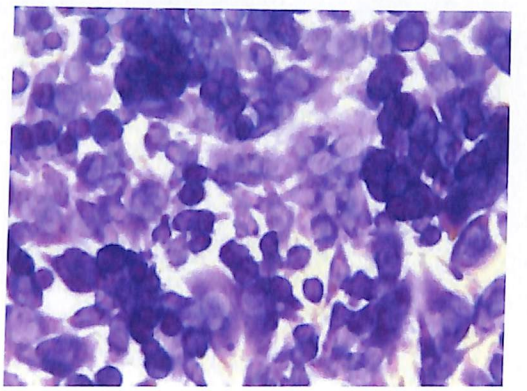
Sample	Enzyme activity(µg/L) (*β*-glutaryl hydroxy-*β* CoA-reductase)	% of Inhibition
Control	15.30	-
(Fenofibrate; 100µg) (standard)	0.99	93.51±2.628
PE	3.36	78.06±1.873
ETHANOL	8.69	43.17±1.861
WATER	9.25	39.53±1.151

4.5.3. Hepato protective effect of nutri flour

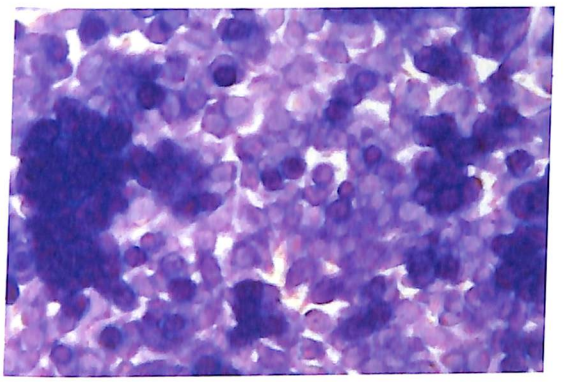
Oxidative stress becomes a detrimental condition when Reactive Oxygen Species (ROS) is an excess. ROS could damage biological molecules such as proteins, deoxynucleic acid, and lipid membranes, which cause apoptotic or necrotic cell death by disrupting cellular function and integrity. HepG2 cells (Human liver carcinoma cells) have been exploited as models to study the hepatoprotective effect of the test compounds. H_2O_2 is widely used as an inducer of oxidative stress in in-vitro models, which could lead to cell death. In addition, it is also reported that the cell damage effects induced by H_2O_2 could be attenuated by treating with antioxidants. Therefore, the protective effect of the test compounds on cell death induced by H_2O_2 was investigated by HepG2 cell model.



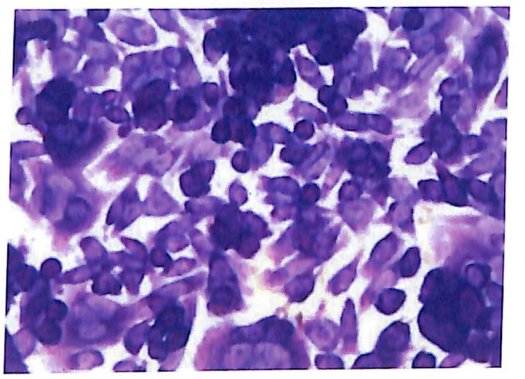
Control



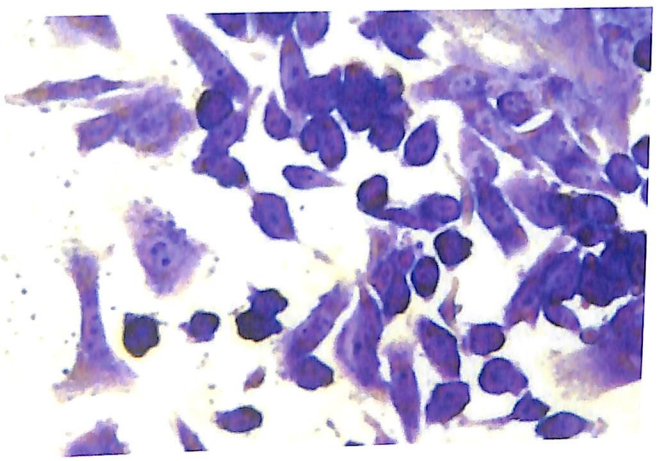
25ug/ml



50ug/ml



100ug/ml



H_2O_2 30ug/ml

Plate. 8. Cell viability after focus Formation Assay

Table.47. Hepato protective effects of nutri flour

Sample	% of cell viability
Control	100±0.000
H_2O_2 (standard)	51.89±2.772
25 JNFµg/l	96.63±2.437
50 JNFµg/l	99.62±1.310
100 JNF µg/l	81.47±1.131

Table.47 shows the MTT assay results of the jackfruit nutri flour in three different concentrations 25ug/ml, 50ug/ml and 100ug/ml showing significant hepatoprotective property. Antiproliferative activity of H_2O_2 on HepG2 cell lines was used as the standard. Cells treated with 50 ug/ml showed comparable proliferation with control (99.62%). When treated with 100ug/ml concentration the percentage of cell viability was reduced to 81.47%.

The results of developed jackfruit based nutri flour and its quality analysis of the standardized flour is discussed in the following chapter.

Discussion

5. DISCUSSION

The result of the study entitled "Development and quality evaluation of a jackfruit based nutri flour" are discussed in the chapter under the following heads:

5.1. Determination of glycemic index of jackfruit parts

5.2. Development of nutri flour

5.3. Quality evaluation of nutri flour

5.4. Quality improvement of nutri flour

5.5. Assessment of in vitro therapeutic efficacy of nutri flour

5.1. DETERMINATION OF GLYCEMIC INDEX OF JACKFRUIT PARTS

5.1.1. Selection and collection of jackfruits

In recent years, the demand of instant food mixes is increasing day by day due to increase in urbanization, breaking up of the traditional joint family system, fast life, convenience and changing lifestyles. Low calorie and highly nutritious instant food mixes are preferred more by consumers. The food industry has focused its efforts in the development of new products, with properties that not only provide the necessary nutrients for human food, but also help prevent diseases related to nutrition such as diabetes, obesity, hypertension, and cardiovascular complications. It has been found that there is a significant correlation between the regular intake of phytochemicals and the prevention of many lifestyle-related diseases. (Gresele *et al.*, 2016).

Jackfruit could be considered as a functional food because it has valuable compounds in different parts of the fruit that display functional and medicinal effects. This largest tree-borne tropical fruit in the world, (*Artocarpus heterophyllus Lam*), belongs to the Moraceae family. It is a monoecious evergreen tree that is thought to be native to the rain forests in the southwest of Western Ghats. It used to be a staple meal in India and is available in the market from spring to summer under the names '*kanthal', 'kathal',* and '*kathar'*. About 60% of the whole jackfruit consists of inedible parts such as outer prickly

rind, inner perigones, and central core and only around 35% of the whole fruit consist of edible flesh (Baliga *et al.,* 2011).

Jackfruit has also been reported to have therapeutic qualities since ancient times. It is used in traditional medicine as an analgesic and immunomodulator. Jackfruit is gluten free and casein free, thus offering systemic anti- inflammatory benefits to skin. The fresh fruit contains health promoting constituents including antioxidants, minerals, vitamins (such as A, C, and E) phytochemicals, (such as folate glucosinolates, carotenoids, flavonoids and phenolic acids lycopene, selenium) Jackfruit contains more protein, calcium, iron, and other essential nutrients in comparison to the common fruits (Prem *et al.,* 2015).

In the present study, a jackfruit cv. *Koozha* and *varikka* based nutri flour was developed on the basis of glycemic index of the various parts of the fruit. Raw jack fruits (12 weeks maturity) were selected from the trees grown in the Instructional farm, College of Agriculture, Vellayani. The bulbs, perigones, seeds, rind, core and testa were separated. Since quality cannot be increased after harvest, it is critical to harvest fruits, vegetables, and flowers at their peak stage and size. Fruits that are immature or overmature may not stay long during storage, as fruits that arre harvested at the right maturity (Wilson *et al.,* 2015)

5.1.2. Pre processing of Jackfruit

The Jackfruit cultivars *koozha* and *varikka*, were picked up fresh from the farm, their whole weights were noted. As the fruit is big in size, it was cut into big pieces, the bulbs, perigones, seeds, rind, core and testa were separated out. Jackfruit parts were cleaned with distilled water to remove any external impurities that had adhered to it during transportation. Gill *et al.* (2009) reported that fruits and vegetables often contain a great diversity of microflora and are frequently involved in food-borne outbreaks, the quality of water used for washing is crucial. Washing was done to remove dirt, pesticides and to detach microorganisms and to enhance quality. Weight of bulbs, perigones, seeds, rind, core and testa were recorded separately to get the final yield, percentage components, fresh

and dry weight, moisture percentage, processing loss and dry matter percentage of the product.

The jackfruit tree (*Artocarpus heterophyllus Lam*) yields more than any other tree species and bears the largest edible fruits known (up to 35 kg). Jackfruit typically weighs 4.5–30 kg, while as high as 50 kg has also been reported (Matin *et al.*, 2017). Krishnan *et al.* (2015) reported that the total fruit weight ranged between
1.69 to 17.50 kg. The total bulb weight and seed weight in this study varied between 0.80 to 10.25kg and 0.16 to 3.63 kg respectively. Veenakumari (2015) reported that the weight of rind, perigones and outer covering ranged from 41.85 to 54.01 per cent. Ejifor *et al.* (2014), reported that jackfruits consisted of 29% pulp, 12% seeds and 54% rind. Srivastava and Singh (2020) stated that the compound jackfruit is made up of three parts: the bulb, seeds, and rind, which account for 30-32, 18 and 50-55 percent respectively of the total weight. In the present study, the total fruit weight of *koozha* ranged between 11.54 to 21.5kg, the total bulb, seed, perigones, testa, rind and core ranged between 4.60 to 11.94kg, 2.10 to 5.48 6.92kg, 0.63 to 1.72kg, 0.142 to 0.223g, 1.12 to 3.83kg and 0.825 to 1.86kg respectively. The total fruit weight of *varikka* ranged between 10.54 to 20.36kg, the total bulb, seed, perigones, testa, rind and core varied between 4.07 to 9.42kg, 2.27 to 6.92kg,0.645 to 0.996g, 0.070 to 0.215kg, 0.998 to 3.05kg and 0.82 to 1.86kg.

Drying removes moisture, as a result the product shrinks and reduces in size and weight, requiring less storage space. As foods are processed, they usually lose volume or weight. The amount of water in the original product has a direct relationship with the yield of dried products. Percentage composition of the jackfruit (cv *koozha* and *varikka*) parts were analysed and the results are presented in the tables 1 to 18. The mean percentage composition of *koozha* and *varikka* bulbs was 45.09 to 43.33 respectively that of seeds were 25.88 to 36.12 respectively, that of perigones were 5.57 to 5.24 respectively, that of testa was 1.12 to 1.97 per cent, that of rind was 12.93 to 11.77 and in for core it was 6.81 to 6.86 respectively. The highest percentage composition was obtained in jackfruit *koozha* compared to *varika* jackfruit because of increase in amount of flour, the yield was also increased.

In a related study on jackfruit based ready to cook products, yield ratio ranged from 35.90 to 37.32 per cent, the yield ratio of jackfruit 'avial' mix was 37.22, 'kootu' mix 35.9, and 'olath' mix 37.32 (Liji, 2014). Another study conducted by Veenakumari (2015) reported that yield ratio of jackfruit based mextruded product varied from 0.86 to 0.97 per cent. Sahoo (2016) reported that with higher amount of jackfruit bulb flour the yield of baked product was higher, jackfruit-based rusk obtained higher yield (63.15%) than the control rusk (56.38%).

The term "processing loss" refers to the removal of non-edible parts of the raw material as well as the decrease of moisture. Drying removes moisture, which reduces weight. The processing loss of the jackfruit (cv *koozha* and *varikka*) bulbs was 79.29 and 84.87 per cent respectively and that of seeds were 86.96 to 88.54 per cent respectively. This difference might be due to the difference in the size, shape and composition of the edible parts. Composition of the fruit varies with tree, location and climatic condition. This study was in line with findings of Veenakumari (2015) who reported that processing loss of jackfruit ranged from 66.45 to 73.98 per cent. Another study conducted by Swami *et al*. (2012) reported that jackfruit is very heavy and bulky, the actual recovery of bulbs or edible portion varies from 20 to 25%.

The difference in dry matter content is corresponding to the difference in moisture content. In the present investigation, the mean value of dry matter percentage of *koozha* and *varikka* bulbs ranged from 26.64 to 53.22 per cent. Dry matter of seeds, perigones, testa, rind and core of both cultivars had varied between
39.93 to 63.33 per cent, 41.83 to 50.85 per cent, 15.71 to 46.63 per cent, 34.66 to 58.03 per cent and 46.66 to 53.57 per cent respectively. This was in line with findings of Goswami and Chacrabati, (2016) that, dry matter of jackfruit seed varied between 35.50% to 47.00%. Another study reported by Abedin *et al.* (2012) reported the dry matter content of jackfruit seeds of different varieties Khaja, Gala and Durosha seeds ranged from 21.10% to 42.25%, 57.75% to 78.90% and 29.24% to 48.23% respectively.

Fig.2. Fresh weight of cv. *Koozha* and cv. *Varikka* parts

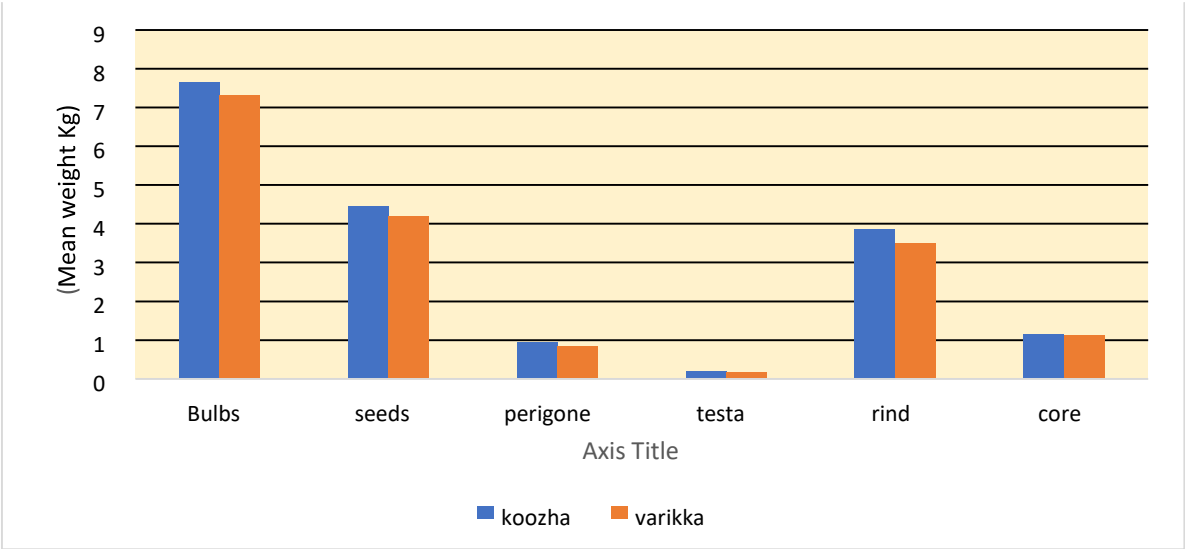


Fig.3. Dry weight of cv. *Koozha* and cv. *Varikka* parts

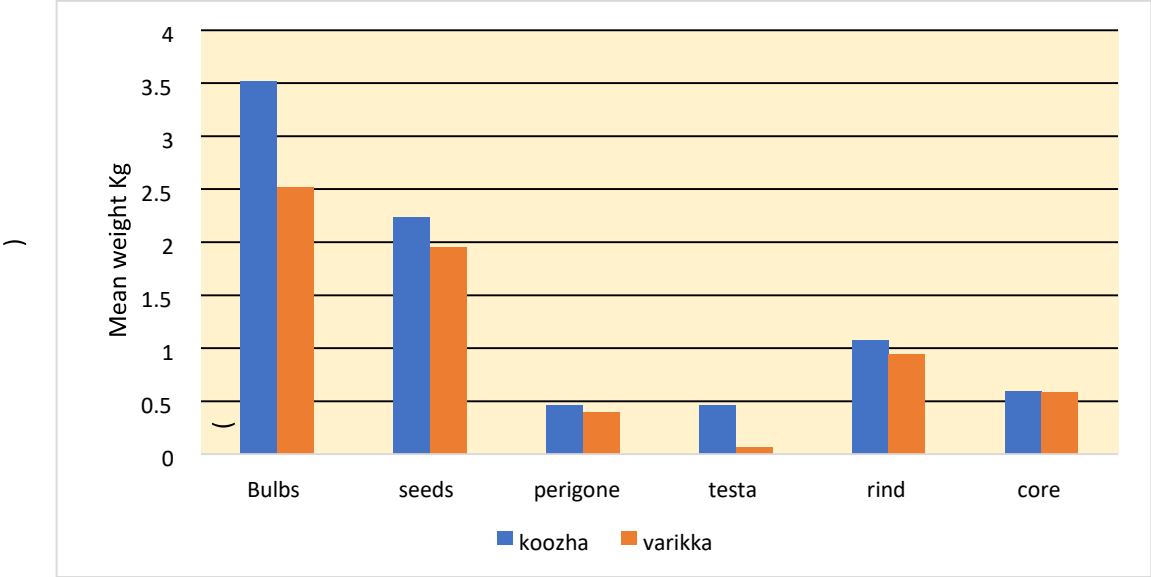


Fig.4. Percentage composition of cv. *Koozha* and cv. *Varikka* parts

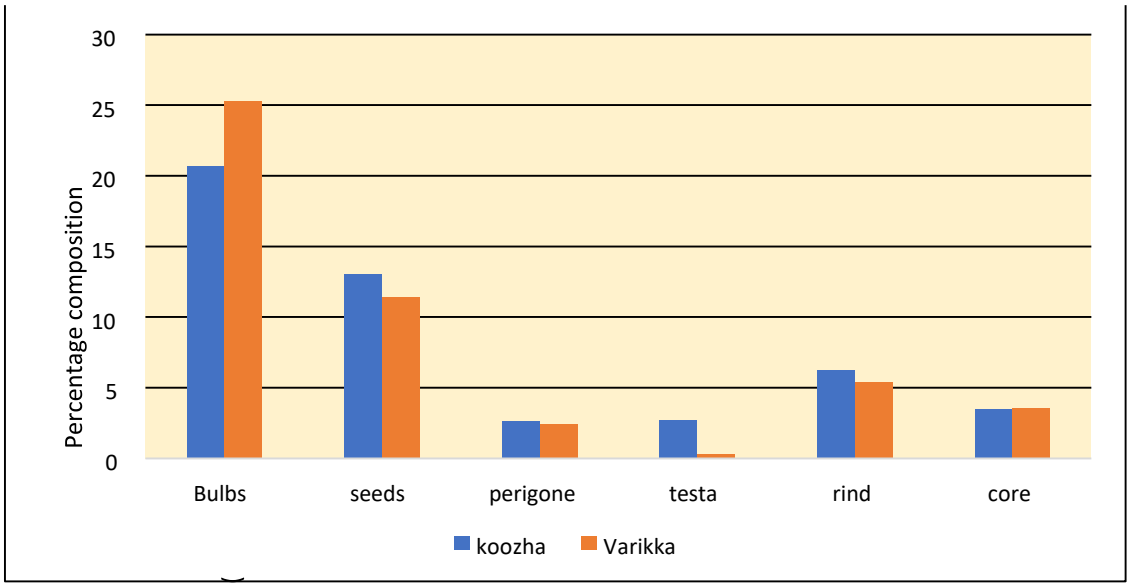


Fig.5. Moisture content of cv. *Koozha* and cv. *Varikka* parts

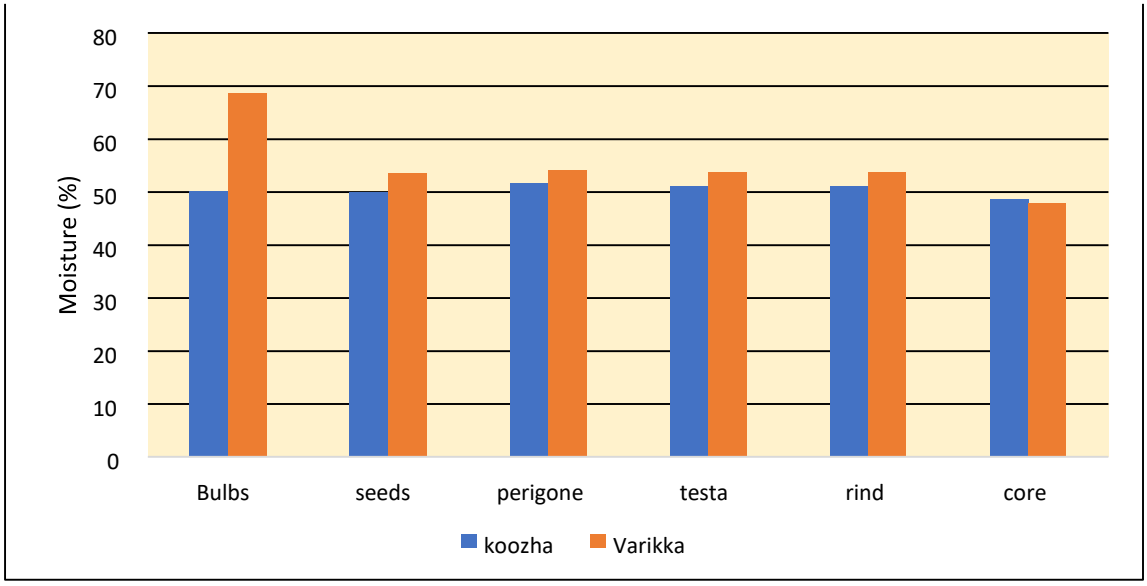


Fig.6. Processing loss of cv. *Koozha* and cv. *Varikka* parts

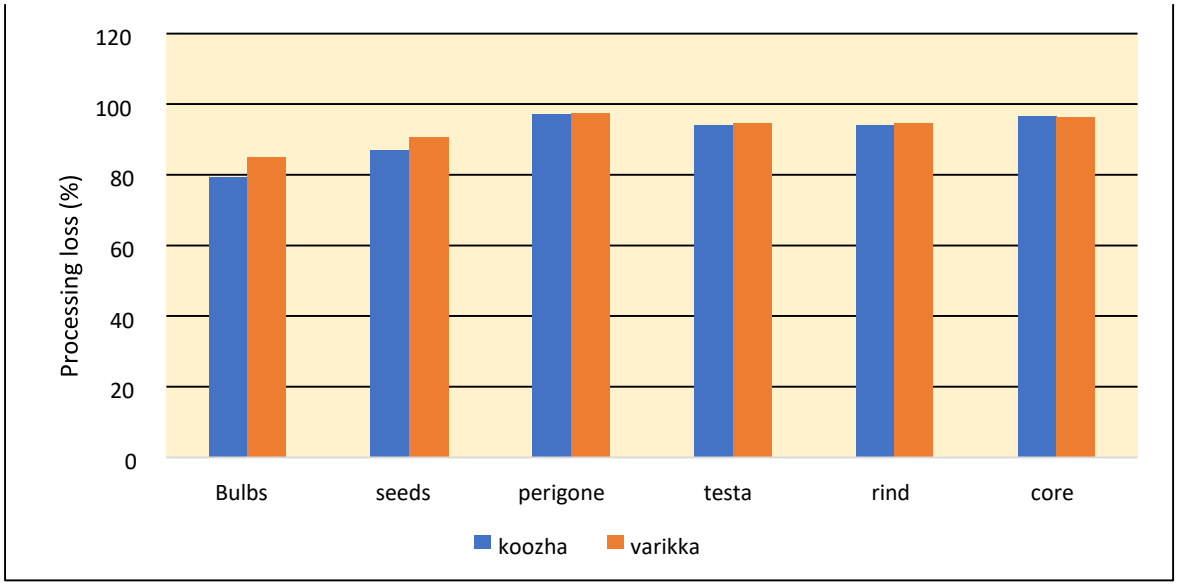
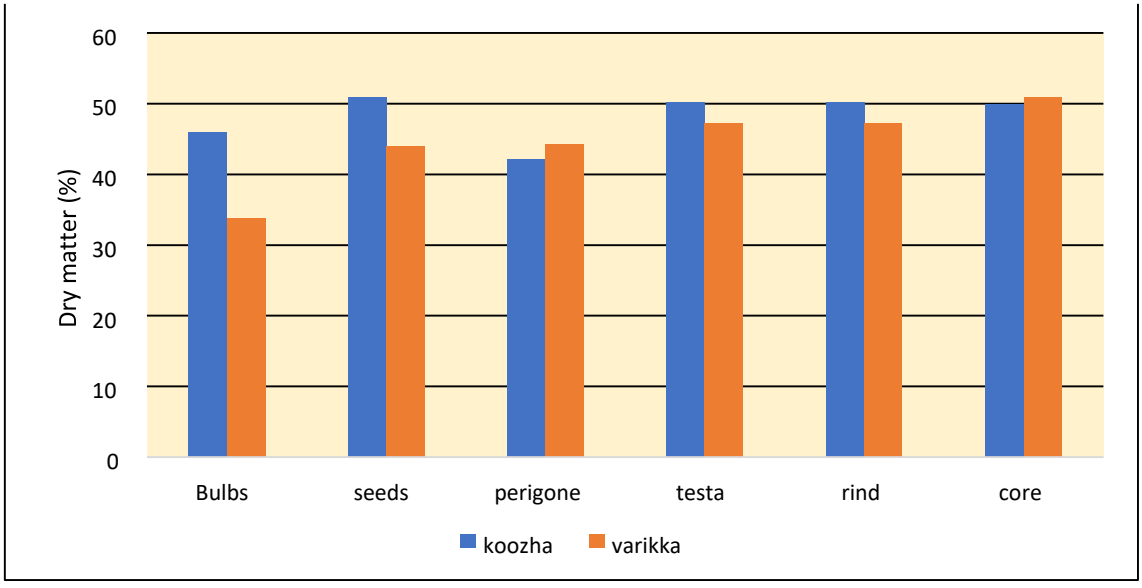


Fig.7. Dry matter percentage of cv. *Koozha* and cv. *Varikka* parts



5.1.3. Glycemic index (GI) and glycemic load (GL) of jackfruit parts

5.1.3.1. Carbohydrate content of test fruit parts

There was a significant difference in the carbohydrate content of jackfruit cultivars (k*oozha* and *varikka*) parts of bulbs, seeds, perigones, testa, rind and core. The result showed that *varikka* bulbs had the highest carbohydrate content (19.79g/100g) followed by *koozha* seeds (17.26g) koozha bulb (14.74g/100g) and *varikka* seeds (10.98 g/100g). The lowest carbohydrate content was seen in *varikka* core (2.73g/100g) followed by *varikka* perigones (2.78g/100g), *koozha* rind (2.82g/100g), *varikka* testa (3.41g/100g) and *koozha* testa (3.70g/100g). *Koozha* core recorded 5.59g/100g. The carbohydrate content in *varikka* bulb was significantly higher from other parts. Amadi *et al.* (2018) reported the carbohydrate content of jackfruit bulbs as - 7.74 g/100g, seeds as 7.89g/100g and leaves as 5.53g/100g. Rahman *et al.* (2000) reported that the carbohydrate concentration of different cultivars of jackfruit seed varied from 37.4% to 42.5%. Anila (2018) analysed different varieties of jackfruit bulbs and seeds for the carbohydrate content and the results revealed that, *Chempikalom varikka* had the highest carbohydrate content (34.69g/100g) and the lowest carbohydrate content was seen in *Then varikka* (11.06g/100g). *Muttan varikka* had 15.36g/100g, *Sindhoor* had 21.11g/100g and Local cv *Koozha* had 21.24g/100g. Singh *et al.* (2000) reported that jackfruit perianth and seeds contained an appreciable percentage of starch, while more carbohydrates and sugars were found in the ripened stage. Chrips *et al.* (2008) reported that carbohydrate content varied from 37.4% to 42.5% in different varieties of jackfruit seeds. Islam *et al.* (2015) stated that the variation of carbohydrate may be due to variety or cultural factors.

5.1.3.2. Dietary fiber of jackfruit parts

Rahman *et al.* (2000) stated that the starch and dietary fiber content of the flesh increased with the fruit's maturity. McCleary (1999) reported that dietary fibers are less digestible, but fiber rich foods could modulate the digestive process and thereby improve absorption in the human body. The result showed that jackfruit *koozha* rind (6.69g/100g) had higher dietary fiber followed by *varikka* rind (5.78g). Fiber content of *koozha*

perigones (2.97g/100g), was on par with *koozha* core (2.95g/100g), similarly fiber content in varikka perigones (2.48) and *varikka* core (2.41g/100g) were on par. The lowest fiber content was reported in *varikka* testa (1.70g/100g) followed by *koozha* testa (1.73g/100g), *varikka* bulb (1.76g/100g) and varikka seed (1.90g). Dietary fiber was higher in *koozha* cultivar compared with *varkka* cultivar. Similar results were also obtained by Anila (2018), who reported that the dietary fiber of different cultivars of raw jack fruit bulbs ranged from 1.14 to2.24g, while for raw jackfruit seeds, it varied between 1.05 to 2.38g. Koh *et al.* (2020) reported that the crude fiber level of raw jackfruit rind was 13.51 %. Feilli, *et al*. (2018) suggest that high fiber content of jack fruit rind powder can be used as food supplement or additive in foods to help preventing constipation.

5.1.3.3. The blood glucose level of subjects after ingestion of jackfruit parts

There are several factors that may affect the digestion and absorption of fruits and thus the blood glucose response. Factors such as the degree of ripeness, the type of sugars present, the presence of fibre and antinutrients and the physical state of the fruits, have contributed to the response of glucose levels (Guevarra and Panlasigui, 2000). The presence of antinutrients such as phytic acid, tannins, lectins and saponins have been known to delay the rate of digestion and absorption (BrandMiller *et al.,* 2014). Jackfruit contains tannins and phytic acids that are found to inhibit intestinal enzymes lowering the rate of absorption, thus producing low glucose response (Guevarra and Panlasigui, 2000).

In this study the blood glucose response produced after consuming the fruit parts was significantly lower, when compared with glucose ($p<0.05$). Jackfruit *koozha* bulb revealed the largest rise of blood glucose (5.8 ± 0.03), while jackfruit *koozha* rind (4.6 ± 0.03) showed the lowest, after 120 minutes. A possible reason for this is due to the higher carbohydrate content of jackfruit bulb which is approximately twice the amount of carbohydrate in jackfruit rind parts (Hermansen *et al.,* 2002). The degree of ripeness of jackfruit may also influence the postprandial blood glucose response (Lintas *et al.,* 2005).

However, several studies have revealed net the outcome was attributed to the type of carbohydrate content of the fruits which mainly consisted of fructose (Wolever *et*

Fig.8. Carbohydrate content of cv. *Koozha* and cv. *Varikka* parts

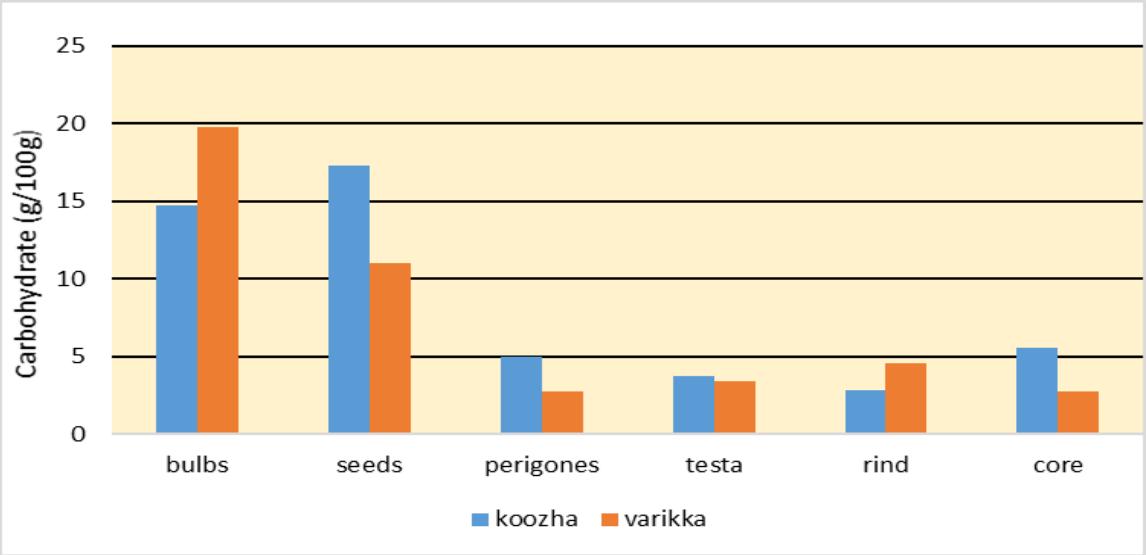
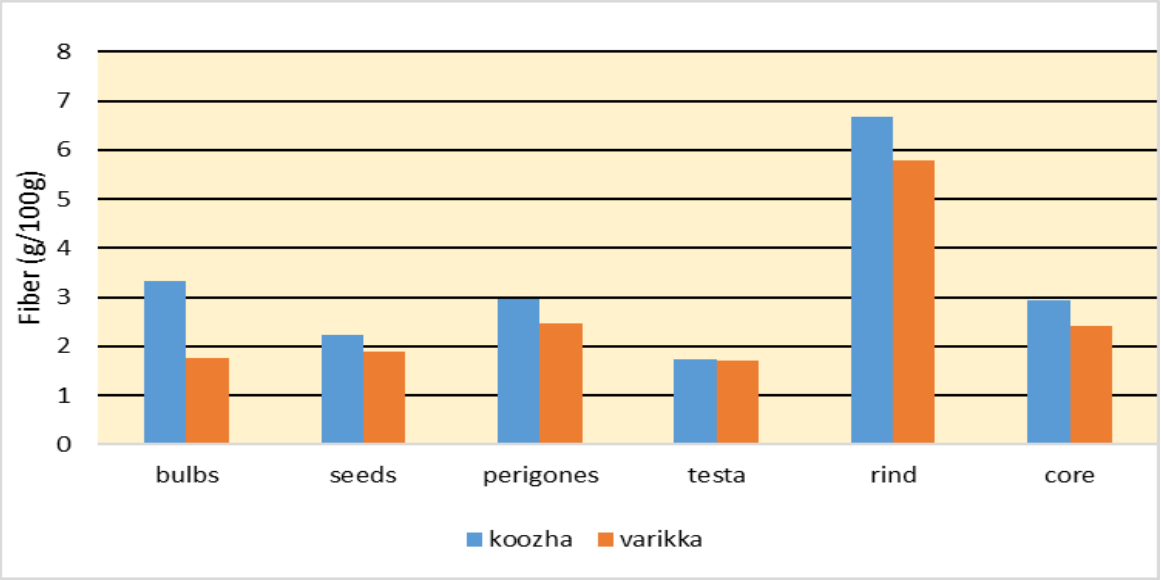


Fig.9. Fiber content of cv. *Koozha* and cv. *Varikka* parts



al., 2003; Lunetta, 2005; Guevarra and Panlasigui, 2000). When compared to other monosaccharides like glucose and lactose, fructose is slowly absorbed and has a lower risk of raising blood glucose levels (Vaccaro *et al.,* 2004). In both normal and type 2 diabetes individuals, fructose is swiftly removed and metabolised by the liver (Wolever and Brand-Miller, 2004). Moreover, fructose has a lower glycaemic index (GI) than glucose and is associated with a lower blood glucose response (Lee *et al.,* 2008). In addition. (Guevarra and Panlasigui, (2000). hypothesised that the rate of the sugar entering the bloodstream varies with the physical state of the fruit. Grapes, rambutan, longan, papaya and watermelon are easily chewed and thus elicit a high glucose response. Fruits like sapodilla, jackfruit, mango, red apple and green pear, however, require some effort in chewing due to their grainy texture, this might also contribute to its low glucose response

Area under the curve (AUC)

The tropical fruits demonstrated larger rise in mean AUC value when compared to temperate fruits (Brand-Miller *et al.,* 2014). Differences among the fruits may arise because of variations, particularly in monosaccharide composition and the nature of fibre (Wolever and Brand Miller, 2004). In the present study, AUC of the test fruit ranged between 111.82 mmol.min/L and 171.13 mmol.min/L. Among different jackfruit parts, the mean AUC was highest for *varikka* seed
(171.13±0.80) followed by *varikka* bulb (167.49±1.04) and *koozha* seed (167.31±1.31) while the lowest was obtained in *koozha* rind (111.82±0.88) which was on par with T_{10}.

Glycemic Index (GI)

The term glycemic index (GI) was introduced by Jenkins *et al.* (1981) to assess the rise in plasma glucose after consuming a particular food. In the present study the rind of jackfruit cultivars *koozha* had reported lowest glycemic index (45.26±0.52), which was on par with *koozha* testa (46.24±0.57), *varikka* testa, (46.53±0.63) and *varikka* rind (47.27±0.62). The highest glycemic index was reported for *varikka* seed (69.31±0.99) followed by *varikka* bulb (67.82±0.90), *koozha* seed (67.74±0.87) and *koozha* bulb (63.29±1.21). Valdivieso and Alonso, (2000) have observed that, the glycemic index of the

fruits depends upon the type of fiber in the fruit. Total dietary fibre in fruits consist of soluble and insoluble fibre. The insoluble fibres such as cellulose and hemi-cellulose are rigid materials, and give structure to plants (Anderson and Akanji, 2000). Soluble fibre like pectin, present abundantly in fruits, may form a viscous solution which has the capacity to bind to carbohydrate. This could limit the accessibility to α-amylase and reduce the blood glucose response. Soluble fibre has been shown to be active on plasma glucose metabolism and consequently, demonstrate the lowering effect of blood glucose response (Riccardi and Rivellese, 2000).

Glycemic load (GL)

Some experts believe that the quantity of food consumed has no effect on the glycemic response, while another stream of thought is that quantity affects the glycemic response. To address this concern, researchers at Harvard University developed the concept of glycemic load in the 1990s. Blood glucose-raising potential of carbohydrate foods relative to glucose or white bread with similar carbohydrate contents, did not usually have the same impact on blood glucose levels. Therefore, the glycemic response to an ingested food was found to depend not only on the glycemic index but also on the total amount of carbohydrates ingested and this led to the concept of glycemic load.

USDHHS (2000) report out that knowledge about the quality and quantity of carbohydrates in fruits and vegetables would be beneficial for diabetic patients as well as for healthy subjects The glycemic load (GL) values express the glycemic effect of realistic serving size of different foods. The GL can be defined as the product of the glycemic index (GI) of a food and the amount of carbohydrate in a serving (Foster-Powell *et al.*, 2002). In the present study lower glycemic load was reported for *varikka* core (1.29±0.01), followed by *koozha* rind (1.30±0.06) and, *varikka* perigones (1.44±0.02), and *koozha* testa (1.66±0.02). The highest value was obtained for *koozha* seed (12.42±0.16), which was on par with *varikka* seeds (11.81±0.17) and *koozha* bulbs (11±0.21). Based on serving size, the jackfruits can be considered as a very low GL food.

Fig.10. Comparison of blood glucose response of *koozha* and *varikka* bulbs with Glucose

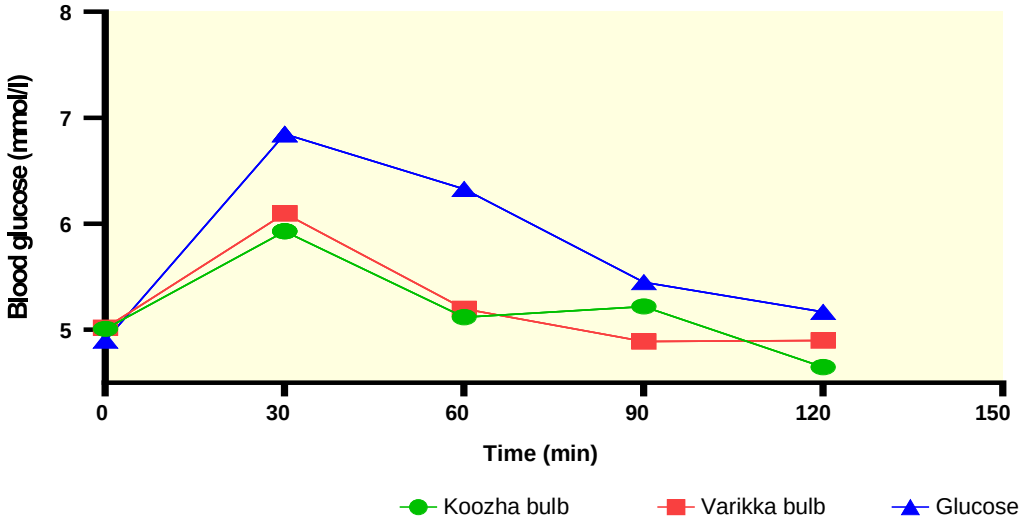


Fig.11. Comparison of blood glucose response of *koozha* and *varikka* seeds with Glucose

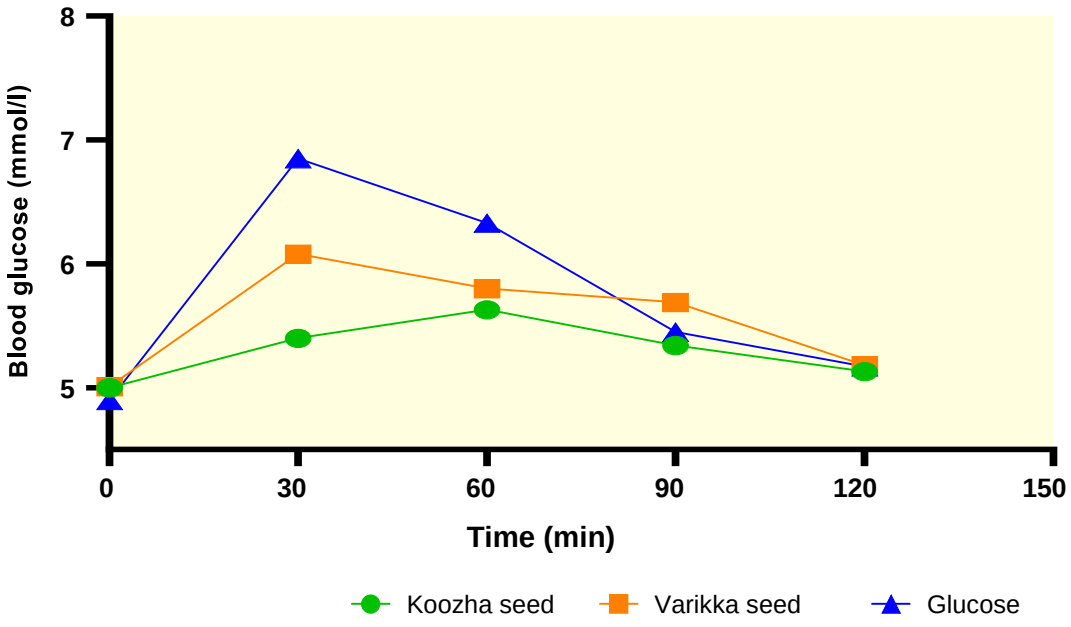


Fig.12. Comparison of blood glucose response of *koozha* and *varikka* perigones with Glucose

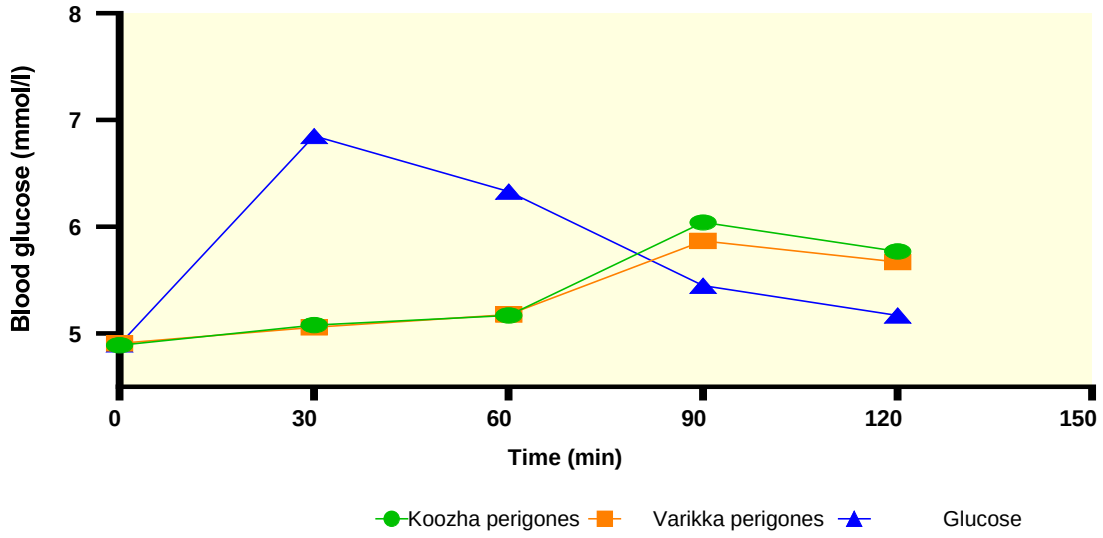


Fig.13. Comparison of blood glucose response *koozha* and *varikka* testa with Glucose

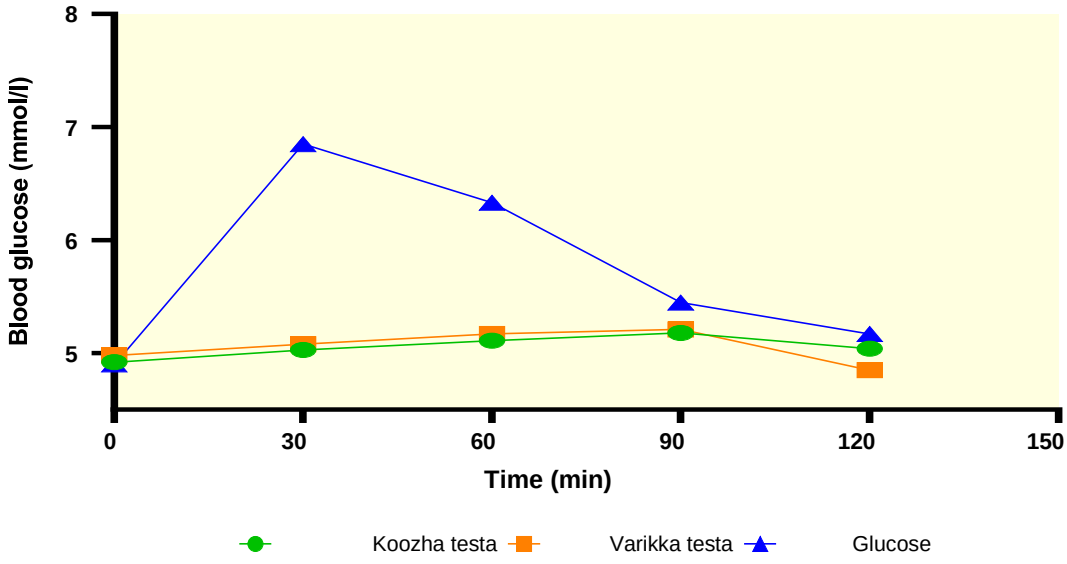


Fig.14. Comparison of blood glucose response *koozha* and *varikka* rind with Glucose

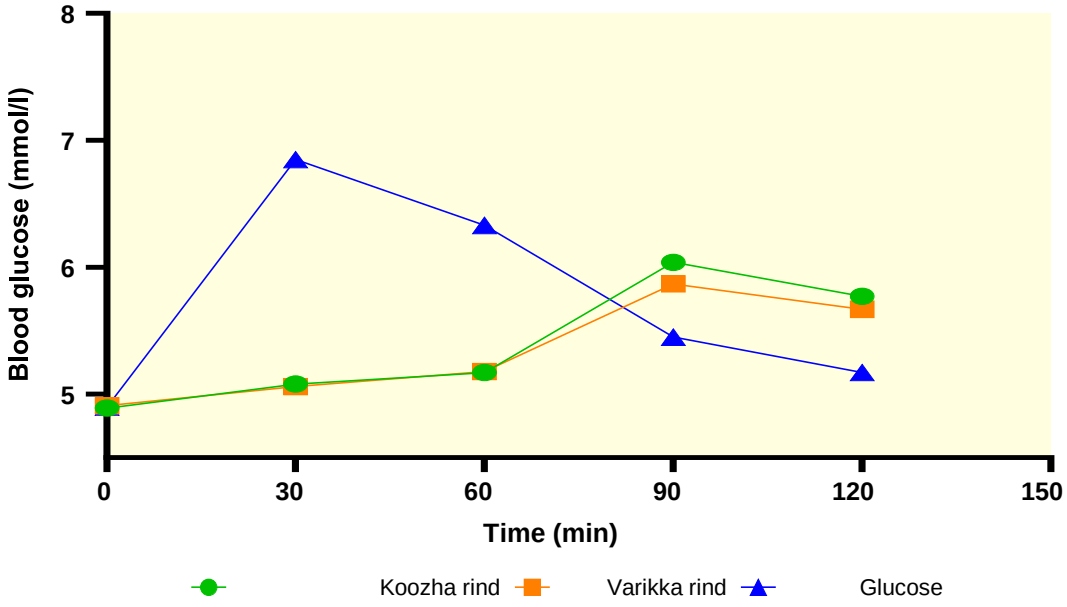


Fig.15. Comparison of blood glucose response *koozha* and *varikka* core with Glucose

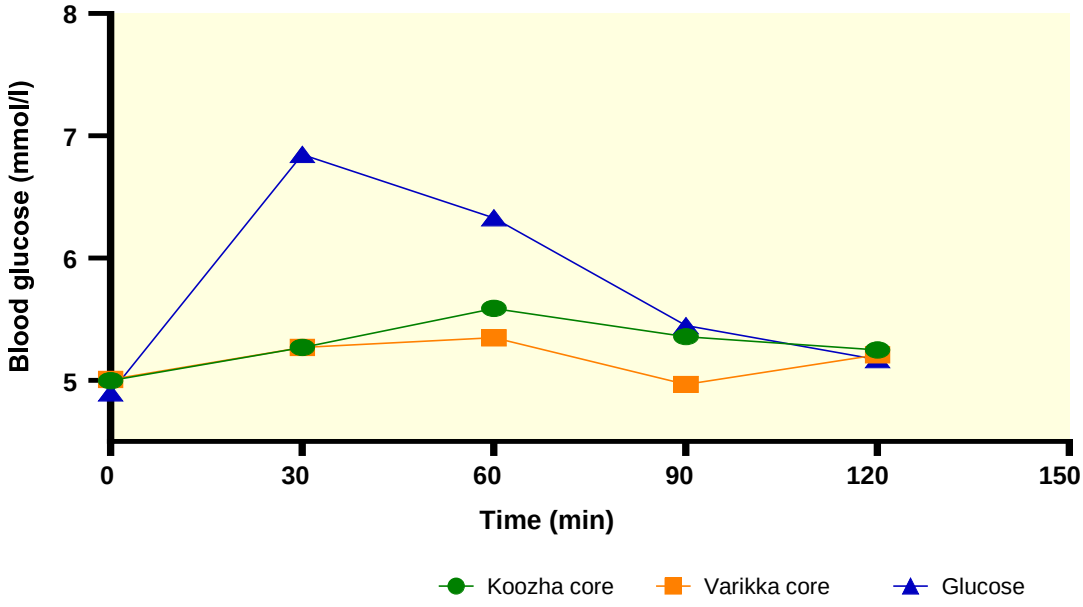


Fig.16. Blood glucose response of different parts of *koozha*

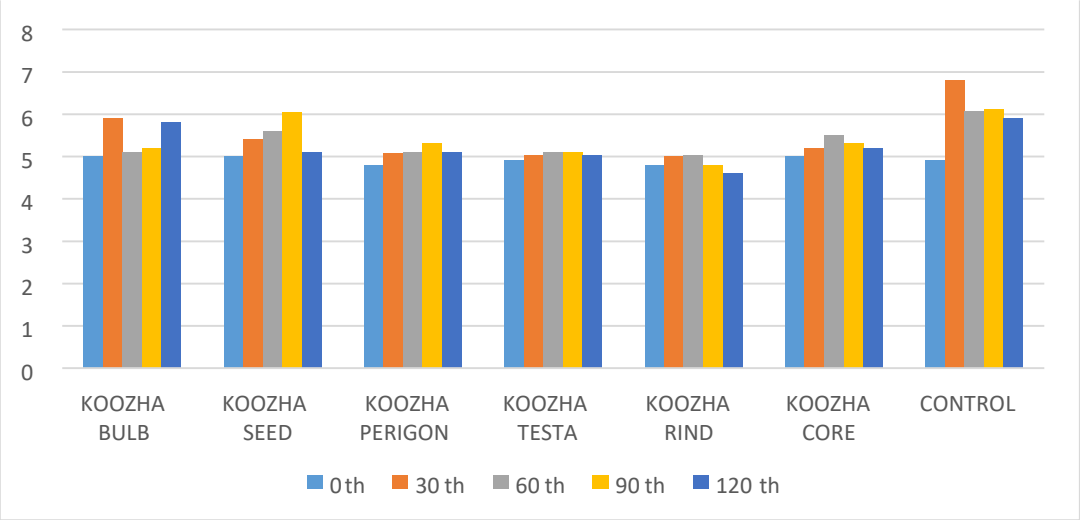


Fig.17. Blood glucose response of different parts of *varikka*

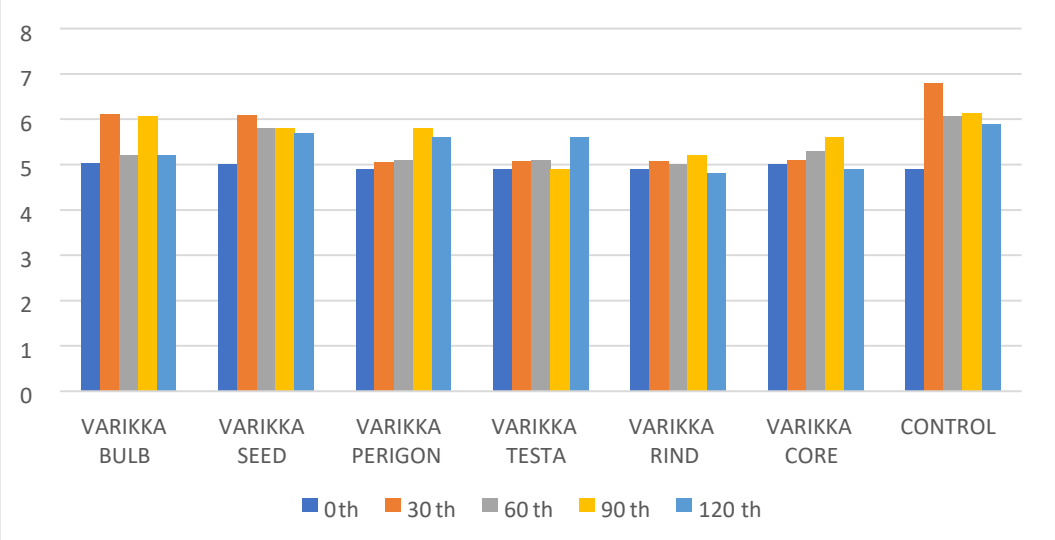


Fig.18.Glycemic index of jackfruit parts compared to glucose

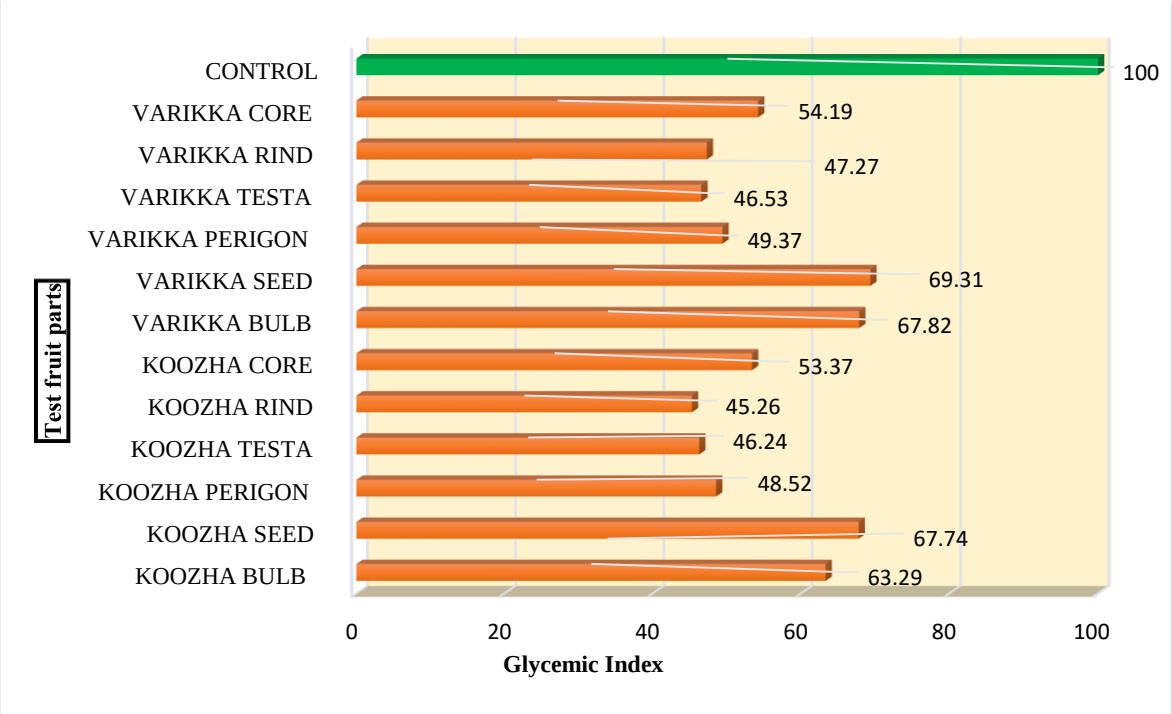
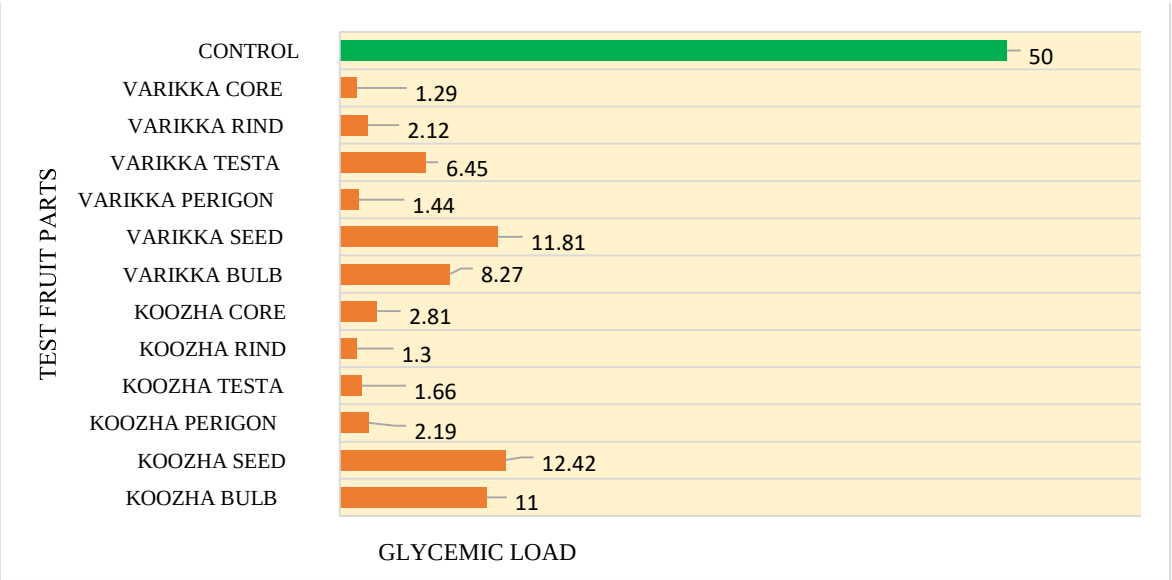


Fig.19.Glycemic load of jackfruit parts compared to glucose



5.2. DEVELOPMENT OF NUTRI FLOUR

Fruits and vegetables have proved to be essential for a balanced diet. Epidemiological and clinical investigations have actually associated diets, rich in fruits and vegetables with reduced risks of cardiovascular, coronary heart, metabolic and degenerative diseases, as well as certain forms of cancers (Dai and Mumper 2010).

Fresh fruits and vegetables are highly perishable commodities due to their high moisture content which is around 80%, that deteriorates over a short period of time if improperly handled (Orsat and Raghavan, 2006). Drying fruits and vegetables is a process where water removal halts the growth of spoilage microorganisms, as well as the occurrence of enzymatic or nonenzymatic browning reactions in the material matrix, thus preserving their structure, sensorial characteristics and nutritional value (Zhang *et al.*, 2006)

The market for dehydrated fruits and vegetables has actually shown a rapid growth rate of 3.3 % in most countries worldwide (Zhang *et al.*, 2006). Fruit and vegetable powders likewise serve as ingredients in instant noodles, dried soups and other food recipes The quality of a fruit and vegetable powder is highly dependent upon the drying or grinding medium and conditions, as well as the composition, physical properties, production system (conventional or organic) and cultivar-field (mechanically or hand harvested) of the raw material (Sablani, 2006)

In the present study, bulbs, perigones, seeds, rind, core and testa of jack fruit cultivars (*koozha* and *varikka*) were used for preparing the jackfruit-based nutri flour. Nutri-flour formulations were made based on the results of glycemic index.

5.2.1. Formulations of nutri flour

Preliminary processing helps to reduce unnecessary parts of the fruits, it also helps to inactivate enzymes by immersing in suitable media for preservation of colour and appearance. Jackfruit parts underwent several preliminary processes like washing, cutting and blanching to enhance the quality of the final product.

Milling and blending of flour

In the present study, the pretreated jackfruit parts were kept for drying at 65^0C in hot air oven for 14 hours. After drying the dried jackfruit parts were milled for separately. Milling is defined as a process of grinding grains or any dried product into fine flour or meal. The milled jackfruit flours were sieved in the mesh size of 0.05 mm. The residues leftover, after sieving was to get a uniform fine powder. (Veenakumari, 2015: Sahoo, 2016). The jackfruit flours were packed in metalized laminated covers for further analysis.

Composite flour is a combination of flours derived from starch-rich, protein-rich flours and cereals, with or without wheat flour which are, produced to meet certain functional qualities and nutrient content. When it comes to minerals, vitamins, fibres, and proteins, Composite flour offers a higher nutritional value than flour milled from a single cereal. (Noorfarahzilah *et al.*, 2014).

Veenakumari (2015) standardised composite flour prepared by using jackfruit bulb (JFBF) and seed flour (JFSF) in combination with refined flour. The proportion of RF: JBF: JSF were 40:30:30, 50:25:25, 50:30:20, 50:40:20, 50;40:10, 50:20:10 in the various treatments. Another study reported by Sahoo (2016) developed jackfruit based composite flour in which refined wheat flour and jackfruit bulbs were the basic materials. The different combinations 40:60 (T1), 45:55 (T2), 50:50 (T3), 60:40 (T4), 70:30 (T5), 80:20 (T6) and (T7) 100 percent refined flour (control) was used for the composite flour formulation. In a study by Tharani (2018) composite flour was prepared with the combination *varikka* and *koozha* jackfruit rind flours in the increasing order from 50 per cent to 80 per cent along with rice flour and constant amount of black gram flour of 10 per cent.

Ramya *et al.* (2020) reported that Jackfruit rind flour (JRF) was incorporated into wheat flour (WF) in three different ratios (5, 10 and 15%) to produce partially substituted wheat flour (WF) with JRF to form Cookies. The incorporation of JRF caused significant influence on the sensory, physical and chemical attributes. Increasing the level of JRF incorporated into WF caused an increase in darkness of cookie treatments, and decrease in

their spread ratio compared to the control. Cookie tretments substituted with 5% JRF had the highest mean scores of overall acceptances. Similarly, Feili *et al.* (2013) developed jackfruit rind flour (JFRF) incorporated with wheat flour (WF) in three different ratios (5, 10 and 15%). Bread samples substituted with 5% JRF had the highest mean scores of overall acceptances. Haque *et al.* (2015) developed cakes incorporating jack-fruit pulp. The seed free jackfruit bulbs blend was used at levels of 10%, 20%, 30% and 40%, to prepare jackfruit cake. The statistical analysis of organoleptic test response of sensory attributes revealed that colour, flavour, taste, texture and overall acceptability were higher in the cakes containing 10% and 20% jackfruit pulp than normal cake

Nandkule *et al.* (2015) formulated Jackfruit Seed and soy flour noodles. Different levels of refined wheat flour, jackfruit seed flour and soy flour were added in the ratio of 100:00:00, 90:5:5, 80:10:10, 70:15:15, 60:20:20, 70:10:20 and 70:20:10, for the development of noodles and their qualities were analyzed. Based on sensory analysis noodles with refined wheat flour, jackfruit seed flour and soy flour (T1) 90:5:5 were found to be more acceptable than other levels.

In the present study, nutri- flour formulations were made based on the results of experiment one. The order of glycemic index of jackfruit parts were observed as KJRF > KJTF > VJTF > VJRF > KJPF > VJPF > KJCF > VJCF KJBF > KJSF > VJBF > VJSF. The major component (50-60%) of flour was contributed from the fruit parts with lower glycemic index and 40 per cent of the mix was formulated by other components in different proportions.

Acceptability of the nutri flour combinations

The treatments were evaluated for their organoleptic qualities like appearance, colour, flavour, texture, taste and overall acceptability. By incorporating jackfruit based nutri flour into 3 commonly consumed popular breakfast dishes like “puttu”, “ada” and “oratti” were developed.

5.2.2. Organoleptic qualities of "Puttu" prepared from jackfruit based nutri flour

'Puttu' means "portioned". 'Puttu' is a breakfast dish from South India mainly in Kerala, Tamil Nadu, some parts of Karnataka, and Sri Lanka. It is steam cooked dish, and so there is absolutely no oil in it, which makes it a simple and healthy food.

Instant 'puttu' mix was prepared with finger and foxtail millet, (50:50) Millet puttu remained in good condition up to 14 days at refrigerated temperature and 28 days in deep freezer. Millets contain high nutritional value compared to rice and wheat (Mamatha Rani *et al.,* 2019).

F_9 had the highest mean rank score for taste (90.05) and over all acceptability (93). Statistical analysis of the data revealed that there was significant difference between the mean rank scores of different quality attributes of the jack fruit based puttu at 5% level.

Jackfruit flour from matured bulbs has a yellowish white colour. This flour has been used as as ingredient in many of the traditional dishes like *puttu, idali, chapathi, kumbilappam, uppuma* and *pappd* etc. Jackfruit flour being a diabetic friendly and gluten free, can be used along with wheat flour and fortified in every dish.

5.2.3. Organoleptic evaluation of 'Ada' prepared with nutri flour

Nandkule *et al.* (2015) developed Jackfruit seed and soy flour-based noodles. Organoleptic analysis showed the scores of treatments as - F_1 (7.54) followed by F_0 (7.52), F_2 (7.2), F_3 (7.06), F_4 (6.86), F_5 (6.74) and F_6 (6.6). The flavour, appearance and overall acceptability increased by 5 percent in jackfruit seed flour and 5 percent in soy flour-based product. Islam *et al.* (2015) reported that Jackfruit seed flour was utilized in composite flour-based biscuit. Biscuits were prepared with 10%, 20%, 30% and 40% jackfruit seed flour and were compared with plain biscuits (0% seed flour). The sensory quality of jack seed flour-based biscuits decreased with increase in incorporation level of seed flour. The incorporation above 40 per cent in biscuits was not acceptable based on sensory quality parameters. It was observed that 10, 20 and 30 per cent seed flour incorporated biscuits

Fig.20. Organoleptic evaluation of 'Puttu'

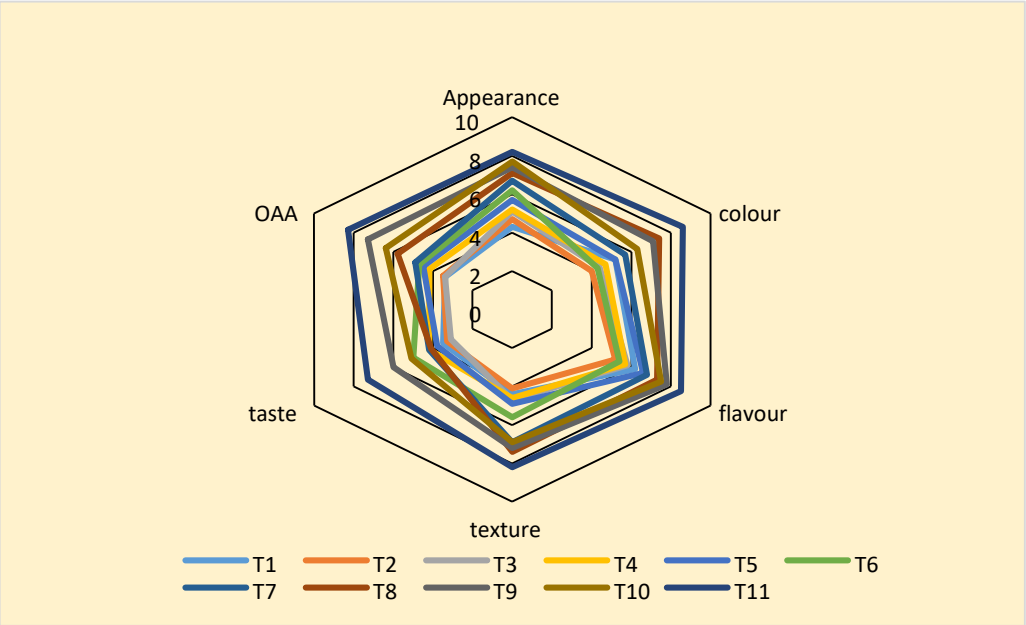


Fig.21. Organoleptic evaluation of of 'Ada'

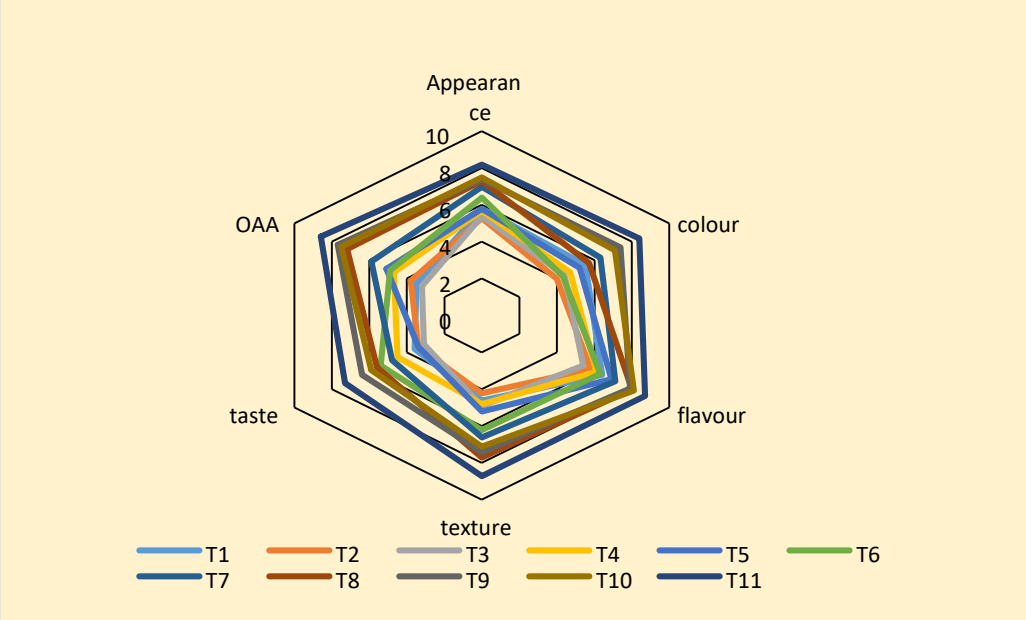
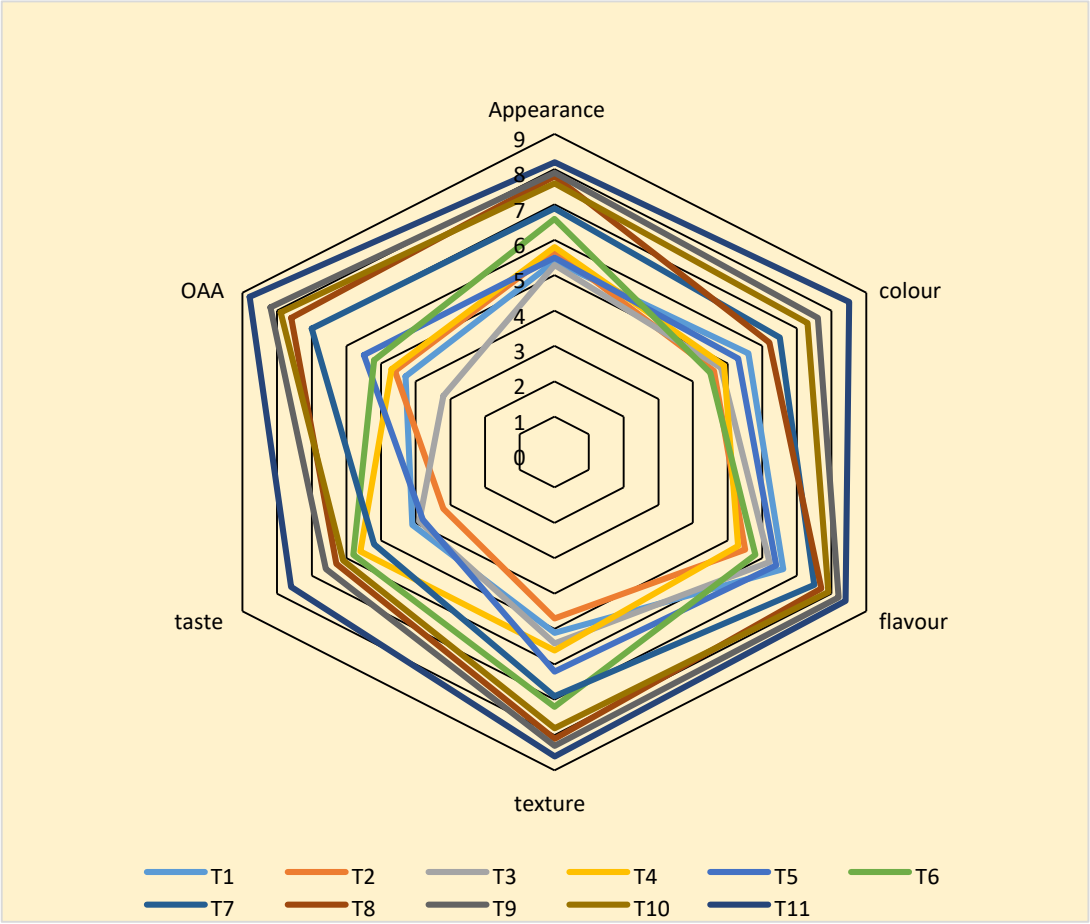


Fig.22. Organoleptic evaluation of of 'Oratti'



were not significantly different from control with respect to sensory qualities. Forty per cent seed flour-based biscuits scored lowest values for all the quality parameters.

The highest mean rank value for taste and overall acceptability were obtained for F_9 (88.75 and 87.60) and lowest mean rank value for taste was obtained by F_3 (20.15) followed by F_2 (23.65), F_5 (25.15) and F_1(28.20).

5.2.3. Organoleptic evaluation of 'Oratti' prepared with nutri flour

According to Grimm and Steinhaus, (2019) a high amount of jackfruit byproducts will affect the aroma of patties as jackfruits have a very strong fruity aroma. The odor-active compounds that give jackfruit its strong and distinctive aroma are 3-methyl butanoate, ethyl butanoate, 3-methylbutanal, and 2-methyl propanal.

Overall acceptability of the eleven treatments are clearly depicted in table.32. Among the eleven treatments F_9 obtained the maximum mean rank value of 89.90 after the control F_{11} (101.60). Least mean rank value of 9.65 and less acceptability was noted for F_3. Result of analysis indicate that there was significant difference in the mean rank scores obtained for the eleven treatments F_1 to F_{11}.

Statistical analysis by applying interpretation of Kruskal-Wallis test revealed that there was a significant difference between the appearance, colour, flavour, texture, taste and overall acceptability of products like '*puttu', 'ada'* and '*oratti'*. On the basis of analysis of mean scores T_9 was selected as the best combination. Among the three products based on overall acceptability scores '*oratti'* was found to be more acceptable.

Ajisha (2018) reported that vermicelli and payasam prepared with 70 per cent jackfruit flour and 30 per cent jackfruit seed flour (T_1) had high mean scores for appearance (8.4 and 8.35), colour (8.35 and 8.37), flavor (8.33 and 8.31), texture (8.26 and 8.33), taste (8.2 and 8.4) and overall acceptability (8.31 and 8.4). Compared to control (T_0), mean score for all sensory parameters of jackfruit-based vermicelli (except appearance) and payasam was lower, but had a score above 8 out of 9.

Swathi *et al.* (2019) developed red amaranthus enriched functional jackfruit pasta with natural red colour, nutritional qualities and consumer acceptability. The red amaranthus paste was added in two different proportions (5% and 10%) to different formulations of jackfruit pasta comprising of jackfruit bulb flour, seed flour and cassava flours replacing a portion of refined flour. The enrichment with 10% of red amaranthus as paste to jackfruit pasta formulations reduced cooking loss, improved the cooking quality characters, nutritional quality, and sensory attributes and produced naturally coloured pasta with higher consumer acceptability.

(Odimegwu *et al.*, 2019) formulated composite flour by mixing Jackfruit seed flour (JSF) and Maize flour (MF). Six samples of breakfast cereal blends were generated by mixing the composite flour of Jackfruit seed flour (JSF) and maize flour (MF) in the ratio of (100:0, 90:10, 80:20, 70:30, 60:40, 50:50). A control sample was produced from 100% maize.

Jackfruit flours provides several health benefits since rice-based food products are not favorable to diabetic patient, so blends with jackfruit flour have been preferred by dieticians, in the preparation of breakfast foods, giving better nutritional and organoleptic value to the consumer. 5.3. QUALITY EVALUATION OF THE NUTRI FLOUR

In the present study, the jackfruit-based nutri flour was analysed for its functional properties viz. swelling power, solubility, water absorption capacity and bulk density.

5.3.1. Functional properties of nutri flour

The functional property of a food is characterized by the structure, quality, texture, nutritional value, acceptability, and (or) appearance of the food product. Functional property of a food often determines the organoleptic, physical, and/or chemical properties of the food.

Swelling power

According to Oh *et al.* (2008) swelling test measures the water uptake during the starch gelatinization. The higher the water uptake, the higher the swelling power.

Fig.23. Functional properties of jackfruit flours

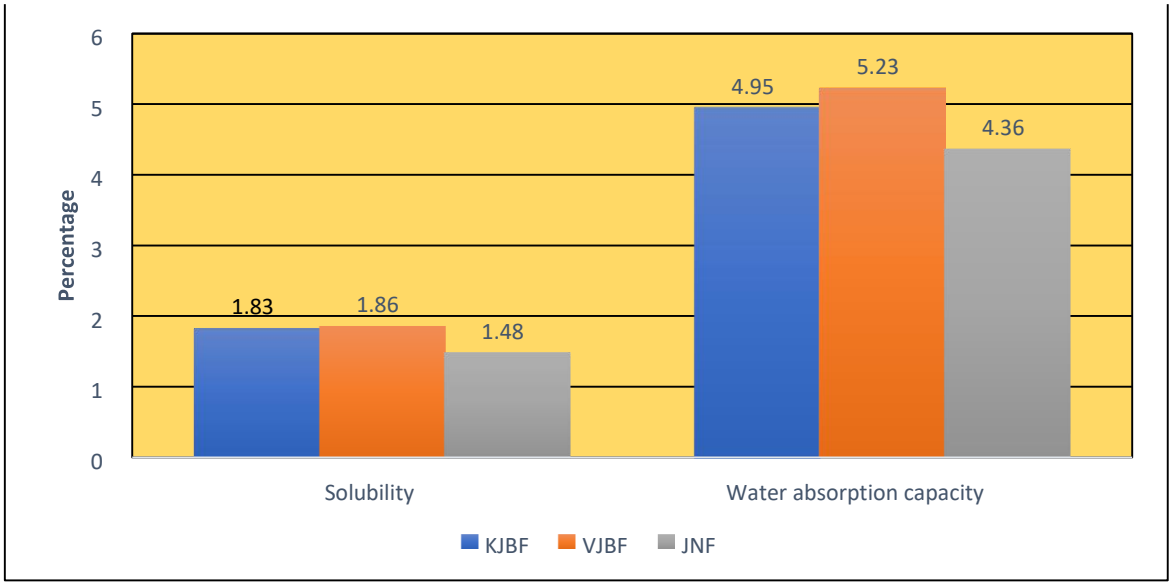
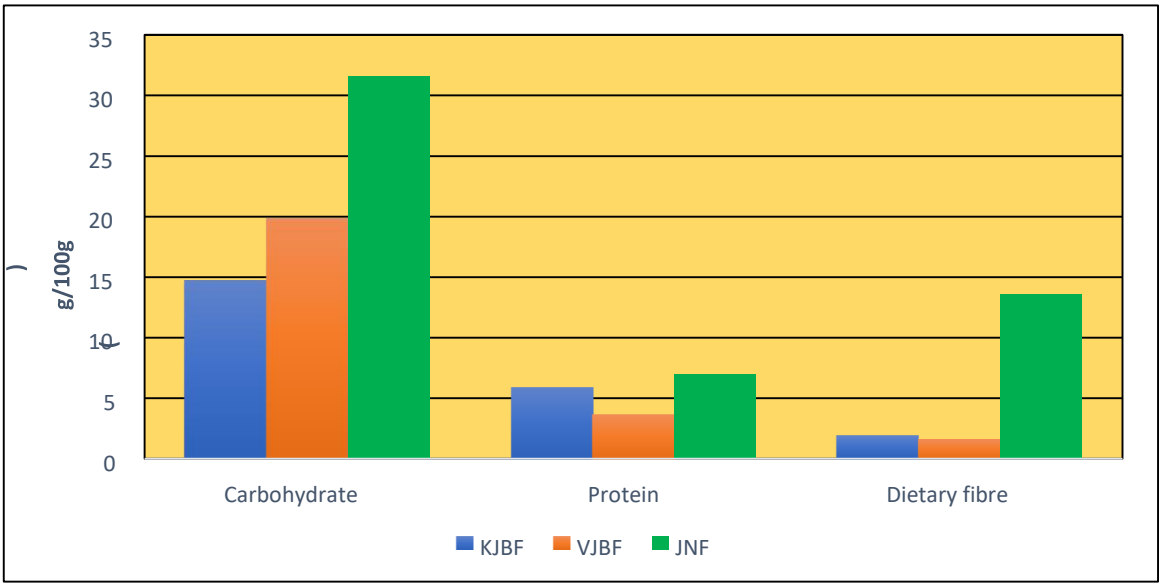


Fig.24. Proximate composition of jackfruit flours



The crystalline and amorphous structures of starch granules are disturbed when they are heated in excess water, and water molecules bond to the exposed hydroxyl group of amylose and amylopectin. King and Anderson (2005) observed that the more soluble the flour is in solution, the stronger will be its swelling power.

In the present study, there was no significant variation in the swelling power of *koozha* jackfruit bulb flour (KJBF) (7.89g) and nutri flour (JNF) (7.65g). Varikka jackfruit flour (8.18 per cent) showed highest swelling power among the treatments Similar findings were also reported by Tharani (2018), that swelling power of jackfruit rind flour was 7.7 and 7.93 per cent for *koozha* and *varikka* rind flour. The low swelling power could be due to the effect of protein and lipid, which inhibits the swelling of starch granules (Wang and Seib, 2006). Several studies have also claimed that amylose acted as swelling inhibitor, with or without the presence of lipids (Hoover, 2001; Noranizan *et al.,* 2010; Oke *et al.,* 2013; Zhang *et al.,* 2006). Amylose tends to hold back swelling and maintain the integrity of swollen granules. In the presence of amylose-lipid complexes, they restrict granular swelling and amylose leaching, hence decrease swelling power.

Solubility

Solubility refers to the ability of water to penetrate starch granules in flours. Modification of starches may be crucial for water absorption and retention, resulting in an increase in starch swelling power. Greater solubility is caused by increased leaching of solubilized amylose molecules from swollen starch granules. The highest solubility was observed in *varikka* jackfruit bulb flour (VJBF) -1.86 per cent, which was on par with *koozha* jackfruit bulb flour (1.83) (KJBF), the lowest was found in nutri flour (1.48). Significant differences were seen between the solubility of nutri flour (JNF) and *varikka* jackfruit bulb flour. The presence of lipids reduces water absorption capacity of foods (flours) which can lead to reduced swelling capacity and consequently reduced solubility (Oppong *et al.,* 2021).

Flour solubility is the amount of the flour that dissolves into solution, usually with water as solvent. (Hasjim *et al.,* 2013). High solubility of food can show high digestibility

of the food, which may indicate excellent application in infant formula and food. On the other hand, insolubility is the inability of a food to dissolve in a liquid, gaseous, or solid solvent.

Water absorption capacity

Water absorption capacity varies by starch type and is influenced by factors such as amylase: amylopectin ratio, intra- and intermolecular forces, and granule size. The smaller the size of the granules, the higher the absorption index (Rahman *et al.*, 2000). Very low or excessive water absorption can negatively affect the quality of food products. Water absorption is often determined by the weight of the food or flour. For instance, 60% water absorption means that 60 lbs of water is used for the hydration of 100 lbs of flour.

A study conducted by Tharani (2018) reports that water absorption capacity of *koozha* and *varikka* jackfruit rind were 4.98% and 4.88% respectively. In the present study, *Varikka* jackfruit bulb flour (VJBF) had higher water absorption capacity (5.23 %) than *koozha* jackfruit bulb flour (KJBF) (4.95 %) and nutri flour (JNF) (4.36%).

Bulk density

Bulk density depends on the particle size and initial moisture content of flours. Bulk density of the composite flour increased with increase in the incorporation of different flours. It is clear that, decrease in the proportion of fibre content in flour increases the bulk density of the flours. The high bulk density of flour suggests its suitability for use in food preparations. In contrast, low bulk density would be an advantage in the formulation of complementary foods (Akapata and Akubor, 2000)

Veenakumari (2015) reported that bulk density of jackfruit bulb flour was higher (0.96g/ml), than seed flour (0.92g/ml). Ocloo *et al.* (2010) reported jackfruit seed flours bulk density as 0.80g/l whereas Odoemelam (2005), reported 0.61g/ml in jackfruit seed. In the present study, the bulk density of *varikka* jackfruit bulb flour (VJBF) was higher with a score of (1.34g/ml) which was followed by 1.23g/ml for *koozha* jackfruit bulb flour (KJBF) and (1.04 per cent) for nutri flour (JNF). This may be due to variation in particle size and

fiber content of the flour; bulk density is generally affected by the particle size and true density of flour (Ocloo *et al.,* 2010).

5.3.2. Chemical and nutritional profile of jackfruit based nutri flour

The fruits are the cheapest and most common store house of nutrients viz., carbohydrates, proteins, vitamins, minerals and essential amino acids (Murphy *et al.,* 2012; Bumgarner *et al.,* 2012).

Proximate composition

In the present study, the proximate composition carbohydrate, protein, dietary fibre and moisture content of the nutri flour was analyzed.

The carbohydrate content of nutri flour was (31.59 g/100g) which was higher than *koozha* jack bulb flour (14.74g/100g) and *varikka* jack bulb flour (19.79g/100g). Tharani (2018) reported *koozha* jackfruit rind flour had a carbohydrate content of 29g/100g whereas Baliga *et al.* (2011) reported 18.9g/100g carbohydrate present in jackfruit bulb.

Jackfruit contains amino acids like arginine, cystine, histidine, leucine, lysine, methionine, threonine, and tryptophan. In this study, protein content was significantly high in nutri flour (7.03g/100g). Protein content of *koozha* jackfruit bulb (KJFB) was 5.84g and a higher content was observed in *varikka* jackfruit bulb flour (VJBF) - 7.03g. Similar findings were reported by Baliga *et al.* (2011) that jack bulb contained 5.9g protein, Chrips *et al.* (2008) also reported that the protein concentration of jackfruit seed varied from 5.3 to 6.8%. Ranasinghe *et al.* (2019) reported that protein content of fresh jackfruit bulbs of different varieties ranged from 0.57 to 0.97%. Amadi *et al.* (2018) reported that protein content of jackfruit bulbs, seeds and leaves were 10.06, 10.09 and 1.19% respectively. Roji *et al.* (2019) had reported that jackfruit bulbs contained 1.72g of protein. Values of 6.34 to 8.57% of protein have also been reported for jackfruit seed flour (Mukprasirt and Sajjaanantakul, 2004).

In the present study, the dietary fibre was higher in nutri flour (13.58g/100g), and this content showed significant difference with values of dietary fiber of *koozha* jackfruit

bulb (KJBF) (1.95g/100g) and *varikka* jackfruit bulb (VJBF) (1.61g/100g). Ong *et al.* (2006) reported that fiber content of jackfruit bulb varied from 0.33 to 0.40%, while no significant difference was observed in different portions of fruit at different ripening stage. Goswami *et al*. (2011) reported that the fiber content of raw and ripe jackfruit bulbs was 2.6% to 0.8% respectively. In raw jackfruit seed the fiber content was seen to vary from 0.50 to 0.90%. Amadi *et al.* (2018) reported that the fiber content in raw jackfruit bulbs, seeds and leaves were 3.01, 3.92 and 4.91% respectively. Hasan (2012) reported that the fiber content of jackfruit flesh varied from 0.57 to 0.86%, depending on the variety and season. Rahman *et al.* (2000) stated that the total dietary fiber of the perianths were almost similar in soft and firm varieties of jackfruit.

Moisture provides a measure of the water content of the flour and for that matter, its total solid content. It is also an index of storage stability of the flour. In the present context, the moisture content of nutri flour was 0.96 per cent, that of *koozha* jackfruit bulb flour (KJBF) was 1.28 per cent and *varikka* jackfruit bulb flour was 1.39 per cent. The lower the moisture content of flour, the better its shelf stability and hence the quality. Veenakumari (2015) reported that jackfruit seed flour moisture content was 7.93% and bulb flours was 7.23%. Ocloo *et al.* (2010) reported that moisture content of raw jackfruit seed flour was 6.09%, whereas Abraham and Jayamuthunagai (2014) reported that the moisture content of jackfruit seed flour was 7.75%. Munishamanna *et al.* (2012) obtained the moisture content of raw jackfruit bulb flour it was (5.2%). Moisture contents of flour generally depends upon the duration of the drying process. Rajarajeshwari and Jamuna (2018) reported the nutritional profile of the jack seed flour. The flour contained moisture (4.43 %), protein (21.30g %), fat (2.73g %), total ash (2.00g %), crude fiber (5.69g %) and carbohydrates (63.85g %). Tanjung, *et al.* (2014) reported the chemical composition of jackfruit seed flour. The major components of the flour were carbohydrates (82.25%), protein (11.17%), lipid (0.99%) and crude fiber (1.67%).

Minerals

Ash content of the food materials represents the total mineral content in that food, Total mineral content value equal to or more than 0.05% is an appreciable level of mineral

Fig.25. Mineral content of jackfruit flour

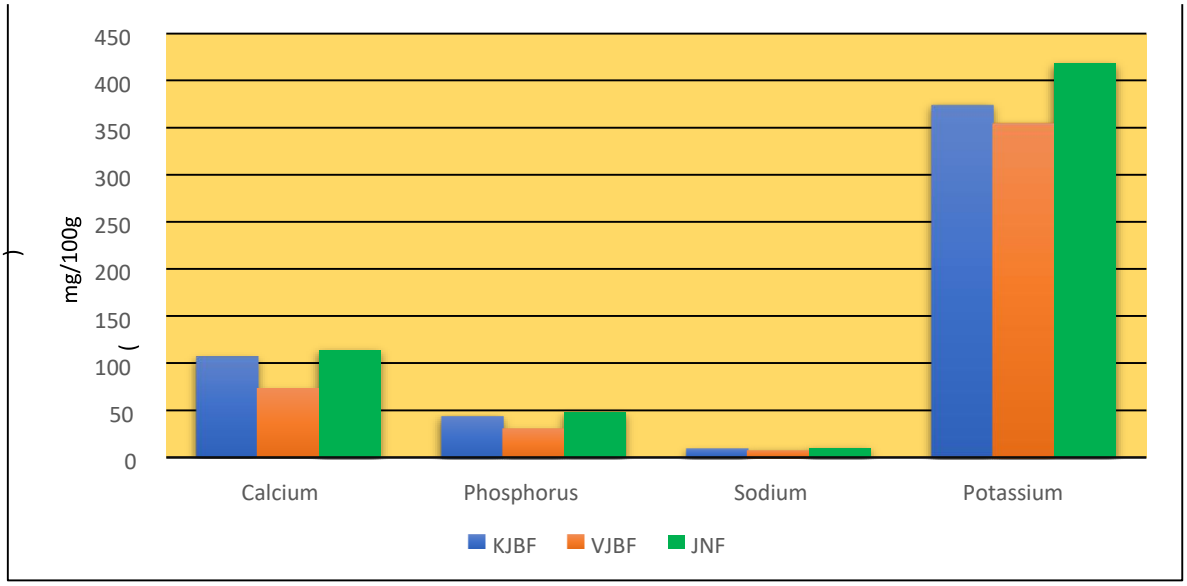
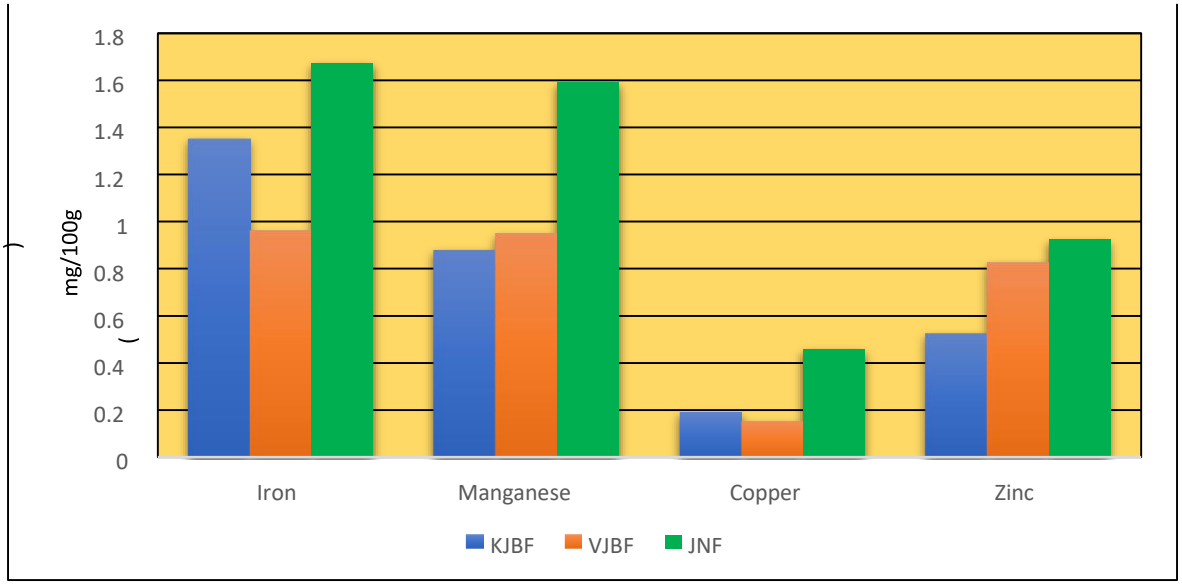


Fig.26. Mineral content of jackfruit flour



content (Adeleke and odedeji, 2010). In the present study, highest total mineral content was observed in nutri flour (0.98g) and lowest was in VJBF (0.84g). Similar findings were reported by Roji *et al.* (2019) who reported that, the total mineral content of raw jackfruit bulb flour was 0.9g whereas Amadi *et al.* (2018) reported that in raw jackfruit bulbs, seeds and leaves, the total mineral contents were 1.02g, 0.89g and 2.53g respectively. Veenakumari (2015) reported that total mineral content of jackfruit bulb flour was 0.8g. The highest calcium content was obtained for nutri flour (114.32 mg) and the lowest value was obtained in *varikka* jackfruit bulb flour (VJBF) 72.4 mg. The highest phosphorus was recorded in nutri flour (114.32mg) and lowest was obtained in *varikka* jackfruit bulb (VJFB) - 30.28mg. Nutri flour had high sodium content of 10.21mg, followed by *koozha* jackfruit bulb flour (KJBF) of 8.71mg. The least score was obtained for *varikka* jackfruit bulb flour (VJBF) - 7.67mg. The highest potassium content was noted for nutri flour (418.10mg) and lowest was seen for *varikka* jackfruit nutri flour (354.11mg). Iron content was found to be higher in nutri flour (1.67 µg/100g) followed by *koozha* jackfruit bulb flour (KJBF) - 1.35 µg/100g and was lowest in *varikka* jackfruit bulb flour (VJBF) 0.96 µg/100g. The highest manganese was recorded in nutri flour - 1.59 mg followed by *varikka* jackfruit bulb flour (VJBF) 0.95 mg and lowest was *koozha* jackfruit bulb flour (KJBF) - 0.88 mg. The highest copper and zinc content were recorded in nutri flour (0.457 mg and 0.92mg).

Similar results were obtained by Baliga *et al.* (2011) who reported that raw jackfruit bulb flour had 20 mg calcium,30 mg phosphorus, 500 mg iron and 540 IU vitamin A. Veenakumari (2015) reported that jackfruit bulb flour contained calcium (20 mg), phosphorus (30 mg), iron (500 mg) and vitamin A (540 IU). Adan (2020) reported that in raw jackfruit seeds, the total minerals varied from 0.9 to 1.2g, while the level of calcium was - 50mg, magnesium -54mg, phosphorus levels ranged from 38 to 97mg, potassium 246mg, sodium 63.2mg, iron 1.5mg and Vitamin A (IU) content ranged from 10 to 17 IU. Swami *et al.* (2012) analysed the nutritive value of jackfruit bulb flour and reported that its protein content varied from 2.0 to 2.6 g, carbohydrate 9.4 to 11.5 g, fiber 2.6 to 3.6 g, total minerals 0.8 to 0.9 g. The level of calcium was 30mg, magnesium 34mg, phosphorus was ranged between 20.0 to 57.2 mg, potassium - (287 to 323 mg), sodium - (35mg), iron - (0.4

to 1.9mg) and vitamin A IU (30 IU). Tiwari and Vidyarthi (2015), reported that jackfruit bulbs are high in nutritive value, further he also reported that every 100 g of bulb flour contained 215 mg of potassium, 35 mg of calcium, and 18 g carbohydrates. Amadi *et al.* (2018) reported the proximate composition of jackfruit seed, pulp and leaves. The calcium content reported was 0.03 g/100g in (pulp) and 0.52 g/100g in leaves. Potassium content ranged from 0.21 g/100g (leaves) to 0.33 g/100g (pulp), manganese content ranged from 9.50 mg/100g (seed) to 12.75 mg/100g (pulp). Iron content ranged from 18.25 mg/100g (seed) to 59.50 mg/100g (leaves); zinc content ranged from 5.20 mg/100g (pulp) to 9.28mg/100g in (seed). Vitamin C content ranged from 0.11 mg/100g (seed) to 2.11mg/100g (pulp). Tiwari and Vidyarthi, (2015) stated that mineral and vitamin contents varied in different maturity stages of jackfruit.

5.3.3. Nutraceutical composition

Most of the fruits have nutraceutical properties due to bio active compounds such as phenolic compounds, carotenoids, flavonoids, phytic acids, phytosterols and non-digestible carbohydrates which have significant health potentials and have the ability of therapeutic role (Rodriguez *et al.,* 2018). Boeing *et al.* (2018) states that fruits can be used as potential sources of nutraceuticals because of their natural composition of beneficial nutrients. Fruits are at par with the medicinal plants in the arena of preventive healthcare. Consumption of fruits and vegetables on a daily basis can reduce the risk of numerous chronic diseases and improve overall health.

According to Sing *et al.* (2000) jackfruit is considered as a functional food because it has valuable compounds that display functional and medicinal effects. jackfruit contains many types of nutraceutical compounds such as carotenoids, flavonoids, volatile acids sterols, and tannins in varying concentrations depending on the variety (Arung *et al.*,2007; Chandrika *et al.*,2004; Venkitaraman, 2001 and ong *et al., 2006*).

Polyphenolics are known to function as antioxidants through a number of methods, including radical scavenging by H-donation, chain initiation prevention via electron donation, and binding of transition metal ion catalysts. Flavonoids prevent platelet

Fig.27. Nutraceutical composition of jackfruit flour

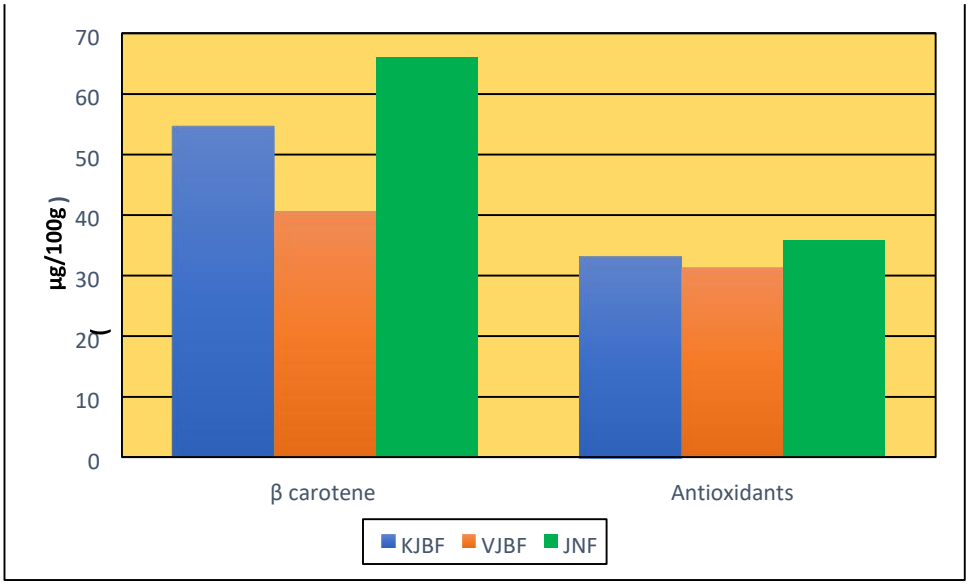
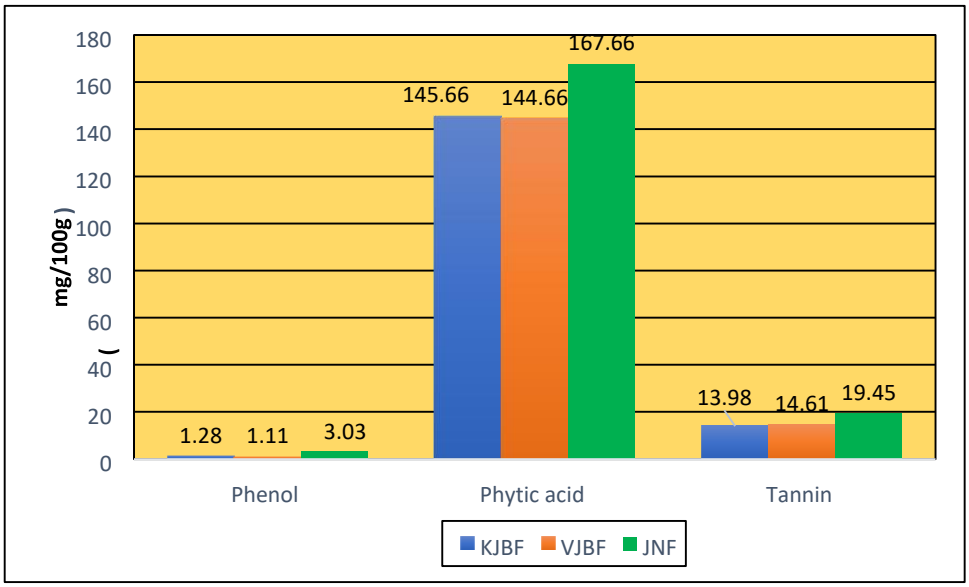


Fig.28. Nutraceutical composition of jackfruit flour



stickiness and hence platelet aggregation (Gupta *et al.,* 2015). Havsteen (2002) states that flavanoids are phenolic compounds that are shown to have powerful anti-oxidant properties. They were also said to have anti-cancer, antiviral, and anti-inflammatory properties. According to Swami *et al.* (2012) phenolic compounds in fruits and vegetables are suggested to be a major source of bioactive compounds for health benefits. Natural sources of phenolic compounds and digestive enzyme inhibitors from food, have provided a low-cost dietary treatment option for cardiovascular disorders.

There are variations in the total phenolic content reported in studies of *A. heterophyllus*: Jagtap and Bapat (2010) reported a concentration of 46mg GAE/100g, in dried jackfruit in ethanolic extracts. Shafiq *et al.* (2017) observed total phenolic content in jackfruit pulp from Lahore, Pakistan and found 239.87mg GAE/100g of dried jackfruit, in methanolic extracts, which represents 20% of amount quantified in this study. Jalal *et al.* (2015), reported the results of the analysis of *Artocarpus altilis* from Kuantan, Malaysia, in which methanolic extractions were performed and found to be 78,100mg GAE/100g of dried jackfruit. In 2011 Almeida *et al.* (2011) reported 29.0mg GAE/100g of fresh weight *Artocarpus integrifolia*.

In the present study, jackfruit based nutri flour (3.03mg) had higher phenol content followed by *koozha* jackfruit bulb flour (1.28mg) and the content was lowest in *varikka* jackfruit bulb flour (1.11mg). This result is in line with the findings of Wongsa and Zamaluddien (2005) who reported that total phenolic content in jackfruit was 0.36 mg GAE/g whereas Anila (2018) reported that of raw jackfruit bulb contained 2.11 mg and ripe stage contained 2.62mg of phenols. According to Tharani (2018) total phenols present in *koozha* jackfruit rind flour was 2g/100g and in *varikka*, it was 0.6g/100g. Nair *et al.* (2012) reported that phenolic content in jackfruit seed was 406.14mg GAE/100g. The decrease in phenolic content in fruits is attributed to a series of chemical and enzymatic alterations of some polyphenols during ripening, mainly the hydrolysis of glycosides by glycosidase, oxidation of polyphenols by phenol oxidases and polymerization of free phenols (Zheng *et al.*, 2012).

Amadi *et al.* (2018) reported that Phytic acid content ranged from 6.14 g/100g (pulp) to 8.11g/100g (seed). Vazquez (2019) observed changes in jackfruit seed which was subjected to extrusion and dehulling treatments, the phytic acid content of whole jackfruit seed flour was 187.6mg/g, which in dehulled jackfruit seed flour it was 173.9mg/g, in extruded whole jackfruit seed flour, it was 185.4mg/g and in extruded dehulled jackfruit seed flour it was 168.7mg/100g. The treatment that combined extrusion and dehulling jackfruit seed process (EDJS) showed a significant decrease in phytic acid. In the present study, Phytic acid was found to be higher in nutri flour (167.66mg) and lower in *varikka* jackEfruit bulb flour (144.6mg).

Amadi *et al.* (2018) reported that the highest tannin content was recorded for jackfruit leaves (0.07g/100g), then the pulp (0.03g/100g) and seed (0.06g/100g). Adan *et al*. (2020) reported high tannin content in the root of jackfruit (3.88–2.69 mg/g) and low content in bark (0.93– 0.52 mg/g). When tannin content of nutri flour was 19.45mg, *varikka* jackfruit flour (VJBF) had 14.61mg and *koozha* jackfruit flour had (KJBF) 13. 98mg/ 100g. Significant variation ($p<5\%$) was observed between the treatments. Vazquez (2019) observed that in jackfruit seeds which were subjected to extrusion and dehulling treatments, the tannin content was high in the whole jackfruit seed flour (65.3mg/g), and in the extruded dehulled jackfruit seed flour, the tannin content was recorded as 12.9 mg/100g. The treatment that combined extrusion and dehulling jackfruit seed method (EDJS) showed a significant decrease in tannin content. Tannins limit voluntary intake of nutrients through astringency, inhibition of enzyme action, and reduction in forage digestibility. From medicinal point of view, the polyphenol to which tannin belongs has been reported to act as antioxidants, by preventing oxidative stress, that causes diseases such as coronary heart diseases, some types of cancer and inflammation (Tapiero *et al.,* 2002).

Carotenoids are natural pigments found in plants, animals, algae and microbes that give them their yellow-reddish colour. They are known to have provitamin A activity, in addition to their colourant properties, they have beneficial effects on a variety of chronic degenerative diseases, including cancer, infection, cardiovascular diseases, and other conditions like age-related macular degeneration (Faria *et al.,* 2009). Coyne (2005)

states that the carotene content of jackfruit increased gradually with the progress of ripening.

Faria *et al.* (2009) reported that the main types of carotenoids present in jackfruits were all-trans lutein (24% to 44%), all-trans-β-carotene (24% to 30%), all-trans neoxanthin (4% to 19%), 9-cis-neoxanthin (4% to 9%), and 9- cisviolaxanthin (4% to 10%). Chandrika *et al.* (2004) reported that about six carotenoids were detected in jackfruit kernel, which were β-carotene, α-carotene, β-zeacarotene, α-zeacarotene, and β-carotene-5,6-epoxide and a dicarboxylic carotenoid and crocetin respectively forming 141.6 retinol equivalents (RE) per 100 g. Another study done by Shyamalamma *et al.* (2017) on five pulp colours of different Jackfruit cultivars, reported that, the red and orange colour pulp contained significantly higher concentrations of β-Cryptoxanthine (45.44mg/100g and 42.57mg/100g), followed by β-Carotene (44.20mg/100g and 43.14mg/100g), α Carotene (39.40mg/100g and 37.30mg/100g) and Lycopene (30.20mg/100g and 27.70mg/100g) respectively. In the present study, β carotene in nutri flour was observed to be 65.98µg. Carotenoid content may be influenced by the growing conditions, variety or cultivars, geographical location, ripeness, harvesting to market conditions (Almela, 2000).

Antioxidants are substances that neutralize the effects of free radicals. Superoxide dismutase (SOD), glutathione peroxidase, glutathione reductase, thioredoxin, thiols, and disulfide bonds are all buffering processes in every cell, that guards against the detrimental effects of free radicals. Antioxidants are compounds that can slow down, stop, or stop the oxidation process (Sies, 2000).

Jackfruits are high in phytonutrients including carotenoids, which can act as antioxidants (Baliga, *et al.*, 2011; Mushumbusi, 2015). According to Jagtap *et al.* (2010) the antioxidant activities of jackfruit fresh extracts are associated with the total phenolic and flavonoids content. Soong and Barlow (2004) stated that fresh seed and fresh fruit had 27.7 and 0.9 Gallic Acid Equivalents of phenolic contents, respectively, which are thought to have contributed to nearly 70% of the overall antioxidant activity.

Adan *et al.* (2020) reported the anti-oxidant activity of *A. heterophyllus* fruit in different extracts of methanol and ethyl acetate and showed activity with IC_{50} value of 636.55 µg/ml and 713.36 µg/ml respectively. Daud *et al.* (2019) indicated that jackfruit rind acted as a potential source of antioxidants, which could be utilized for developing value added products. Bhat *et al.* (2017) studied the various parts of jackfruits and concluded that high antioxidant activity was seen in seeds with IC_{50} value of 410 µg/ml. According to Biworo *et al*. (2015) the highest antioxidant activity was revealed in the hydroxyl radical scavenging activity followed by scavenging of hydrogen peroxide and chelating of ferrous iron. Total antioxidant capacity of jackfruit seeds was found to be 170.75 ± 0.001 mg/ gm equivalent of ascorbic acid (Sharma *et al.,* 2015).

In the present study the antioxidant content of flours varied between 31.23µg to 35.85µg, there was significant difference ($p<0.05\%$) between the treatments. Antioxidants were significantly high in nutri flour (35.85µg). Soong and Barlow (2004) confirmed high antioxidant activity and the presence of phenolic contents in the edible portions of *A. heterophyllus* fruit.

5.3.4. Shelf-life Studies of nutri flour

The shelf life of the product starts from the time the food is prepared or manufactured. The shelf life is dependent on many factors such as types of ingredients, manufacturing process, types of packaging materials and place of storage. Adequate shelf life affects the acceptance of consumer and sale of brand product (Robertson, 2016). The changes which occur in stored flour are probably due to enzymes produced or liberated in the flour; fats may also be hydrolyzed by lipolytic enzymes. Flour components, such as protein, starch and lipids change and these changes can directly affect organoleptic properties (Dobaldo-Maldonado *et al.,* 2012).

Packaging is very essential in food systems because it helps to reduce losses, enhance value, extend shelf life, maintain product quality, wholesomeness, raise market standards, and ensure food safety (Inyang *et al.,* 2008; Opara and Mditshwa, 2013). It is the simplest and most cost-effective method of preventing food contamination by pathogens

Fig. 29. Moisture content of packed jackfruit bulb flour and nutri flour

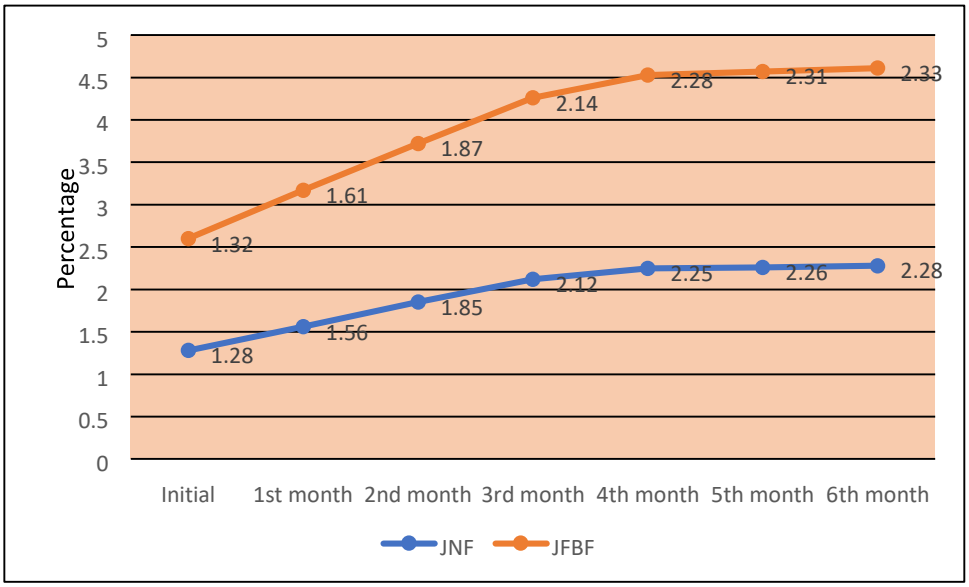


Fig.30. Bacterial colony count (10^{-6}) of jackfruit flour

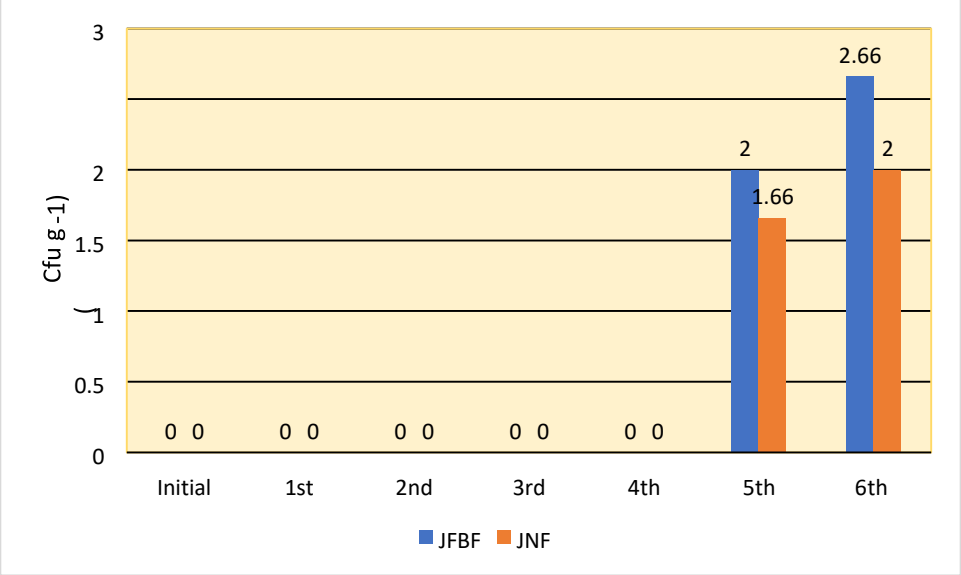


Fig.31. Bacterial colony count (10^{-7}) of jackfruit flour

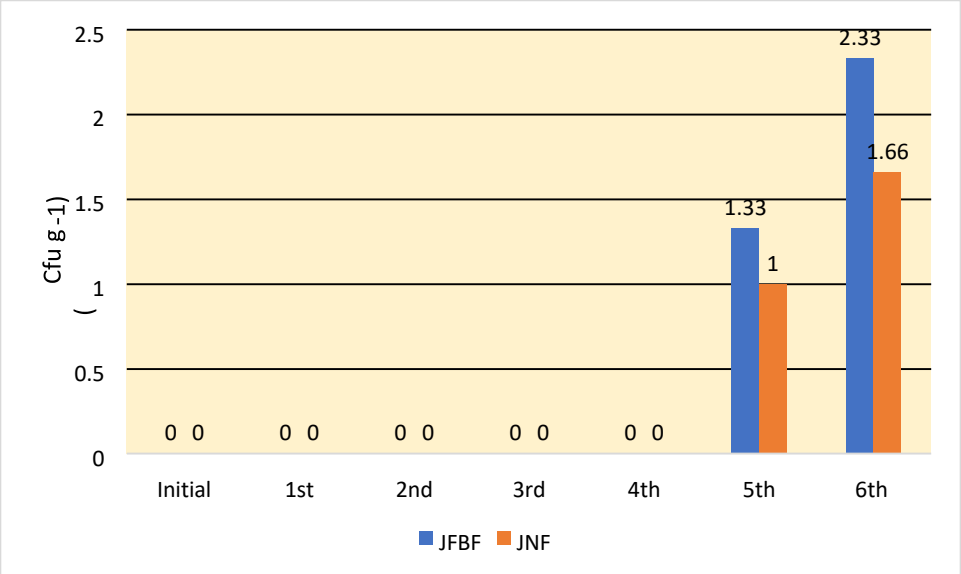


Fig.32. Fungal colony count (10^{-4}) of jackfruit flour

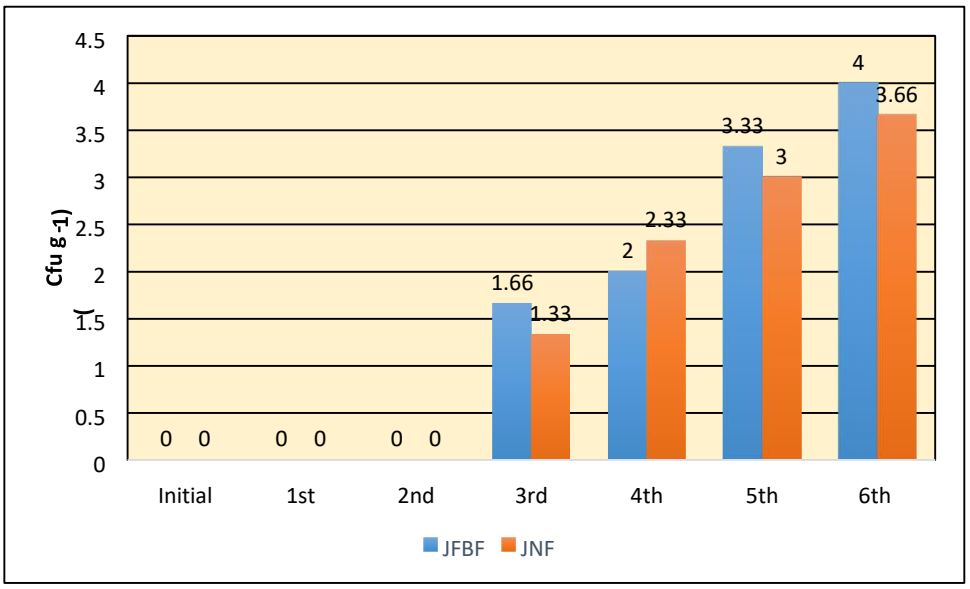
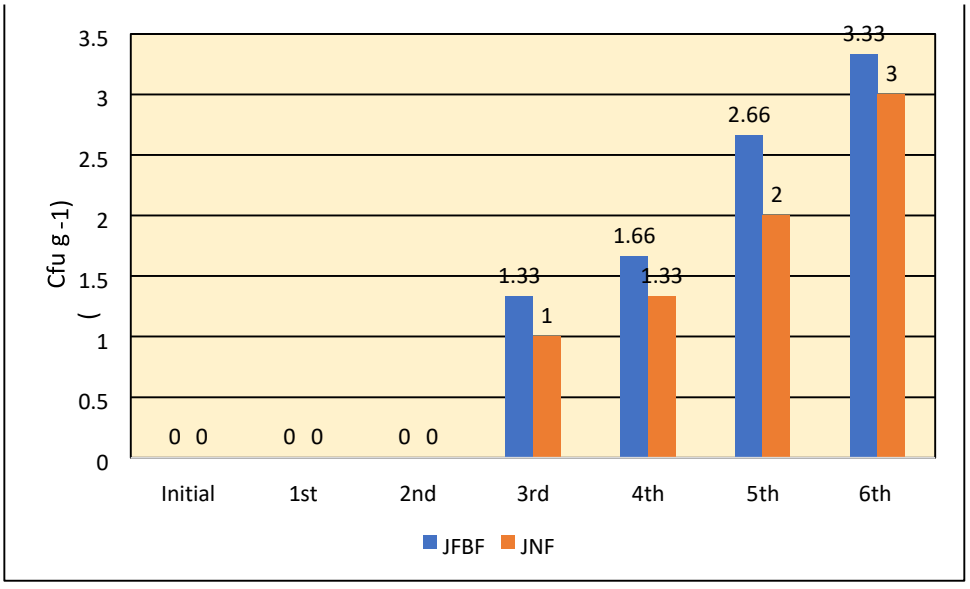


Fig.33. Fungal colony count (10^{-4} cfu g^{-1}) of jackfruit flour



and foreign matter (Opara and Mditshwa, 2013). Poor or insufficient packaging causes postharvest losses, resulting in shelf-life instability (Ogiehor and Ikenebomeh, 2006). In the present study, the developed jack-based flours were stored in metallized laminated covers, and were tested up to successive six months for their quality. The products were analysed for changes in sensory qualities, moisture and microbial parameters at intervals of one month.

Moisture content of stored jackfruit flours

During storage, moisture content, and water activity (aw) of packaged products have an impact on their shelf life (Ikhu-Omoregbe, 2006). High moisture content in flour was found to lead to lipolytic and proteolytic activities, which further leads to loss in nutrients (protein and fat) and production of more free fatty acids (FFA) resulting in inferior sensory characteristics. Initially jackfruit bulb flour packed with laminated pouches had a moisture content (1.32%) and jackfruit based nutri flour had a moisture content (1.28). After six months of storage, moisture content gradually increased and reached (2.28%) and (2.33%) for JFBF and JNF respectively, by the end of six months. The increase in moisture content did not influence the quality of the flour as increase in moisture content was negligible.

Ajisha (2018) reported that moisture content of jackfruit-based vermicelli increased during storage from 7.62 to 7.67 per cent in 3rd month whereas Veenakumari (2015) reports that after three months of storage the moisture content of JFBF increased due to the varying composition of flour in the different treatments and moisture absorption rate of package. Another study reported by Krishnaja (2014) revealed that the moisture content of the developed functional food supplements gradually increased during storage period whereas similarly Saranya (2012) also stored enriched soup mix (ESM), whose moisture content increased during storage. Anila (2018) standardized jackfruit based TVP, the moisture content of this product also increased from 7.41 to 8.72% after three months of storage. Malathidevi (2015) reported that moisture content of a jackfruit-based pasta product increased from 7.9 to 14.3% after 3rd month. The increasing moisture content during storage period may be due to relative humidity and atmospheric temperature.

Microbial profile of stored jackfruit flours

Water activity is generally accompanied with increased moisture content and high relative humidity, it increases microbial load and enhances physico chemical deterioration. (Ikhu-Omoregbe, 2006). Most of the powdered products are hygroscopic in nature and if exposed to atmosphere could absorb moisture and gases from the environment and will in turn encourage the growth of microbes (Ogugbue and Gloria, 2011). Ogiehor and Ikenebomeh (2006) reported that when gari was stored in various packaging materials, at the end of the storage period, each of the stored samples in the materials exhibited an increase in the fungal and viable bacterial count, which differed by material. Tharani (2018) reported fungal colonies in *varikka* rind flour (1.0×10^{-4}) after three months of storage and bacterial colonies in *varikka* pappad from third month (3.0×10^{-6}), *koozha* rind flour also recorded bacterial colonies in the same period ($3x10^{-4}$). Anila (2018) observed that during three months of storage jackfruit based TVP products, the bacterial colonies appeared in the third month (1.0×10^{-7}), while fungal colonies were seen within the second month ($1.5x10^{-3}$). Veenakumari (2015) developed jackfruit-based noodles and stored for three months; in the second- and third-month fungal growth was observed in treatment T_2 ($1.5x10^{-2}$ and 3.0×10^{-2}cfu). Nasheeda (2006) reported that banana powder packed with polypropylene cover after three months of storage showed bacterial population which increased from 6.68 to 6.88 $x10^{-3}$.

In the present study after fifth month of storage 2.0 and 1.33 bacterial colonies in jack fruit bulb and 1.66 and 1.00 colonies in nutri flour were observed in 10^{-6} and 10^{-7} dilution respectively. After sixth month of storage 2.66 and 2.33 bacterial colonies in jack bulb flour and 2 and 1.66 where in nutri flour at the dilution of 10^{-6} and 10^{-7} respectively were found. After 3 months the fungal growth varied between 1.66 to 4 cfu/ml in jack fruit bulb flour and 1.33 to 3.66 in nutri flour at 10^{-4} dilution and between 1.33 to 3.33 cfu/ml in jackfruit bulb flour and 1 to 3 in nutri flour at10^{-5} dilution.

Organoleptic Qualities of jackfruit-based nutri flour and jackfruit bulb flour – during storage

According to the Institute of Food Technologists (IFT), organoleptic evaluation is a scientific approach for evoking, measuring, analysing, and interpreting product as perceived through the senses of sight, hearing, touch, smell and taste (Stone and Sidel 2004; IFT, 2007). Organoleptic evaluation has become an important part for the development of food products and food by testing, analysing, and interpreting sensory results. In the present study, organoleptic evaluation was done for six consecutive months with the stored jackfruit flour, 'Oratti' was prepared and given for sensory evaluation to judges.

Hamid *et al.* (2020) reported that during storage periods, sensory properties of meat analogue with 58% jackfruit by-products and 20% vital wheat gluten was the most preferred meat analogue in terms of appearance, aroma, taste, color, hardness, juiciness and overall acceptability. Mondal *et al.* (2013) developed jackfruit-based products and observed the product's storage stability, after six months of storage, Quality of the processed products with respect to color, taste, flavour and texture were similar to that of freshly processed products. But after 8-9 months of storage the quality of jam, jelly and squash started to deteriorate and the quality of pickles (i.e., green pickle and sweet-pickle) remained unchanged even after 12 months of storage. In the present study the overall acceptability score was higher for JFBF (7.21) than JNF (6.82) respectively after six months of storage. Nandkule *et al.* (2015) reported that Jackfruit seed and soy flour noodle had shown significant changes during the storage from 0 day to 60 days. Haque *et al.* (2015) reported that shelf life of jack-fruitcakes decreased with increased level of substitution of jackfruit pulp during seven-day storage, on the basis of microbial count. Cakes containing 10% jack-fruit showed acceptable physical characteristics, sensory attributes and microbial load

5.4. QUALITY IMPROVEMENT OF NUTRI FLOUR

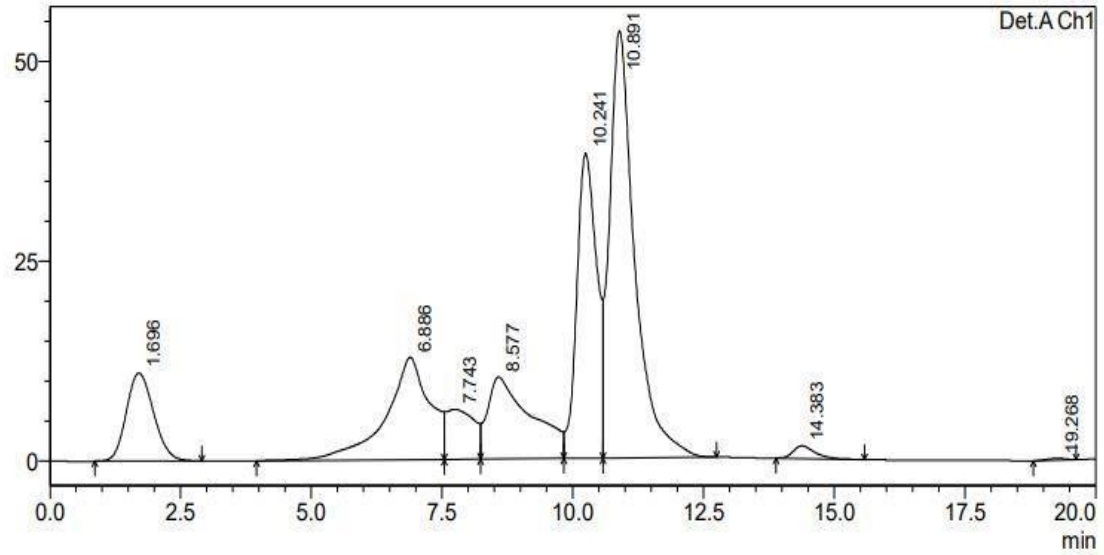
Many antinutritional factors are present in foods of plant origin. Antinutritional factors are molecules that lower the nutrient utilisation and food intake of plants or plant products used as human foods. Anti-nutritional factors can be reduced with proper processing techniques (Soetan, and Oyewole, 2009). In the present study in order to reduce the level of oligosaccharides and to increase the starch digestibility, the flour was fermented with *Saccharomyces cerevisiae* @ 5g/kg for 8hrs.

5.4.1. Reduction of oligosaccharide content in nutri flour

An oligosaccharide is characterised by a carbohydrate chain made up of 310 monosaccharides. In the foods we eat, oligosaccharides are often components of the dietary fibre. Oligosaccharides are malabsorbed by the small intestine and therefore go on to undergo fermentation in the 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.

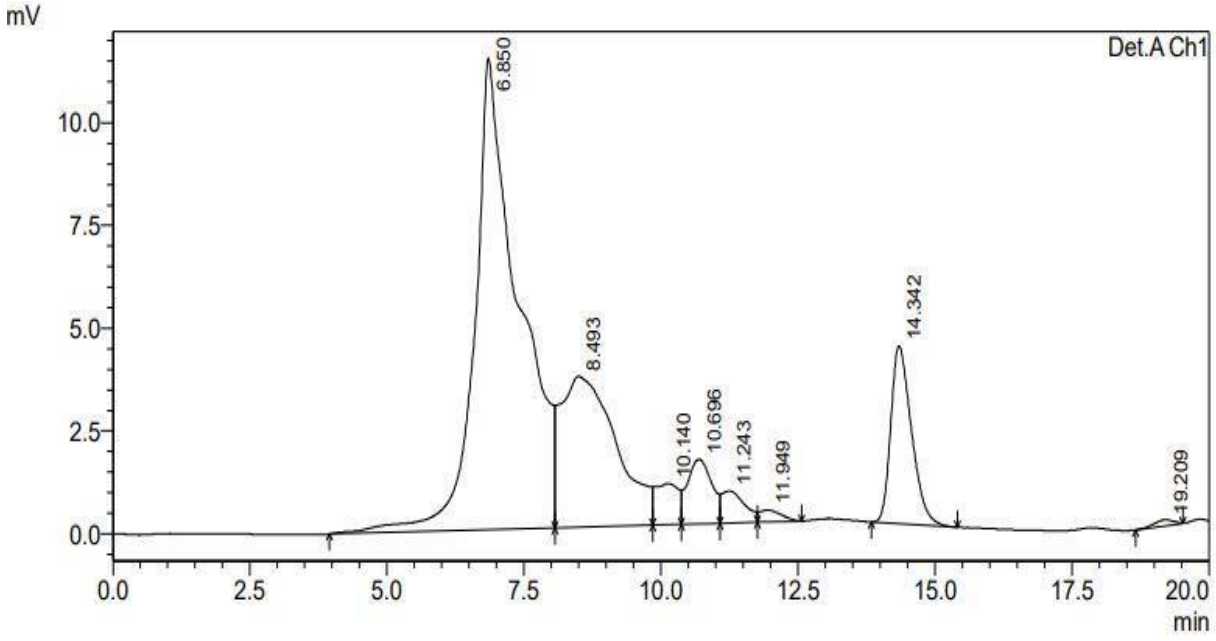
Raffinose family oligosaccharides (RFOs) are complex sugars that contain chains of 'galactose' that cannot be digested in the human upper intestine due to a lack of galactosidase, the enzyme that breaks the links in the galactose chains. As a result, the RFOs make it to the lower intestine, where they are encountered by bacteria, that utilise them as a substrate for fermentation. Methane, carbon dioxide, and hydrogen gas are produced, which can cause bloating, stomach pain, and excessive flatulence (Guillon and Champ, 2002; Shimelis and Rakshit, 2007).

Fermented foods with their microbial activity play 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 the mineral bioavailability, protein digestibility and reduction of flatulence causing oligosaccharides



Time (Min)

Fig. 35. Chromatogram of treated nutri flour



Time (Min)

Gu *et al.* (2013) suggested that an alternative technique to reduce oligosaccharides in beans through is fermentation process. Sumarna, (2008) reported that Several microbes have been widely used in the fermentation of foodstuffs like lactic acid bacteria (LAB), such as *L. plantarum* SMN 25, *L. plantarum pentosus* SMN 01 and *L. plantarum pentosus* FNCC 235, isolated from the fermentation of traditional foods, showing the ability to produce αgalactosidase, which are able to degrade oligosaccharides According to Lee *et al.* (2011), lactic acid bacteria can ferment various types of carbohydrates which include raffinose and stachyose, as these oligosaccharides are found in many plants, especially in grains. Setiawan (2016) reported that jackfruit seed flour fermented by *L. plantarum pentosus* for 32 hours resulted in degradation of the oligosaccharides (stachyose and verbascose).

In the present study, In HPLC analysis, the retention time of standard stachyose was 6.93. Retention time recorded in the untreated nutri flour was 6.93 minutes, and that of nutri flour with 8 hrs fermentation was also 6.93minutes, which was comparable. Nutri flour treated with *Saccharomyces cerevisiae* @ 8 hrs was found to be low in oligosaccharides compared to control. In a similar study by Anila (2018), it was reported that retention factor of standard Raffinose and pretreated jackfruit bulb flour was 0.79. Bulb flour with 6 hrs fermentation F_1 (0.79), 8hrs fermentation F_2 (0.79) and 12 hrs was F_3 (0.80) were analysed through HPLC. Raffinose content in jackfruit flour was 0.75,0.63,0.58 and 0.74% in control, F_1, F_2 and F_3 respectively. In the case of jackfruit seed flour, the raffinose contents were 1.28,0.42,0.31 and 0.62% in control, F_1, F_2 and F_3 respectively. Raffinose content was found to reduce highly after 8 hrs fermentation time in both jackfruit bulb flour and seed flour treatments. In another work reported by Krishnaja (2014) in order to reduce the oligosaccharide content enriched flours, were treated with *Saccharomyces cerevisiae* @ 5gms/kg for 6 hrs, 8 hrs and 12 respectively.

Fraberger (2018) reported that yeast fermentation with *Saccharomyces cerevisiae* isolated from Austrian traditional sourdough showed the highest degree of degradation of the total fructan content and the highest gas building capacity.

Nutri flour treated with *Saccharomyces cerevisiae* and untreated nutri flour were analysed in HPLC it was revealed that treated flour had very low sugar content than untreated flour. Oluseyi and Temitayo (2015) reported that fermentation resulted in proteolytic degradation of protein into amino acids and amylolytic break down of carbohydrates into sugars and organic acids.

5.4.2. In vitro starch digestibility

Food fermentation is an important approach for reducing antinutrient content and so improving the nutritional value and digestibility of foods. In the present study in vitro starch digestibility was significantly high in yeast treated nutri flour (82.81 per cent) when compared to untreated nutri flour (54.84 per cent). Sharon (2010) reported that in vitro starch digestibility of banana based un fermented food ranged between 51.41 to 56.34 %. On fermentation the starch digestibility was enhanced for 78.57 to 83.60%. Rani *et al*. (2008) reported that starch digestibility of unfermented autoclaved RSMT mixture was 62.65%, fermentation improved it to 78.33%. Fermentation of sorghum flour led to an increase in the in vitro starch digestibility from 34.55 to 56.69% after 28 h. (Elkhalifa *et al.,* 2004). In vitro starch digestibility increased after fermentation which may be due to the fact that fermentation led to changes in the endosperm protein fractions which makes starch more accessible to the digestive enzymes (Baker and Samjoo 2008).

5.5. ASSESSMENT OF IN VITRO THERAPEUTIC EFFICACY OF NUTRI FLOUR

Food is no longer considered as a mere source of energy and essential nutrients. It is now widely accepted as a disease preventive and curative agent. Recognizing the importance of diet in the prevention and treatment of a variety of health problems; consumers, researchers, and food technologists have shown an increased interest in food products that can assist and sustain health in recent years.

The consumption of vegetables and fruits has a large and consistent effect on the risk of cancer, diabetes, cardiovascular disease, cataract, and macular degeneration, according to an epidemiological study (Turkmen *et al.,* 2005; Vinuda *et al.,* 2010).

Plant products are thought to be the most significant components of a healthy diet for humans. Fruits and vegetables have been shown to have protective effect against diseases. Carotenoids, alkaloids, vitamins, minerals and polyphenols are some of the phytochemicals present in fruits and vegetables, which are free from undesirable side effects and possess powerful pharmacological actions (Deepika *et al.,* 2011). Jackfruit has also been used in traditional medicine as an analgesic and immunomodulator because, it is rich in phytochemicals including phenolic compounds. Jackfruit is considered as a functional food because the valuable compounds present in different parts of the fruit display functional and medicinal properties.

5.5.1. Anti-diabetic activity

The modern oral hypoglycemic agents produce undesirable side effects. Thus, alternative therapy is preferred. The traditional medicines have demonstrated a bright future in therapy of diabetes (Malviya *et al.,* 2010). According to Hettiaratchi *et al.* (2011) the postprandial glycemic response to raw and ripe jackfruit elicits low glycemic index The flavonoids present in jackfruit extract has been identified to be responsible for the non-toxic hypoglycemic action.

Biworo *et al.* (2015) reported that, jackfruit extract can inhibit the glycation of haemoglobin. The inhibition might be caused by the presence of phytochemical constituents in jackfruit extract such as ascorbic acid, □-carotene and lycopene. Furthermore, the jackfruit extract also has antioxidant activity, so the extract can inhibit the hemoglobin glycation. Koh *et al*. (2020) reported the effectiveness of the fermented jackfruit leaf beverage as an anti-diabetic agent, which was compared with Streptozotocin-induced Sprague on Dawley rats for 4 weeks. The results indicated that, fermented jackfruit leaf beverage has similar anti-diabetic properties as commercial anti-diabetic drugs, with no adverse side effect.

Kumar *et al.* (2015) reported that delaying glucose absorption by inhibiting the associated enzymes, such as α-glucosidase, could be one of the therapeutic methods in diabetes mellitus treatment. Plant extracts were reported to be important sources of

α-glucosidase inhibitors compounds. Flavonoids and alkaloids are the two major groups of compounds associated with α-glucosidase inhibition activity in plants.

In a study conducted by Krishnapriya and Kanjana, (2019), the anti-diabetic activity of the jackfruit seed extract was tested for α-amylase inhibitory and αglucosidase inhibitory activity. The results revealed that, the anti-diabetic screening using both the assays showed very good anti-diabetic property of the seeds. The ethanol extracts of seeds (at a concentration 100 µg/mL) exhibited 95.4% of α -amylase inhibitory activity and 90.9% of α-Glucosidase inhibitory activity. In another study by Ajiboye *et al*. (2016), the ethanolic extract of *A. heterophyllus* stem bark was observed to show inhibitory activities on αamylase and α-glucosidase with IC_{50} of 4.18 ± 0.01 and 3.53 ± 0.03 mg/mL, respectively. The Lineweaver-Burk plot revealed that ethanolic extract of *A. heterophyllus* stem bark exhibited non-competitive inhibition for α-amylase and uncompetitive inhibition for α-glucosidase activities. Culas *et al.* (2021) developed liquid based tea products made from bark extracts of *Cinnamomum zeylanicum* (cinnamon) and leaves of *Artocarpus heterophyllus* (Jack), which were evaluated for their antidiabetic effects; the percentage of inhibition of alphaamylase was 31.03 ± 0.29 at a concentration of 4 µg/mL of Jack tea and 13.27 ± 0.32% at a concentration of 17.5 μg/mL of cinnamon brew. In the present study, the petroleum ether extract of nutri flour at a concentration of 100 µg/mL showed maximum inhibition of 47.17% on the activity α -amylase with an IC_{50} value 40.86 µg/mL. and 63.93% of α -Glucosidase inhibitory activity with an IC_{50} values 43.82 µg/mL. The jackfruit based nutri flour can thus be recommended for the management of diabetes mellitus. The bioactive compounds observed in the extract or the glycosides present in the crude extracts act as a substrate for the αglucosidase enzyme and may be responsible for the inhibitory activity (Elya *et al.,* 2012).

5.5.2. Hypolipidemic activity of nutri flour

Hyperlipidemia is a crtical condition of elevated lipid levels in the body that ultimately leads to the development and progression of various CVDs. In the present study the nutri flour extracts in petroleum ether recorded high inhibition rates of the enzyme β-hydroxy-β glutaryl CoA- reductase than other fractions (78.06%), which was comparable to

Fig. 36. α-Amylase Inhibition assay

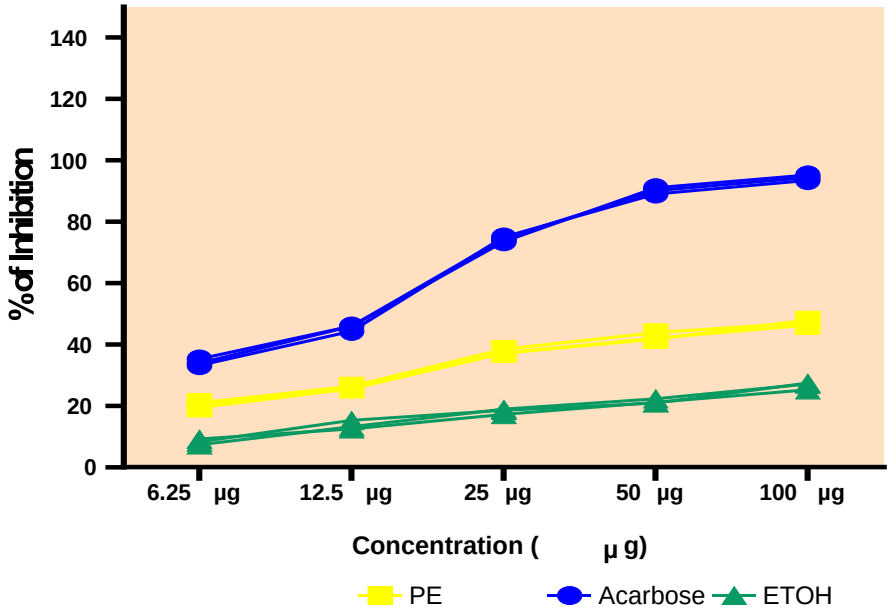
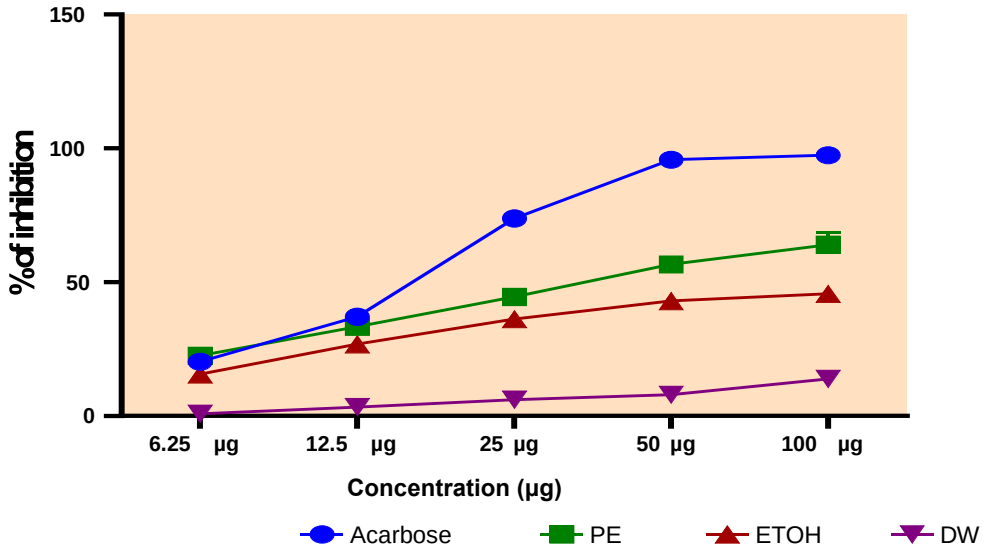


Fig. 37. α-Glucosidase Inhibition assay



fenofibrate drug (93.51%). The ethanol extracts of nutri flour exhibited 43.17% inhibition. The lowest inhibition percentage was observed for nutri flour extract in distilled water 39.53%. Gupta *et al.* (2015) reported that the aqueous extract of *A. heterophyllus* supplementation for 21 days showed antidiabetic and antihyperlipidemic potential, as shown by restoration of blood glucose levels and biochemical profiles. Burci *et al.* (2019) conducted a study of ethanol extracts taken from seeds of the jackfruit (*Artocarpus heterophyllus* Lam.) for testing its ability to reduce the hyperglycemic levels of mice at a dose of 50 milligrams per kilogram of body weight. The extract of *A. heterophyllus* supplementation for 21 days showed antidiabetic and antihyperlipidemic potential, as shown by restoration of blood glucose levels and biochemical profiles.

5.5.3. Hepato protective effect of nutri flour

The Proliferative activity of H_2O_2 on HepG2 cell lines, was used to study the hepatic protective effect of jackfruit extract. Cells treated with 25ug/ml JNF recorded almost 100 % viability and with 50% showed very slight proliferation activity compared to control (99.62%). When treated with a concentration of 100ug/ml, the percentage of cell viability was reduced to 81.47%.

Phukan *et al.* (2018) reported the results of the aqueous extract of seeds, leaves and fruit of plants for their effects on CCl_4 induced hepatotoxicity in Swiss albino mice. Animals of either sex were treated with CCl_4 for one day followed by oral administration of a constant dose of aqueous extract of Jackfruit seeds, leaves and fruits for 30 days. The hepatoprotective activity of the extracts were determined by assessing the biochemical parameters in rat serum. Serum ALP, AST, ALT, Bilirubin and total protein levels was, found to significantly change in CCl_4 treated animals. After administration of aqueous extract of Jackfruit seed, leaf and fruits, these levels recovered close to normal levels except for total bilirubin level. The results revealed that aqueous extract of Jackfruit seeds, leaves and fruits have beneficial effects on liver function. It is assumed that this hepatoprotective effect may be due to the presence of secondary metabolites that respond to the stimuli in natural environment along with the influence of abundant calcium, potassium, magnesium.

The therapeutic efficacy of nutri flour observed in this study is justified with the results of related studies on various parts of jackfruit proving their anti-diabetic, hypolipidemic, hepatoprotective and anti-oxidant activity.

Future line of work

Consumer demand for convenience foods is now on the rise around the globe. Convenience has an immense impact on the food choices of today's consumers. The modern consumers are increasingly interested in their personal health and expect the food that they eat to be healthy and even capable of preventing illness. Developed nutri flour is rich in fiber, antioxidants and other phytochemicals with lot of therapeutic properties. Hence, to confirm these properties supplementation studies on humans need to be taken up.

Summary

6. SUMMARY

jackfruit (*Artocarpus heterophyllus Lam*.) locally called ‘chakka’, belonging to the family Moraceae, is one of the most popular and evergreen trees in tropical regions, including Kerala. It is said to have originated from the Western Ghats of India (Goswami *et al.,* 2010). Owing to its abundant nutritional qualities, high production and popularity, this fruit was declared as the official fruit of Kerala from march 21, 2018 in order to promote the 'Kerala jackfruit' as a brand in markets across the country and abroad. The climatic condition of Kerala suits the growth of jackfruit trees. Jackfruit has excellent sensory appeal and processing qualities hence it is highly suitable for value addition (Shruthy, 2005). About 55 to 60 percent of this fruit is made up of the outer rind or peel, inner core, and perianth (Subburamu *et al.,* 2002). The by-products of the fruit (perigones, rind core and skins) make up about 70 to 80 percent of a jackfruit. Seed is a valuable by-product that accounts for about 12- 14 percent of a jackfruit's total weight (Prathima, 2008).

The study entitled, “Development and quality evaluation of a jackfruit based nutri flour” was undertaken with the objective to formulate and standardize a jackfruit based nutri flour, comprised of all the edible parts of the fruit and to evaluate its qualities and in vitro therapeutic efficacy. The developed nutri flour was studied in depth for its functional qualities, chemical and nutritional profile, sensory qualities and shelf-life. The study also envisaged the improvement of digestive quality of the developed nutri flour through removal of oligosaccharides (Stachyose) and to assess its in vitro therapeutic efficacy.

Raw mature jackfruits were collected from the Instructional farm, College of Agriculture, Vellayani and also from the adjacent home yards. Weight of whole jackfruits of cv *koozha* and cv *varikka*, were noted. The bulbs, perigones, seeds, rind, core and testa were separated out. The details of fresh and dry weight, percentage composition, yield, moisture percentage, processing loss and dry matter percentage of the various edible portions of jackfruit were recorded. The total weight of *koozha* fruit ranged between 11.54 to 21.5kg, the weight of total bulb, seed, perigones, testa, rind and core weight ranged between 4.60 to 11.94kg, 2.27 to 6.92kg, 0.63 to 1.72kg, 0.142 to 0.223g, 1.12 to 3.83kg

and 0.825 to 1.86kg respectively. The total weight of *varikka* fruits ranged between 10.54 to 20.36kg, the total weight for bulb, seed, perigones, testa, rind and core ranged between 4.07 to 9.42kg, 2.10 to 5.48 kg, 0.64 to 0.99g, 0.07 to 0.21kg 0.99 to 3.05kg and 0.82 to 1.86kg respectively.

There was a significant variation among cultivars in carbohydrate content of bulbs, seeds, perigones, testa, rind and core of both cultivars. Varikka bulb had the highest carbohydrate content (19.79g/100g) and the lowest carbohydrate content was seen in *varikka* core (2.73g/100g). Jackfruit *koozha* rind (6.69g/100g) had higher dietary fiber than other parts followed by *varikka* rind (5.78g).The lowest fiber content was reported in *varikka* testa (1.70g/100g), dietary fiber was higher in *koozha* cultivar compared to *varkka* cultivar.

For determination of glycemic index of jackfruit parts, blood glucose response of glucose and jackfruit parts were calculated. The blood glucose response produced after consuming the fruit parts was significantly lower, when compared with glucose ($p<0.05$). Jackfruit *koozha* bulb had the largest rise of blood glucose response (5.8 mmol/L ± 0.03), while jackfruit *koozha* rind (4.6 mmol/L ± 0.03) showed the lowest, after 120 minutes. Among different jackfruit parts, the mean AUC was highest for *varikka* seed (171.13±0.80) followed by *varikka* bulb (167.49 mmol/L ±1.04) and *koozha* seed (167.31 mmol/L ±1.31). The highest glycemic index value was reported for *varikka* seed (69.31±0.99) followed by *varikka* bulb (67.82±0.90), *koozha* seed (67.74 mmol/L ±0.87) and *koozha* bulb (63.29 mmol/L ±1.21) while the lowest glycemic index was observed for *koozha* rind (45.26 mmol/L ±0.52). In the case of glycemic load, the lowest glycemic load was reported for *varikka* core (1.29 mmol/L ±0.01), the highest value was obtained for *koozha* seed (12.42±0.16), which was on par with *varikka* seeds (11.81 mmol/L ±0.17) and *koozha* bulbs (11 mmol/L ±0.21).

Nutri- flour formulations were made based on the results of experiment one. The order of glycemic index of jackfruit parts were observed as KJRF> KJTF >VJTF >VJRF > KJPF > VJPF >KJCF >VJCF > KJBF >KJSF > VJBF >VJSF. The major component (50-60%) of flour was contributed from the fruit parts with low glycaemic index and 40 percent

was formed by other components in different proportions. The ten formulations of nutri flour and control were evaluated for their sensory qualities like appearance, colour, flavour, texture, taste and overall acceptability. Jackfruit based nutri flour was processed into 3 commonly consumed popular breakfast dishes namely "puttu", "ada" and "oratti". On the basis of analysis of mean scores F_9 was selected as the best formulation. Among the three products, based on overall acceptability scores '*oratti'* was found to be more acceptable.

The functional quality of nutri flour and bulb flour was analysed. Nutri flour had the lowest swelling power (7.65g), solubility (1.48%), water absorption capacity (4.36%) and bulk density (1.04g/ml) as compared to jackfruit bulb flour.

The proximate composition of carbohydrate content of nutri flour was 31.59 g/100g, which was higher than koozha jack bulb flour (14.74g/100g) and *varikka* jack bulb flour (19.79g/100g). The protein content was significantly higher in nutri flour (7.03g/100g) compared with *koozha* and *varikka* bulb flours. The dietary fibre was higher in nutri flour (13.58g/100g), and this content showed significant difference with values of dietary fiber of *koozha* jackfruit bulb (KJBF) (1.95g/100g) and *varikka* jackfruit bulb (VJBF) (1.61g/100g). The moisture content of nutri flour was 0.96 per cent, that of *koozha* jackfruit bulb flour (KJBF) was 1.28 per cent and *varikka* jackfruit bulb flour was1.39 per cent.

The mineral content of nutri flour was analysed for, calcium (114.32mg), phosphorus (47.92mg), sodium (10.21mg), potassium (418.10mg), iron (1.67mg), manganese (1.59mg), copper (0.457mg) and zinc content (0.923mg) which was higher in nutri flour compared to *koozha* and *varikka* jackfruit bulb flours.

The nutraceutical properties such as phenol, phytic acid, tannin, β carotene and antioxidants of the jackfruit flours were analysed. Jackfruit based nutri flour had higher phenol content (3.03mg) followed by *koozha* jackfruit bulb flour (1.28mg) and *varikka* jackfruit bulb flour (1.11mg). Phytic acid was found to be higher in nutri flour (167.66mg) and lower in *varikka* jackfruit bulb flour

(144.6mg). Level of tannins (19.45mg), β carotene (65.98 µg) and antioxidant content (35.85 µg) was found to be significantly higher in nutri flour compared to *koozha* and *varikka* jack bulb flours.

The developed jackfruit nutri flour formulation (F_9) and control, were was packed in metallised laminated pouches and kept for storage studies under ambient conditions for a period of six months storage. After each month the products were analysed for changes in sensory qualities, moisture and microbial parameters.

Initially, moisture content of jackfruit bulb flour packed with laminated pouches was 1.32% and jackfruit based nutri flour was 1.28%. After six months of storage, moisture content gradually increased and reached a maximum of 2.28% and 2.33% by the end of six months. Sensory Qualities of jackfruit-based flour during storage revealed that the overall acceptability score were higher for JFBF (7.21) than JNF (6.82) respectively after six months of storage. During storage period bacterial colonies were observed from fifth and sixth month in jackfruit based nutri flour and jackfruit bulb flour at the dilution of 10^{-6} and 10^{-7} respectively. Simultaneously, fungi were detected from the third month of storage at the dilution of 10^{-4} and 10^{-5} respectively.

To reduce the level of oligosaccharides and to increase the starch digestibility, the nutri flour was fermented with *Saccharomyces cerevisiae* @ 5g/kg for 8hrs. In HPLC analysis, the retention time of standard stachyose, untreated nutri flour and treated nutri flour was 6.93. Nutri flour treated with *Saccharomyces cerevisiae* @ 8 hrs was found to be low in oligosaccharides compared to control. In vitro starch digestibility was also significantly high in yeast treated nutri flour (82.81 per cent), when compared to untreated nutri flour (54.84 per cent).

Through in vitro therapeutic methods anti-diabetic, hypolipidemic and hepatoprotective activity of nutri flours were analysed. Anti-diabetic activity of nutri flour was investigated through α-glucosidase and α-amylase inhibitory activity, by testing the samples in petroleum ether, ethanolic and distilled water extracts of jackfruit-based nutri flours and compared with the control sample of acarbose. Maximum inhibition activity was revealed in nutri flour extracted with petroleum ether at the concentration of 100 µg/mL on α -amylase (47.17%) with an IC_{50} value of 40.86 µg/mL and on α -Glucosidase (63.93%) with an IC_{50} value of 43.82 µg/ml. As for hypolipidemic activity, lowest inhibition percentage was observed in nutri flour extracted in distilled water 39.53% and highest

inhibition percentage was observed in petroleum ether (78.06%). Hepato protective effect of nutri flour showed that cells treated with 25ug/ml JNF recorded almost 100 % viability and with 50% showed very slight proliferation activity compared to control (99.62%).

On the whole, the study concluded that the nutri flour developed from different parts of the raw jackfruits (12 weeks maturity) of cv *koozha* and cv *varikka* was high in nutrients and had acceptable sensory qualities and reasonable shelf-life. The jackfruit based nutri flour was highly versatile, which has scope to be incorporated in many recipes. The developed nutri flour revealed hypolipidemic and hepatoprotective activity, it also displayed low glycemic index and effective anti-diabetic property. So, jackfruit based nutri flour can be recommended for diabetic patients without significantly increasing the blood glucose response. However, the stantadised product needs to be further scaled up for commercialization and marketing.

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Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Community Science

CONSENT LETTER OF SUBJECTS

I have no objection in participating in the study entitled "Development and quality evaluation of a jackfruit based nutri flour"

I understand that my identity will not be disclosed to anyone without my permission. I have the right to withdraw from the study at any moment and the data so far collected will be utilized only with my prior permission.

I understand that my responses will be treated with the confidentiality required by ethical research standards.

I also agree that research data gathered from the study may be published; used in future studies and that potentially identifiable information will not be used in any reports at any time.

Signature of the subjects

Name

Date

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Community Science

Title: Development and quality evaluation of a jackfruit based nutri flour

Hedonic rating scale for the sensory evaluation of 'Oratti', 'Puttu' and 'Oratti'

PARTICULATES	TREATMENTS										
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
Appearance											
Colour											
Flavour											
Texture											
Taste											
Overall acceptability											

*Kindly indicate your rating between 1-9 (1 stands for poor and 9 stands for excellent)

Like Extremely	9
Like Very much	8
Like Moderately	7
Like slightly	6
Neither like nor Dislike	5
Dislike Slightly	4
Dislike Moderately	3
Dislike Very much	2
Dislike Extremely	1

NAME:

SIGNATURE:

APPENDIX III

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

Abstract

DEVELOPMENT AND QUALITY EVALUATION OF A JACKFRUIT BASED NUTRI FLOUR

SOUMYA, P. S.
(2018 - 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,
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KERALA, INDIA

2022

ABSTRACT

The study entitled “Development and quality evaluation of a jackfruit based nutri flour” was carried out at the Department of Community Science, College of Agriculture, Vellayani, during the period 2018-2021. The main objectives of the study were to formulate and standardize a jackfruit based nutri flour comprised of all the edible parts of the fruit and to evaluate its qualities and invitro therapeutic efficacy.

Jackfruit cv. *Koozha* and *varikka* based nutri flour was developed on the basis of glycemic index of the various parts of the fruit. Raw jack fruits (12 weeks maturity) were selected. Weight of bulbs, perigones, seeds, rind, core and testa were recorded separately to get the final yield, wet and dry weight, moisture percentage, processing loss and dry matter percentage of the product. The order of glycemic index of jackfruit parts were observed as KJRF> KJTF >VJTF >VJRF > KJPF >
VJPF >KJCF >VJCF > KJBF >KJSF > VJBF >VJSF. The major flour was constituted with greater percentage of fruit parts with low glycaemic index (50 – 60 %) and 40 % was formed by other components in different proportions.

Ten formulations of nutri flour and control were evaluated for their sensory qualities. For these three popular breakfast dishes like “puttu”, “ada” and “oratti” were developed. On the basis of analysis of mean scores of sensory parametersF_9 was selected as the best combination. Among the three products based on overall acceptability scores ‘*oratti’* was found to be more acceptable.

Analysis of functional quality revealed that nutri flour had lower swelling power (7.65g), solubility (1.48%), water absorption capacity (4.36%) and bulk density (1.04g/ml) compared to jackfruit bulb flours.

The proximate composition of carbohydrate (31.59 g/100g), protein (7.03g/100g), dietary fiber (13.58 g/100g) were significantly high in nutri flour compared with *koozha* and *varikka* bulb flours. The moisture content of nutri flour was lower (0.96%), than *koozha* jackfruit bulb flour and *varikka* jackfruit bulb flour (1.28% and 1.39%) respectively. The mineral content such as, total minerals (0.98g), calcium (114.32mg), phosphorus (47.92mg), sodium (10.21mg), potassium (418.10mg), iron (1.67mg), manganese (1.59mg), copper (0.457mg) and zinc (0.923mg) content were higher in nutri flour in comparison to *koozha* and *varikka* jackfruit bulb flours. The nutraceutical

components like phenol (3.03mg) phytic acid (166.77mg), tannin (19.45mg), β carotene (65.98 µg) and antioxidant content (35.85 µg) was significantly higher in nutri flour compare to *koozha* and *varikka* jack bulb flours.

The developed jackfruit nutri flour formulation (F_9) was packed in metallised laminated pouches and kept for storage studies under ambient conditions for a period of six months storage. During the storage period moisture content, microbial profile and organoleptic qualities were found to be acceptable.

To reduce the level of oligosaccharides and to increase the starch digestibility the flour was fermented with *Saccharomyces cerevisiae* @ 5g/kg for 8hrs. In HPLC analysis, at a retention time of 6.93 minutes standard stachyose, untreated and treated nutri flour. Nutri flour treated with *Saccharomyces cerevisiae* @ 8 hrs was found to be low in oligosaccharides compared to control. In vitro starch digestibility was significantly high in yeast treated nutri flour (82.81%) when compared to untreated nutri flour (54.84%).

Anti-diabetic activity of nutri flour was investigated through α-glucosidase and α-amylase inhibitory activity, by using different solvents. A maximum inhibitory activity was observed in petroleum ether extracted of nutri flour at a concentration of 100 µg/mL in α -amylase (47.17%) and α -Glucosidase (63.93%) enzymes. Hypolipidemic activity of nutri flour showed, highest inhibition percentage with petroleum ether (78.06%) and lowest with distilled water (39.53%). Hepato protective effect of nutri flour was higher in cells treated at 50% concentration.

From the above study, it can be concluded that jackfruit based nutri mix has hypoglycemic, hypolipidemic as well as hepatoprotective properties. The nutri mix is formulated from all edible parts of jackfruit, which adds on to the therapeutic value of the product. The entire fruit utilization answers the answers the problem of environmental contamination with these underutilized fruit parts.

ആമുഖം

2018 - 2021 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിലെ കമ്മ്യൂണിറ്റി സയൻസ് ഡിപ്പാർട്ട്മെന്റിൽ ചക്കയുടെ വിവിധ ഭക്ഷ്യയോഗ്യ ഭാഗങ്ങൽ കൊണ്ട് **"ഒരു ന്യൂട്രീഫ്ലോറിന്റെ തയ്യാറാക്കലും അതിന്റെ ഗുണനിലവാര വിലയിരുത്തലും"** എന്ന വിഷയത്തിൽ ഒരു പഠനം നടത്തുകയുണ്ടായി. ഗുണ നിലവാരത്തിൽ ആരോഗ്യ ദായകമായ പ്രവർത്തനങ്ങൾ ഉണ്ടോ എന്ന് കൂടി ഉറപ്പാക്കി.

കൂഴയുടേയും വരിക്കയുടേയും വിവിധ ഭാഗങ്ങൾ നിശ്ചിത അളവിൽ മിശ്രിതപ്പെ ടുത്തിയാണ് ഈ കൂട്ട് തയ്യാറാക്കിയത്. ഗ്ലൈസീമിക് സൂചികയുടെ അടിസ്ഥാനത്തി ലാണ് ഇവയുടെ അനുപാതം നിശ്ചിയിക്കപ്പെട്ടത്. ചക്ക (12 ആഴ്ച പ്രായ പൂർത്തിയായ ത്) തെരെഞ്ഞടുത്തു. ചുള, കുരു, ചവിണി, ചക്കപ്പാട, ചക്കപ്പൂഞ്ച്, ചക്ക മടൽ എന്നിവ യുടെ തൂക്കം വെവ്വേറെ രേഖപ്പെടുത്തി, കൂടാതെ ഈർപ്പമുള്ളതും ഉണങ്ങിയതുമായ ഭാഗങ്ങളുടെ ഈർപ്പത്തിന്റെ ശതമാനം, സംസ്കരണ നഷ്ട്ടം, ഉൽപ്പന്നത്തിന്റെ ഉണങ്ങിയ പദാർത്ഥത്തിന്റെ ശതമാനം എന്നിവ കണക്കിൽ എടുത്തു. ചക്കയുടെ വിവധ ഭാഗങ്ങളുടെ ഗ്ലൈസീമിക് സൂചിക യഥാക്രമം കൂഴച്ചക്കയുടെ മടൽ → കൂഴച്ചക്കയുടെ പാട → വരിക്കച്ചക്കയുടെ പാട → വരിക്കച്ചക്കയുടെ മടൽ → കൂഴച്ചക്കയുടെ ചവണി → വരിക്കച്ചക്കയുടെ ചവണി → കൂഴച്ചക്കയുടെ പൂഞ്ച് → വരിക്കച്ചക്കയുടെ പൂഞ്ച് → കൂഴ ച്ചക്കയുടെ ചുള →കൂഴച്ചക്കയുടെ കുരു → വരിക്കച്ചക്കയുടെ ചുള → വരിക്കച്ചക്കയുടെ കുരു എന്നിങ്ങനെ ആയിരുന്നു. കുറഞ്ഞ ഗ്ലൈസീമിക് ഇൻഡക്സ് ഉള്ളത് കൂടുതൽ ശതമാനത്തിലും (50-60 %) കൂടാതെ 40% മറ്റ് ഭാഗങ്ങളാൽ ചേർത്ത് വിവിധ അനുപാ തങ്ങളിൽ കൂട്ടുകൾ തയ്യാറാക്കി.

ചക്കയിൽ നിന്നുള്ള ഈ കൂട്ടുകളുടെ 10 എണ്ണം F_1 മുതൽ F_{10} വരെ രുചി നില വാരം വിലയിരുത്തുകയുണ്ടായി. മൂന്ന് പ്രധാനപ്പെട്ട പ്രഭാത ഭക്ഷണങ്ങളായ **"പുട്ട്,**

അട, ഒരട്ടി" എന്നിവ ഈ മിശ്രിതങ്ങൾ കൊണ്ട് തയ്യാറാക്കി. സെൻസറി പരാമീറ്ററുക ളുടെ ശരാശരി സ്കോറുകളുടെ വിശകലനത്തിന്റെ അടിസ്ഥാനത്തിൽ F_9 മികച്ച മിശ്രിത മായി തിരഞ്ഞെക്കപ്പെട്ടു. സ്വീകാര്യതയുടെ സ്കോറുകളെ അടിസ്ഥാനമാക്കി മൂന്ന് ഉൽപ ന്നങ്ങളിൽ **'ഒരട്ടി'** കൂടുതൽ സ്വീകാര്യമാണെന്ന് കണ്ടെത്തി.

ചക്കച്ചുള പൊടിയെ അപേക്ഷിച്ച് ചക്കയിൽ നിന്നുള്ള ന്യൂട്രീഫ്ലോറിന്റെ സ്വെല്ലിംഗ് പവർ (7.65 ഗ്രാം) സോളിബിലിറ്റി (1.48%) ജല ആഗിരണം ചെയ്യാനുള്ള ശേഷി (4.36%) ബൾക്ക് ഡെൻസിവിറ്റി (1.04 ഗ്രാം /മി.ലി) എന്നിവ കുറവായിരുന്നു. കാർബോ ഹൈഡ്രേറ്റ് (31.59 ഗ്രാം/100 ഗ്രാം), മാംസ്യം (7.03ഗ്രാം /100 ഗ്രാം), നാരുകൾ (13.38 ഗ്രാം / 100ഗ്രാം) എന്നിവയുടെ തോത് കൂഴയുടെയും വരിക്കയുടെയും ചുളയുടെ പൊടിയെ അപേക്ഷിക്ക് ന്യൂട്രീഫ്ലോറിൽ ഗണ്യമായി ഉയർന്ന തോതിൽ അടങ്ങിയിരു ന്നു. ന്യൂട്രീഫ്ലോറിന്റെ ഈർപ്പത്തിന്റെ തോത് (0.96 %), കൂഴയുടേയും വരിക്കയു ടേയും ചുളകളുടെ പൊടിയേക്കാൾ (1.28%, 1.39%) കുറവായിരുന്നു. അതുപോലെ തന്നെ ധാതുക്കളുടെ മൊത്ത അളവ് (0.98 ഗ്രാം), കാൽസ്യം(114.32 മി.ഗ്രാം) ഫോസ്ഫ റസ് (47.92 മി.ഗ്രാം), സോഡിയം (10.21 മി.ഗ്രാം) പൊട്ടാസ്യം (418 -10 മി.ഗ്രാം, ഇരുമ്പ് (1.67 മി.ഗ്രാം), മാംഗനീസ് (1.59 മി.ഗ്രാം) കോപ്പർ(0.457 മി.ഗ്രം) സിങ്ക് (0.923 മി.ഗ്രാം) എന്നിവ ന്യൂട്രീഫ്ലോറിൽ കൂടുതലായിരുന്നു. ഫീനോൾ (3.03 മി.ഗ്രാം), ഫൈറ്റിക് ആസിഡ് (166.77 മി.ഗ്രാം), ടാനിൻ (19.45 മി.ഗ്രം), ബീറ്റാകരോട്ടിൻ (65.98 മൈക്രോ. ഗ്രാം), ആന്റി ഓക്സിഡന്റ് (35.85 മൈക്രോ.ഗ്രം) തുടങ്ങിയ ന്യൂട്രാസ്യൂട്ടിക്കൽ ഘടകങ്ങ ൾ ചക്കയിൽ നിന്നുള്ള ന്യൂട്രീഫ്ലോറിൽ വളരെ കൂടുതലാണ്.

വികസിപ്പിച്ചെടുത്ത ചക്കയിൽ നിന്നുള്ള ന്യൂട്രീഫ്ലോർ (ഫോർമുലേഷൻ) ലാമിനേ റ്റഡ് പൗച്ചുകളിൽ ആറു മാസത്തെ സംഭരണത്തിനായി സൂക്ഷിക്കുകയും ചെയ്തു. സംഭരണ കാലയളവിൽ ഈർപ്പത്തിന്റെ അളവ് , മൈക്രോബിയൽ പ്രൊഫൈൽ, ഓർഗനോലെപ്റ്റിക്ക് ഗുണങ്ങൾ എന്നിവ സ്വീകാര്യമാണെന്ന് കണ്ടെത്തി.

ഒലിഗോസാക്രൈഡുകളുടെ അളവ് കുറയ്ക്കുന്നതിനും അന്നജത്തിന്റെ ദഹന ക്ഷമത വർദ്ധിപ്പിക്കുന്നതിനുമായി ഈ മാവ് 8 മണിക്കൂർ നേരത്തേക്ക് "സക്കറോമൈസസ് സെറിവിസിയ" 5 ഗ്രാം / കിലോ എന്ന തോതിൽ ചേർത്തു പുളിപ്പിച്ചു. എച്ച്. പി.എൽ.സി. വിശകലനത്തിൽ 6.93 മിനിറ്റ് സാധാരണ സ്റ്റാക്കിയോസ് റിറ്റെൻഷൻ ടൈമിൽ യീസ്റ്റ് ചേർക്കാത്തതും യീസ്റ്റ് ചേർത്തതുമായ ന്യൂട്രീഫ്ലോറുകൾ താരതമ്യം ചെയ്തപ്പോൾ യീസ്റ്റ് ചേർത്തതിൽ ഒലിഗോസാക്കറൈഡുകൾ കുറവാണന്ന് കണ്ടെത്തി. ഇൻവിട്രോ സ്റ്റാർച്ച് ഡൈജസ്റ്റബിലിറ്റി യീസ്റ്റ് ചേർക്കാത്തത് (54.84%), യീസ്റ്റ് ചേർത്തതിൽ (82.81 %) കൂടുതലാണന്ന് കണ്ടെത്തി.

ആൽഫാ ഗ്ലൂക്കോസിഡേസിന്റെയും ആൽഫാ അമിലേസിന്റെയും പ്രവർത്തനത്തെ തടയാനുള്ള ശേഷിയെ ആസ്പദമാക്കി പ്രമേഹത്തെ നിയന്ത്രിക്കാനുള്ള ന്യൂട്രീഫ്ലോറിന്റെ കാര്യക്ഷമത വിലയിരിത്തി. 47 ശതമാനം അമിലേസിന്റെ പ്രവർത്തനത്തെയും 67% ശതമാനത്തിൽ ഗ്ലൂക്കോസിഡേസിന്റെ പ്രവർത്തനത്തേയും 100 ഗ്രാം പൊടിക്ക് നിയന്ത്രിക്കാൻ സാധിച്ചു. 78% വരെ കോശങ്ങളിലെ കൊഴുപ്പിന്റെ അഴലിനെ നിയന്ത്രിക്കാൻ പെട്രോളിയം ഈഥറിൽ മിശ്രിതപ്പെടുത്തിയ ന്യൂട്രീഫ്ലോറിന് സാധിച്ചു. 50% സാന്ദ്രതയിലുള്ള ന്യൂട്രീഫ്ലോർ മിശ്രിതത്തിന് കരൾ സംരക്ഷണ പ്രവർത്തനം നടത്താൻ കഴിവുള്ളതായി തെളിഞ്ഞു.

ഈ പഠനത്തിൽ നിന്ന്, ചക്ക അടിസ്ഥാന മാക്കിയുള്ള ന്യൂട്രീഫ്ലോറിന് ഹൈപ്പോ ഗ്ലൈസീമിക്, ഹൈപ്പോ ലിപിഡെമിക്, ഹൈപ്പറ്റോപ്രൊട്ടക്റ്റീവ് എന്നി ഗുണങ്ങൾ ഉണ്ടെന്നു നിഗമനത്തിൽ എത്താം. ചക്കയുടെ എല്ലാ ഭക്ഷ്യ യോഗ്യമായ ഭാഗങ്ങളിൽ നിന്നും ന്യൂട്രീഫ്ലോർ തയ്യാറാക്കിയത് കൊണ്ട് ഈ ഉൽപ്പന്നത്തിന്റെ ചികിത്സാ മൂല്യം വർദ്ധിപ്പിക്കുന്നു. ചക്കയുടെ എല്ലാ ഭാഗങ്ങളുടെ ഉപയോഗിക്കുന്നത് കൊണ്ട് പരിസ്ഥിതി മലിനീകരണത്തിന്റെ പ്രശ്നത്തിനു പരിഹാരമാകുന്നു.