STANDARDISATION OF PROCESSING METHODS FOR PRODUCTION OF JACKFRUIT SEED FLOUR WITH FUNCTIONAL PROPERTIES

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KERALA, INDIA

2021

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by

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THESIS

Submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2021

DECLARATION

I, hereby declare that this thesis entitled **"STANDARDISATION OF PROCESSING METHODS FOR PRODUCTION OF JACKFRUIT SEED FLOUR WITH FUNCTIONAL PROPERTIES"** 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"STANDARDISATION OF PROCESSING METHODS FOR PRODUCTION OF JACKFRUIT SEED FLOUR WITH FUNCTIONAL PROPERTIES"** is a record of research work done independently by Ms. Sreelekshmi S. Kumar (2019-12-049) 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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We, the undersigned members of the advisory committee of Ms. SREELEKSHMI S. KUMAR (2019-12-049), a candidate for the degree of **Master of Science in Horticulture** with major in Post Harvest Technology, agree that the thesis entitled **"STANDARDISATION OF PROCESSING METHODS FOR PRODUCTION OF JACKFRUIT SEED FLOUR WITH FUNCTIONAL PROPERTIES"** may be submitted by Ms. SREELEKSHMI S. KUMAR (2019-12-049), in partial fulfilment of the requirement for the degree.

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Acknowledgement

"Thank God"

As a prelude to my thanksgiving, I wish to bow my head before the Almighty God for making me confident and optimistic throughout my journey and enabled me to complete the thesis work successfully on time.

With immense pleasure, I wish to express my sincere gratitude and indebtedness to ***Dr. P.R. Geetha Lekshmi,*** *Assistant Professor, Department of Post Harvest Technology, College of Agriculture, Vellayani, the Chairperson of my Advisory Committee, for her precious suggestions, invaluable inspiration, effective stimulus and wholehearted support rendered to me throughout the research work. This work would not have been possible without her valuable help and support. It was her sincerity, dedication and attachment towards me and our work which inspired me deeply to attain a certain level of self- improvement in all aspects. I consider myself extremely fortunate in having the privilege of being able to be guided by her.*

I am indebted to ***Dr. Mini. C.*** *Professor and Head, Department of Post Harvest Technology, College of Agriculture, Vellayani,, for her valuable advice, extreme patience, constructive criticism and treasured suggestions for the successful completion of the thesis.*

The inspirational words, constant criticism and support of ***Dr. Suma Divakar,*** *Professor and Head, Department of Community Science, College of Agriculture, Vellayani and a member of Advisory Committee aided me in finishing my work successfully and I express my heartfelt thanks to her.*

I am indebted to ***Dr. Aparna. B.*** *Associate Professor and Head, Department of Organic Agriculture, College of Agriculture, Vellayani and a member of Advisory Committee for her valuable advices throughout the period of research work.*

I am very thankful to ***Ms. Athulya S Kumar,*** *Assistant Professor, Department of Post Harvest Technology, College of Agriculture, Vellayani for her support and valuable suggestions rendered throughout the period of research work and course of study.*

I am very grateful to ***Rejitha Chechi, Lekshmi Chechi and Suja Chechi*** *for their support and assistance during the lab work.*

Mere words cannot express my special thanks and indebtness to my alltime support, motivation and inspiration ***Ms Anila V.S.*** *for her unconditional love, help, sacrifice and support during my hard periods.*

Words are inadequate to express my special thanks to my classmates ***Pathu, Pavi and Aishu*** *who motivated and helped me throughout my work. I am also indebted to express my thanks to my dear seniors,* ***Archana Chechi, Athira Chechi, Aparna Chechi and Greeshma Chechi*** *for their whole hearted support throughout my research work.*

A special mention of thanks to ***Greeshma, Reshna and Neeraja*** *for their constant support, love, care and for the happiest moments we cherished together and my dearest friends* ***Minnu, Athira, Nayana, Nadiya, Sneha, Shanmu, Ragin, Nainu, Pavithra, Merin, Sruthy, Nimisha, Alen, Akshay, Jijoo and Shaji Chettan*** *for all their love and support.*

I am extremely thankful to ***Mr Prasad, Lali, Surabhi, Manil Kumar, Anuja, Kannan, Jyothi, Moly, Aishwarya, Sasi, Sivakala and Joshy*** *for their constant help and support without which my work wouldn't have been completed.*

Last but not the least , this two-year course would not happened without the unconditional love, sacrifices, time and support bestowed on me by my beloved father ***Sri. G. Sunil Kumar,*** *my dearest mother* ***Smt. Sushama. S,*** *my beloved sister* ***Sethulekshmi S Kumar*** *who I miss a lot today and other family members and I wish to express my profound indebtedness towards them.*

I once again express my sincere gratitude to all those who helped me in one way or another in the successful completion of this venture.

Sreelekshmi S. Kumar

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LIST OF ABBREVIATIONS

et al.	Co- workers/ Co- authors
%	Per cent
@	at the rate of
µg	Micro gram
ANOVA	Analysis of variance
CD	Critical difference
CRD	Completely Randomised Design
DPPH	2, 2- diphenyl-1- picrylhydrazyl
g	Gram
g cm^{-3}	Gram per centimetre cube
g g^{-1}	Gram per gram
kg	Kilogram
K	Koozha
KW	Kruskall- Wallis
LP	Lye Peeling
MR	Manual removal
mg	Milligram
min	Minute

mL	Millilitre
mm	Millimetre
No.	Number
NS	Not Significant
OD	Oven Drying
PC	Pressure cooking
PR	Pan roasting
SEm	Standard error of mean
V	Varikka
viz.,	Namely
χ^2	Chi- square

Introduction

1. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.), belongs to the family Moraceae, is one of the most popular tropical fruits grown in India and profusely bearing fruit in homesteads of Kerala. Ripe jackfruit bulbs are consumed as fresh and also used for the preparation of various value added processed products. But seeds are generally discarded or used only in local cuisine. Jackfruit seeds are rich in carbohydrate, protein, dietary fibre, vitamins, minerals, phytonutrients and it constitutes around 10 to 15 percentage of the total fruit weight. The fresh seeds could not be stored for a longer time due to its perishability. It is worthwhile to process the edible seeds into flour for the development of acceptable products, which will assist to boost consumer acceptance of jackfruit. Various researchers have recognised jackfruit seed as a novel functional ingredient with desirable nutraceutical potential due to its high content of phytonutrients. Jackfruit seed is nutritious as it contains many vitamins and minerals and could be used an economic alternative protein source to tackle the malnutrition. Huge quantity of jackfruit seeds are wasted every year due to their perishable nature and the challenges are experienced while processing and storage (Waghmare *et al*., 2019). Jackfruit seed flour had good potential in innovative food formulations and jackfruit seeds can be processed by different methods in order to improve the nutritional, functional, and organoleptic qualities of the resultant flour. As jackfruit is highly seasonal and seeds have shorter shelf life, are wasted during seasonal glut. The processing of jackfruit seeds to seed flour with longer shelf life can reduce the wastage and also provide an additional source of revenue.

For efficient utilization of jackfruit seed flour, it is desirable to study the nutritional and functional properties of the flour as they are important in food industry for the development of new products. The functional qualities of jackfruit seed protein are influenced by the inherent biochemical composition of seeds, processing methods, and environmental conditions (Chowdhury *et al*., 2012). The addition of jackfruit seed flour to numerous baked and cereal products enhanced their overall nutritional quality and improved the physicochemical, textural, and sensory properties. Thus jackfruit seed flour could be an alternative intermediary product, which can be stored and utilized for processing into value added food products or to blend with other grain flours without affecting the functional and sensory profile of the final product with improved its nutritional quality (Akter and Haque, 2018).

The processing methods for jackfruit seed flour influenced its nutritional composition as well as functional properties, which determine its usage as a functional food ingredient. Jackfruit seed flour has immense potential in food industry as a functional ingredient, thickener binding agent and also in convenient foods.

Hence the present study entitled ‘Standardisation of processing methods for production of jackfruit seed flour with functional properties’ was conducted with the objective of quality evaluation of jackfruit seeds of varikka and koozha types, standardisation of processing methods for jackfruit seed flour with functional properties and assessment of storage stability.

Review of literature

2. REVIEW OF LITERATURE

Jackfruit seed flour is a potential food ingredient due to its health benefits. Jackfruit seeds processed to seed flour can be stored and used for a longer time. It can be blended with other grain flour without altering the functional and sensory profile of the product with improved nutritional quality. Jackfruit seeds are processed in different methods to get the flour that influence seed flour quality. The present study is focused on the effect of different processing methods on jackfruit seed flour quality and to assess the storage stability of jackfruit seed flour. The reports on nutrient composition of jackfruit seeds, different processing methods for preparation of jackfruit seed flour and flour quality are reviewed in this chapter.

2.1. IMPORTANCE OF JACKFRUIT

The jackfruit (*Artocarpus heterophyllus* Lam) is one of the most important underutilised fruits and belongs to the genus Artocarpus, which produce higher yield than any other fruit tree species and bears the largest edible fruit (Ranasinghe *et al.,* 2019).

The jackfruit, also known as “kathal” in Bangladesh, is the country’s national fruit (Akter and Haque, 2018) and is referred as ‘nutrients of giants’ (Ravindra, 2018). The word Artocarpus originates from the Greek word ‘Artos’ means ‘Bread’ and ‘Karpos’ means ‘Fruit’ (Sundarraj and Ranganatham, 2018) and it consists of 30% bulb, 12% seed and 50% rind (Satheeshan *et al.,* 2019). According to Borgis and Bharati (2020), only 10% of jackfruit seeds were used and remaining 90% seeds were discarded as waste.

The ripe fruit is eaten as fresh or preserved in syrup, and has a wide range of applications in food preparation such as jam, jelly, beverages and other value added products (Elevitch and Manner, 2006). Being an energy rich fruit, jackfruit is used for treating several disorders as it exhibit antimicrobial, antioxidant and antifungal properties (Shanmugapriya *et al*., 2011) and the antioxidant characteristics of jackfruit contributes to the health benefits (Swami *et al*., 2012). Jackfruit bulb of full maturity is a rich source of sugar and dietary fibre which aids in digestion (Mandave *et al*., 2018). Different stages of jackfruit such as tender, immature, mature and ripe stages can be utilized for various purposes. Sucrose and fructose are the main components of ripe bulbs and they serve to provide rapid energy to the body while immature fruits lower blood sugar levels and have therapeutic benefits against diabetes mellitus (Satheeshan *et al.*, 2019).

According to Day *et al*. (2009), the food industries are facing with the task of creating food products that contain functional ingredients in order to suit the nutritional needs of consumers who have health issues. Munishamanna *et al.* (2010) investigated the use of jackfruit seeds in the development of healthy and nutritional foods and found it as a suitable source. Use of jackfruit seed flour in convenience food not only creates marketability but also provide employment opportunities for rural women (Butool and Butool, 2013). According to David *et al.* (2016), jackfruit seed flour based products had higher levels of phenolic and antioxidant activity. Jackfruit seed flour is free from gluten which can be used for gluten free food products (Mandave *et al.*, 2018) and jackfruit seed flour incorporated products recorded nutraceutical properties and better consumer acceptability (Waghmare *et al*., 2019). Jackfruit seed flour had good potential in innovative food formulations along with other flour and use of jackfruit seeds to make flour could provide an additional source of revenue and to reduce the wastage (Kushwaha *et al*., 2020).

2.2. COMPOSITION OF JACKFRUIT SEEDS

Jackfruit seeds constitute to more than 15% of the total jackfruit weight (Prathima, 2008) and the seed is encircled by a white aril and inner spermoderm which encloses the cotyledon (Swami *et al*., 2012). Babu *et al.* (2018) reported that jackfruit seeds are rich source of carbohydrates and contributes to about 51.82% which makes it suitable in food processing industries.

Jackfruit seeds contain higher amount of protein, carbohydrate, vitamins and are consumed generally either after boiling or roasting. But as jackfruit is seasonal and seeds have a limited shelf life, seeds are wasted and remain underutilized. Jackfruit seeds are rich in protein and starch and starch content in seeds increased with fruit maturity (Rahman *et al*., 1999) and it can be used as probiotics, as it contain some amount of non- reducing sugars also (Bhornsmithikun *et al.*, 2010). Every 100g of jackfruit seeds contain about 27.3g of carbohydrates, 5.2 g of protein, 0.4 g of protein, 1.9 g of ash and 65.2 g of moisture (Hasan *et al*., 2010) and less amount of fat is present in seeds which provides a diet free from fat (Omale and Friday, 2010).

Gupta *et al*. (2011) detected secondary mainly alkaloids, saponins, flavanoids, and phenolics in jackfruit seeds. Jackfruit seed flour can be a useful intermediate product that can be stored and used for value addition as well as blending with other grain flour without compromising the functional and sensory profile of the final product (Butool and Butool, 2013).

The single most abundant protein in jackfruit crude seed extract is jacalin, which accounts for more than half of the total protein content (Kabir, 1993). As far as chemical and nutritional factors, jackfruit seed protein is a natural complement to the proteins in cereal- based diets (Altschull, 1994). Jackfruit seed protein have both necessary and non- essential amino acids, each of which has its own unique role (Miah *et al.,* 2017) and jackfruit seeds are high in protein content, and is cholesterol-free (Kumari *et al*., 2018). Akter *et al.* (2020) reported that plant protein sources serve an important role in human nutrition in under developed nations, especially where protein intake average is much lower than the recommended quantity and jackfruit seeds have immense potential.

Ocloo *et al*. (2010) reported that due to the presence of higher amount of fibre in jackfruit seed, the whole meal can be replaced by the seeds. Jackfruit seeds can be used as a good substitute in nations with a large population where seasonal crops do not meet the food requirements (Gupta *et al*., 2011). High content of fibre in seeds help in the protection of colon mucous membrane, smooth bowel movements and prevention of constipation (Mondal *et al*., 2013). Chowdhury *et al*. (2014) reported that the nutrient rich jackfruit seeds could be dried and stored for further processing and value addition. Processing of jackfruit seed not only improved the overall quality parameters such as nutrition, storage, antioxidant activity but also reduced the anti- nutritional factors present in the seeds (Banerjee and Datta, 2015).

Jackfruit seeds contain phytochemicals which protects the human body from cellular damage (Baliga *et al*., 2011). Seeds have antifungal, anticarcinogenic and antibacterial properties due to the presence of jacalin and artocarpin (Chowdhury *et al*., 2012). Seeds play an important role in hair growth and blood circulation in human body and are rich in magnesium which is useful to prevent osteoporosis (Swami *et al*., 2012). Maurya and Mogra (2016) reported that antimicrobial properties of jackfruit seeds help to prevent food borne diseases and reduce the blood pressure.

Tulyathan *et al*. (2002) reported that the jackfruit seed starch had 25% water absorption capacity, 17% oil absorption capacity, and 6% amylogram concentration. Rengsutthi and Charoenrein (2011) extracted starch from jackfruit seed and was compared with corn starch to use as a thickener and stabilizer in chilli sauce and jackfruit seed starch was found beneficial and jackfruit seeds are used as a source of starch by many industries (Borgis *et al*., 2018). According to Wong *et al*. (2021), jackfruit seed starch could be utilised as a starch substitute in a variety of foods as jackfruit seed starch has three crucial characteristics: heat stability, the ability to create strong starch gels, and small monodispersed starch granules as compared to rice and potato starch.

2.3. PROCESSING OF JACKFRUIT SEEDS

Jackfruit seeds are light brown in colour, with a length of 2 to 3 cm and a diameter of 1 to 1.5 cm and will sprout immediately after maturity and could not be stored for a longer period of time without being processed, hence remain unexploited and need postharvest techniques for its better usage (Kushwaha *et al.*, 2019). Due to low storage life of jackfruit seeds, it could be processed to seed flour and starch which could be used for the preparation of processed food products. The processing methods of jackfruit seeds influenced compositional, functional, and pasting properties of jackfruit seed flour (Ejiofor *et al.*, 2014).

In addition to nutrients, jackfruit seed contains some anti- nutritional factors like tannin, trypsin inhibitors and phytate as reported by Morton (1987). Seeds cooked for 60 minutes showed the largest percentage reduction in all anti-nutritional elements *viz.*, 49.72% reduction in phytin, 32.98% tannin, 50% oxalate, 44% saponin and 100 % trypsin inhibitors (Akinmutimi, 2006). Jackfruit seed flour processing methods affected nutritional and functional properties of seed flour such as antioxidants, fat, protein, sugar and pectin (Reis *et al.*, 2012). Flour obtained from different processing methods under various heat treatments reported that at low temperature processing, methionine and alanine were absent whereas, leucine was reduced at higher temperature

(Chowdhury *et al.,* 2014). Ejiofor *et al.* (2014) reported that the roasting of jackfruit seeds before flour manufacturing enhanced protein availability and lowered oil absorption and increased the water absorption capacity. According to Akter and Haque (2018), jackfruit seeds are commonly processed to improve the nutritional, functional or organoleptic qualities of flour as the functional qualities are crucial for developing new products in food processing industry.

When thermal treatment is given to seeds, protein denaturation occurred and as a result loss in solubility was reported by (Kinsella, 1976). It has been found that strong heat treatment denatures proteins more effectively than inhibitor activation (Qin *et al.*, 1998). With regard to nutrition, gross amino acid present in jackfruit seed flour treated at 60ºC should be considered as a higher grade flour (Machado, 2008) and higher content of amino acid is observed in thermal jackfruit seed flour in comparison with raw jackfruit seed flour (Zuwariah *et al.,* 2018).

Boiling and cooking of jackfruit seeds resulted in 77% increase in starch content so that it can be included as a part of diet as well as a source of starch (Odoemelam, 2005). Before eating, the jackfruit seeds are usually boiled, steamed and roasted, giving a low- cost supply of fibre, protein, and minerals like potassium, calcium and sodium (Mahanta and Kalita, 2015).

The colour and texture of jackfruit seeds are drastically affected during the roasting process and these alterations are most commonly linked to non- enzymatic browning process (Buckholz *et al.*, 1980). Ejiofor *et al*. (2014) reported that roasting increased the amount of amylose, which is a key element in end use qualities of the product and possessed a high peak viscosity, trough viscosity, breakdown viscosity, as well as a short pasting time with greater water absorption capacity. Pyrazine, like fermented and roasted cocoa beans, is the most common odour active volatile component found in roasted jackfruit seeds (Tran *et al.,* 2015). The Maillard reaction is aided by roasting jackfruit seeds which resulted in distinctive cocoa aroma (Spada *et al.,* 2017) and roasted jackfruit seed powder could be used for partial replacement of cocoa in cappuccinos (Spada *et al.,* 2018). Spada *et al.* (2021) reported that jackfruit seeds fermented prior to drying had more esters and acids that contribute to chocolate aroma than dried or acidified and dried jackfruit seeds.

According to Ojwang *et al.* (2015), boiling followed by drying of jackfruit seeds showed a drastic reduction in the content of polyunsaturated fatty acids such as omega-3 and omega-6, making it as a unsuitable procedure for jackfruit seed processing. Borgis and Bharati (2020) reported that the nutritional profile of jackfruit seed flour was greatly altered by processing and the processed flour could be used to boost nutritional advantages in product creation and value addition.

According to Gaol *et al*. (2020), the best and most acceptable quality of jackfruit seed flour was obtained by blanching the seeds for 5 minutes followed by soaking with 200 ppm sodium metabisulphite. Inositol, sorbitol, glucose, fructose, sucrose, maltose, and raffinose are all found in jackfruit seed flour, and glucose, fructose, and raffinose content increased with maturity (Kushwaha *et al*., 2020).

Tulyathan *et al*. (2002) studied the biochemical composition of jackfruit seed flour prepared by lye peeling of the seeds using 5% NaOH for 2 minutes which removed the spermoderm followed by drying @ 50°C. The study reported a moisture content of 7.70%, crude protein (11.02 %), ash (3.97%), fat (1.01%), fibre (2.36%) for jackfruit seed flour with spermoderm, and the seed flour without spermoderm recorded a moisture content of 8.57%, crude protein (11.17%), ash (3.92%), fat (0.99%), and fibre (1.67%). Abedin *et al*. (2012) and Noor *et al.* (2014) studied the biochemical composition of jackfruit seed flour prepared from three varieties (Khaja, Gala and Durosha) by lye peeling of the seeds followed by drying @ 60˚C and found that Khaja seed flour had moisture, protein, ash and fat in the range of 6.28%, 9.19%, 1.18%, 2.51%, and for Gala it was 1.02%, 11.34%, 1.40%, 2.66% and Durosha recorded 9.06%, 9.75%, 1.40% and 2.66% respectively.

Hasan *et al.* (2010) reported a moisture content of 10.2%, 6.2% protein, 1.2% ash, 0.04% fat and 81.50% carbohydrate in ripe jackfruit seed flour prepared after removing the spermoderm manually. In a study conducted on functional properties of jackfruit seed flour for food application by Chowdhury *et al*. (2012) found that the seed flour had a moisture content of 10.1%, 12.6% crude protein, 2.24% ash, 3.37% fat, 1.47% fibre in lye peeled jackfruit seed flour (without spermoderm) and the seed flour prepared without lye peeling (with spermoderm) recorded a moisture content of 10.7%, 14.02 g $100g^{-1}$ crude protein, 2.54% ash, 4.08% fat and 1.8% fibre.

Ejiofor *et al*. (2014) studied different processing methods for the production of jackfruit seed flour which involves autoclaving, pan roasting, drying, boiling and germination followed by lye- peeling and drying and found that autoclaved jackfruit seed flour recorded a moisture content of 6.58%, ash 2.59%, protein 12.25%, fat 0.68%, crude fibre 6.17%, starch 36.03%, sugar 0.50%. In case of roasted jackfruit seed flour, moisture content was 4.44%, ash 2.45%, protein 16.80%, fat 0.27%, crude fibre 3.38%, starch 30.71%, sugar 2.48% and dried jackfruit seed flour (control) recorded 5.07% moisture, 2.46% ash, 12.45% protein, 0.77% fat, 3.53% crude fibre, 26.55% starch, 1.60% sugar and germinated jackfruit seed flour had moisture content of 3.20%, ash 2.76%, protein 12.47%, fat 0.13%, crude fibre 2.43%, starch 32.15%, sugar 1.52%. Azeez *et al.* (2015) studied the chemical composition of three cultivars (J29, J31, J33) of ripe jackfruit seeds from Malaysia processed by slicing and drying @ 40˚C reported a moisture content 24.08%, protein 7.62%, ash 3.70%, fat 1.09%, carbohydrate 60.71%, fibre 2.80%, starch 62.04%, fructose 0.02%, glucose 0.22%, sucrose 0.04%, pH 5.91 in J29 cultivar and it was 14.26% moisture content, protein 8.46%, ash 3.39%, fat 1.48%, carbohydrate 65.40%, fibre 7.19%, starch 15.95%, fructose 0.08%, glucose 0.18%, sucrose 0.13%, pH 4.57 for J31 cultivar. The biochemical parameters differed in the cultivar J33 and recorded a moisture content of 14.26%, protein 8.24%, ash 3.19%, fat 1.17%, carbohydrate 66.20%, fibre 5.70%, starch 29.55%, fructose 0.03%, glucose 0.18%, sucrose 0.02% and pH of 4.86. Kumari and Divakar (2016) reported that jackfruit seed flour of koozha type had a moisture of 7.97%, 3.13% fibre, 81.46 g carbohydrate, 10.48 g protein, 353.87 kcal energy, with calcium (308.56 mg), potassium (1478 mg), sodium (60.63 mg), magnesium (338.04 mg) in 100 g of seed flour and could be used for the processed products.

Abiola *et al*. (2018) studied the biochemical composition of raw, roasted and fermented jackfruit seed in Nigeria and observed that raw sample contain carbohydrate 65.31%, protein 24.90%, moisture 2.56%, fat 1.63%, fibre 2.66%, ash 3.56%, dry matter 97.50% and fermented seed recorded the values as 62.75%, 26.92%, 3.48%, 1.28%, 2.58%, 3.35%, 96.56% respectively. The roasting processing increased protein content to 29.50%, fat (1.68%), ash (3.67%), dry matter (97.77%). Babu *et al.* (2018) studied the biochemical composition of jackfruit seed and reported a moisture content of 2.78%, protein 20.19%, carbohydrate 51.82%, fibre 7.10%, and fat content of 11.39%.

Zuwariah *et al*. (2018) studied the chemical composition of jackfruit seed flour obtained from raw, germinated and thermal processing and found that thermally processed jackfruit seed flour contain moisture content of 5.98%, ash 2.43%, protein 24.94%, fat 0.22%, dietary fibre 14.33%, starch 50.97%, vitamin C 21.71 mg $100g^{-1}$ whereas raw jackfruit seed flour contain 3.215% moisture, 2.75% ash, 9.78% protein, 0.56% fat, 25.43% dietary fibre, 55.90% starch, 31.98 $mg100g^{-1}$ vitamin C.

According to Mohamad *et al*. (2019), jackfruit seed flour had about 10.78% moisture, 13.67% protein, 2.41% ash, 0.75% fat and 3% fibre in 100 g of seed flour. Kushwaha *et al.* (2019) studied the physicochemical and physical characters of three cultivars of jackfruit seeds namely Khaja, Safeda and Katahri in Allahabad and found that average length, thickness and width ranged from 2.30 to 2.77cm, 1.2 to 1.64 cm and 1.45 to 1.93cm respectively. Seeds also contain a good amount of protein which ranged from 13.30 to 16.60%, bulk density of 0.44 to 0.53 g cm^{-3}, moisture content of 48.62 to 67.84%, ash 3.75 to 4.03%, fat 0.55 to 0.63% and a fibre content of about 2.84 to 3.35%.

Sivaranjini *et al*. (2020) studied the biochemical composition of germinated and non- germinated jackfruit seed flour after removing the spermoderm and reported that germinated jackfruit seed flour contain high phenol (148 mg g^{-1}), flavonoids (403 mg g^{-1}) and antioxidant activity (4.1%) as compared to non- germinated jackfruit seed flour with a phenol content of 104 mg g^{-1}, flavonoid (102 mg g^{-1}), and antioxidant capacity (1.4%).

Water absorption capacity of flour varied with the molecular structure of flour, structural properties, protein concentration, particle size, interaction with water, hydrophilic groups, presence of husk, degree of milling, damaged starch, protein content, and carbohydrates (Kaushal *et al*., 2012). Chowdhury *et al*. (2014) reported that functional qualities are features that influence the behaviour of proteins, starch, and other food ingredients during processing, storage, and preparation, and had an impact on food quality. Both processed and unprocessed jackfruit seed flour had strong functional properties and could be utilised for value addition in home scale, commercial, and industrial settings to substitute grain flour in traditional and conventional products or to create new products (Borgis and Bharati, 2020).

Water binding capacity of flour is aided by its protein and carbohydrate composition. The hydrophilic subunits in jackfruit seeds allow them to bind more water and water absorption capacity is critical in bulking and consistency of product as well as baking applications (Niba *et al.*, 2001). According to Odoemelam (2005), heat treatment, pH, and NaCl content had an impact on the functional qualities of flour. When comparing water absorption measurements to oil absorption values, the effect of high temperature was more obvious, showing higher loss of native protein and starch properties of jackfruit seed flour (Chowdhury *et al.*, 2014). The roasted sample had a higher water absorption capacity, indicating an essential processing characteristic that affects viscosity and water absorption which are vital qualities in baking and confectionery (Ejiofor *et al*., 2014).

Water and oil absorption capacity of 112.00 mL/100g and 126 mL/100g, respectively, and a dispersibility of about 30% indicated that jackfruit seed flour is acceptable for processing industry (Airani, 2007). Jackfruit seed flour could be used in food systems such as ground meat formulation, due to its high flavour retention rate (Ocloo *et al*., 2010). Akter and Haque (2018) stated that the feature of dispersibility governs tendency of flour to separate from water molecules, revealing its hydrophobic effect and the flour made from jackfruit seeds had good foaming qualities, which are essential factors of physical quality (swelling and softness) in bakery products.

Swelling power is a measurement of swollen starch granules, and the retention of water swollen starch granules is linked to food eating quality. According to Ejiofor *et al*. (2014), the jackfruit seed flour samples had a swelling power ranging from 6.58 to 9.46%.

The bulk density of flour is adaptable, and the lower the bulk density value, the easier it is to carry and package. According to Odoemelam (2005), the bulk density of jackfruit seed flour was lowered by 11.5% as a result of heat processing. The bulk density of flour is a measurement of its weight and is crucial for identifying packaging needs, material handling, and application in the food industry for wet processing (Ocloo *et al.,* 2010). According to Chowdhury *et al.* (2014), the bulk density rised as the processing temperature increased, and it remain inversely proportional to the water and oil absorption capabilities.

Jackfruit seed flour yield varies with variety, moisture content, composition, pre-treatments and processing techniques. Wet processed jackfruit seeds recorded lower flour yield as compared to dry processed seeds due to leaching out of solids and other water soluble components (Borgis and Bharati, 2020).

Hausner factor of jackfruit seed flour processed at different temperature was analysed by Leite *et al*. (2020) and reported that at 55ºC processing temperature it was 1.049 and 1.047 at 65ºC and 1.045 at 75ºC with no significant difference among the treatments.

2.4. STORAGE STABILITY OF JACKFRUIT SEED FLOUR

The shelf life of a product is the amount of time it can be stored while maintaining the stated quality under predicted storage, and display conditions (Azanha and Faria, 2005). The storage conditions after milling and packing are critical for jackfruit seed flour quality since they affect the shelf life and consumer safety (Veenakumari, 2015).

Airani (2007) studied the storage stability of jackfruit seed flour and found that there was an increase in moisture content from 7.16 to 11.03% at ambient temperature storage and 8.39% under refrigerated condition. According to Sultana *et al*. (2015), the moisture content of jackfruit seed flour during storage increased slowly in refrigerated condition as compared to ambient storage. Jackfruit seed flour produced by pressure cooking and boiling recorded higher moisture content as compared to unprocessed jackfruit seed flour (Borgis *et al.*, 2018).

Processing of jackfruit seed to seed flour is one of the most effective ways to use jackfruit seeds. Fresh seeds had only 15 days resistance to microbes, whereas seed flour recorded 6 month resistance which might be due to the lower moisture content that slowed down the oxidation process by preventing external oxygen which is necessary for the survival of microorganisms (Saha *et al*., 2016).

Borgis *et al.* (2018) analysed the microbial count of jackfruit seed flour for a storage period of 180 days and observed that pressure cooked seed flour had higher number of bacterial and fungal colonies followed by boiled and unprocessed seed flour. The result indicated that bacterial and fungal colonies were substantially reduced in pan roasted seed flour and there was no *E. coli* found and the moisture and microbial levels were within acceptable limits and recorded a longer shelf life.

According to Morshed *et al.* (2019), jackfruit seed flour had a storage stability of 11 months at room temperature without any microbial population and could be recommended to entrepreneurs and consumers as a natural product with good nutritional content making it suitable for food processing industry.

Materials and Methods

3. MATERIALS AND METHODS

The materials used and methodologies adopted during the investigation of "Standardisation of processing methods for production of jackfruit seed flour with functional properties" are described in this chapter.

3.1 EFFECT OF PROCESSING METHODS ON JACKFRUIT SEED FLOUR QUALITY

The experiment was conducted at the Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram during the year 2019-2021.

3.1.1. Selection of raw materials

Matured jackfruit of varikka and koozha types of good quality were procured from the Instructional farm, Vellayani and selected homesteads. Seeds were separated from fully ripened fruits (varikka and koozha) and were subjected to different processing treatments.

3.1.2. Processing methods of jackfruit seeds for jackfruit seed flour preparation

The jackfruit seeds extracted from ripe jackfruits (varikka and koozha types) were washed thoroughly with clean water and were subjected to different processing treatments like roasting, pressure cooking, lye peeling, and oven drying as described below.

T_1- Pan Roasting + Lye Peeling for spermoderm removal (PR+LP)

T_2- Pan Roasting + Manual Removal of spermoderm (PR+ MR)

T_3- Pan Roasting (PR)

T_4-Pressure Cooking +Lye Peeling (without spermoderm) (PC+ LP)

T_5- Pressure Cooking + Manual Removal of spermoderm (PC+ MR)

T_6- Pressure Cooking (PC)

T_7- Lye Peeling for spermoderm removal (LP)

T_8- Manual Removal of spermoderm + Oven Drying (OD+ MR)

T_9- Oven Drying (OD)

Pan roasting of jackfruit seeds was done till a sweet aroma and brown colour for seeds was obtained and pressure cooking was done for 10 minutes and in oven drying, seeds were oven dried at 60^0C. For spermoderm removal through lye peeling, seeds were treated with 3% NaOH and spermoderm was removed by rubbing with hands and manual removal of spermoderm was done using a clean knife. The processing methods for jackfruit seed flour through Pan roasting, Pressure cooking, Lye peeling and Oven drying is depicted in (Plate 1), (Plate 2), (Plate 3) and (Plate 4) respectively.

The jackfruit seeds after the treatments were finally dried in hot air oven at 60^0C and milled to get fine flour and were subjected to analyse for biochemical, functional and physical qualities. The jackfruit seed flour obtained through different processing methods are given in (Plate 5).

3.1.3. Biochemical qualities of jackfruit seed flour

3.1.3.a. Moisture content (%)

Moisture content was determined by measuring the mass of flour before and after the removal of water by evaporation.

Moisture % by weight = $[(M_1-M_2)] / [(M_1-M)]$ x100

M_1- Weight in gram of dish with flour before drying
M_2- Weight in gram of dish with dried flour
M- Weight in gram of empty dish

3.1.3.b. Protein (%)

Protein content of jackfruit seed flour was estimated as per the method described by Bradford (1976) and expressed as percentage.

3.1.3.c. Crude fat (%)

Crude fat was extracted in soxhlet apparatus using petroleum ether as solvent and was calculated as percentage according to the following formula.

Pan roasted seeds without spermoderm (manual removal)

Pan roasted seed flour without spermoderm

Pan roasted seeds with spermoderm

Pan roasted seed flour with spermoderm

Plate 1. Preparation of jackfruit seed flour by Pan roasting method

$$\text{Crude fat (\%)} = \frac{\text{Initial weight (g) - Weight after extraction (g)} \times 100}{\text{Sample weight (g)}}$$

3.1.3.d. Crude fibre (%)

Crude fibre was estimated using the method described by Sadasivam and Manickam (1992) and expressed as percentage.

$$\text{Crude fibre (\%)} = \frac{\text{Loss in weight in ignition } [(W_2 - W_1) - (W_3 - W_1)] \times 100}{\text{Weight of sample}}$$

W_1 - Weight of crucible

W_2 - Weight of crucible and sample after ignition

W_3 - Final weight of crucible

3.1.3.e. Total ash (%)

Ash content was determined by the method described in the Manual of Analysis of Fruit and Vegetable Products by Ranganna (1986).

3.1.3.f. Vitamin C (mg 100g $^{-1}$)

Ascorbic acid content was estimated by the titrimetric method described by Ranganna (1986) using 2, 6-dichloro phenol indophenol (DCPIP) dye.

$$\text{Ascorbic acid (mg 100g}^{-1}) = \frac{\text{Titre value x Dye factor x Volume made up (mL)}}{\text{Aliquot of extract taken (mL) x Weight of sample (g)}}$$

Dye factor = $0.5/V_1$ mL

3.1.3.g. Starch (%)

Titrimetric method of Lane and Eynon was adopted for the estimation of starch using the formula:

$$\text{Starch (\%)} = \frac{0.0025 \times \text{Fehling's factor} \times \text{Hydrolysed sample volume made up} \times 100 \times 0.925}{\text{Titre value (mL)} \times \text{Sample weight (g)}}$$

3.1.3.h. Total Soluble Solids (ºBrix)

Total Soluble Solids (TSS) was recorded using a digital refractometer (Atago-0 to 53 %) and expressed in degree brix (^{0}Brix).

3.1.3.i. Titrable Acidity (%)

Titrable acidity was estimated using the method described by Ranganna (1986) and is expressed in percent citric acid equivalent using the formula:

$$\text{Acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of NaoH (0.1N)} \times \text{Equivalent weight of citric acid} \times \text{Volume made up} \times 100}{\text{Weight of sample} \times \text{Volume of aliquot} \times 1000}$$

3.1.3.j. Total sugar (%)

The total sugar was expressed in terms of invert sugar according to the method described by (Ranganna, 1986).

Pressure cooked seeds with spermoderm

Pressure cooked seed flour with spermoderm

Pressure cooked seeds without spermoderm (manual removal)

Pressure cooked seed flour without spermoderm

Plate 2. Preparation of jackfruit seed flour by Pressure cooking method

$$\text{Total sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total volume made up (mL) x Volume made up after inversion (mL) x 100}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (mL)}}$$

3.1.3.k. Reducing sugar (%)

For estimating reducing sugar, the titrimetric method of Lane and Eynon was adopted as described by (Ranganna, 1986).

$$\text{Reducing sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total volume made up (mL) x 100}}{\text{Titre value x Weight of sample taken (g)}}$$

3.1.3.l. Carotenoids (µg 100g^{-1})

Total carotenoids were estimated as per the procedure described by Saini *et al*. (2015) and expressed as µg 100g^{-1} of jackfruit seed flour.

3.1.3.m. Antioxidant activity (%)

Total antioxidant activity of jackfruit seed flour was determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. Scavenging effect was measured as per the procedure described by Sharma and Bhat (2009).

$$\text{\% inhibition of DPPH} = \frac{[A_{blank} - A_{sample}] \times 100}{A_{blank}}$$

A_{blank} = Absorbance of DPPH solution without sample

A_{sample} = Absorbance of the sample

3.1.4. Functional qualities of jackfruit seed flour

3.1.4.a. Water absorption capacity (mL 100g^{-1})

Water absorption capacity of jackfruit seed flour was determined as per the procedure described by Ejiofor *et al*. (2014) and expressed in mL 100g^{-1}.

3. 1.4.b. Oil absorption capacity (mL 100g^{-1})

Oil absorption capacity of jackfruit seed flour was calculated as per the procedure followed by Islam *et al*. (2015) and expressed in mL 100g^{-1}.

3.1.4.c. Swelling power (g g^{-1})

Swelling power of jackfruit seed flour was calculated according to the method of Islam *et al*. (2015) and expressed as g g^{-1}.

3.1.5. Physical qualities of jackfruit seed flour

3.1.5.a. Yield (%)

Weight of jackfruit seed flour was recorded after processing of jackfruit seeds and expressed as percentage.

3.1.5.b. Bulk density (g cm^{-3})

Bulk density of jackfruit seed flour was calculated following to the method adopted by Narayana and Rao (1984).

3.1.5.c. Tapped density (g cm^{-3})

For the determination of the tapped density, the methodology described by Leite *et al*. (2020) was used.

3.1.5.d. Hausner factor

The Hausner factor was calculated by the ratio between the tapped density and the bulk density (Leite *et al*., 2020).

3.1.5.e. Carr index (%)

The Carr index of jackfruit seed flour was calculated according to Bhusari *et al.* (2014) and expressed as percentage (%).

Jackfruit seeds

Lye peeling

Lye peeled seeds

Lye peeled seed flour without spermoderm

Plate 3. Preparation of jackfruit seed flour by Lye peeling method

3.1.5.f. Colour

Jackfruit seed flour developed by different processing methods were evaluated for colour by 30 member semi trained panel comprising of research scholars of College of Agriculture, Vellayani. The panel were asked to score the colour of the sample using score card in the order of preference as shown below.

White -5	Cream -4	Creamish yellow- 3
Creamish brown- 2	Brown- 1	

Based on biochemical, functional and physical qualities, jackfruit seed flour obtained from varikka and koozha types (with and without spermoderm) having superior quality were selected for the storage stability studies for two months.

3.2. STORAGE STABILITY STUDIES OF JACKFRUIT SEED FLOUR

The best eight treatments selected from 3.1 of the study *viz*., Pan roasting and Pressure cooking (with and without spermoderm) of varikka and koozha types of jackfruit seed flour were packed in polypropylene and stored under room temperature for storage stability studies. Biochemical, functional and physical quality of the selected jackfruit seed flours were analysed at monthly interval for a period of 2 months.

3.2.1. Biochemical qualities of jackfruit seed flour

3.2.1.a. Moisture content (%)

Moisture content of jackfruit seed flour was calculated as described in 3.1.3.a.

3.2.1.b. Protein (%)

Protein content of jackfruit seed flour was calculated as described in 3.1.3.b.

3.2.1.c. Crude fat (%)

Crude fat content of jackfruit seed flour was calculated as described in 3.1.3.c.

3.2.1.d. Crude fibre (%)

Crude fibre content of jackfruit seed flour was calculated as described in 3.1.3.d.

3.2.1.e. Total ash (%)

Total ash content of jackfruit seed flour was calculated as described in 3.1.3.e.

3.2.1.f. Vitamin C (mg 100g^{-1})

Vitamin C content of jackfruit seed flour was calculated as described in 3.1.3.f.

3.2.1.g. Starch (%)

Starch content of jackfruit seed flour was calculated as described in 3.1.3.g.

3.2.1.h. Total Soluble Solids (ºBrix)

Total Soluble Solid content of jackfruit seed flour was calculated as described in 3.1.3.h.

3.2.1.i. Titrable Acidity (%)

Titrable acidity of jackfruit seed flour was calculated as described in 3.1.3.i.

3.2.1.j. Total sugar (%)

Total sugar of jackfruit seed flour was calculated as described in 3.1.3.j.

3.2.1.k. Reducing sugar (%)

Reducing sugar of jackfruit seed flour was calculated as described in 3.1.3.k.

3.2.1.l. Carotenoids (µg 100g^{-1})

Carotenoid content of jackfruit seed flour was calculated as described in 3.1.3.l.

3.2.1.m. Antioxidant activity (%)

Antioxidant activity of jackfruit seed flour was calculated as described in 3.1.3.m.

3.2.1.n. Peroxide value (meq kg^{-1})

The peroxide value of jackfruit seed flour was calculated as per the procedure described by Akter *et al.* (2020).

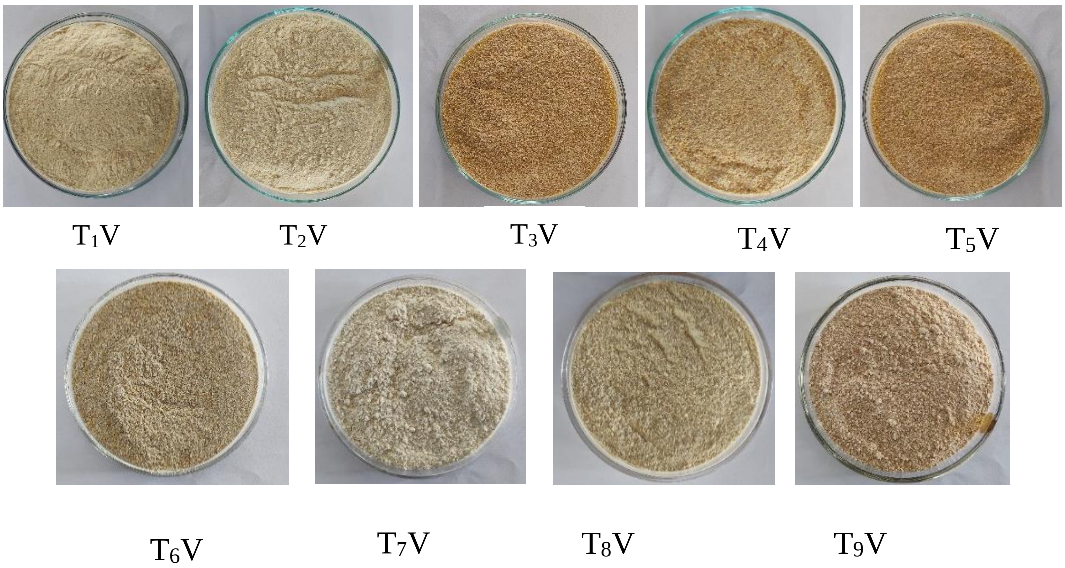
Jackfruit seeds

Oven drying

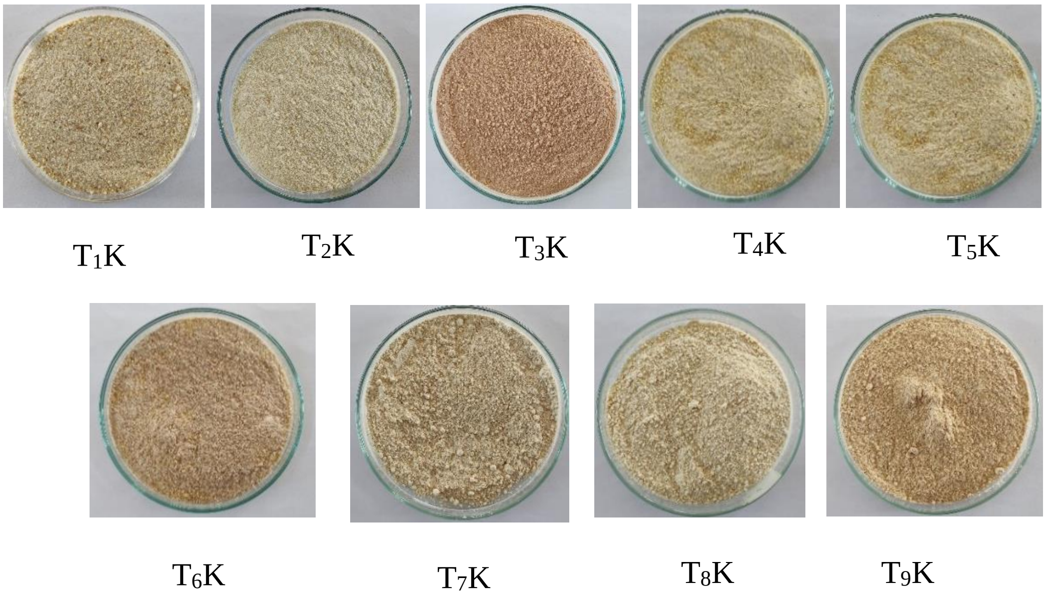
Seed flour with spermoderm

Oven dried seeds with spermoderm

Plate 4. Preparation of jackfruit seed flour by oven drying method



a. Jackfruit seed flour (varikka)



b. Jackfruit seed flour (koozha)

Plate 5. Jackfruit seed flour obtained from different processing methods

3.2.2. Functional qualities of jackfruit seed flour

3.2.2.a. Water absorption capacity (mL 100g^{-1})

Water absorption capacity of jackfruit seed flour was calculated as described in 3.1.4.a.

3.2.2.b. Oil absorption capacity (mL 100g^{-1})

Oil absorption capacity of jackfruit seed flour was calculated as described in 3.1.4.b.

3.2.2.c. Swelling power (g g^{-1})

Swelling power of jackfruit seed flour was calculated as described in 3.1.4.c**.**

3.2.2.d. Bulk density (g cm^{-3})

Bulk density of jackfruit seed flour was calculated as described in 3.1.5.b.

3.2.2.e. Colour scoring

Colour of jackfruit seed flour was calculated as described in 3.1.5.f.

3.2.2.f. Microbial analysis

The quantitative assay of bacterial and fungal population in stored jackfruit seed flour was carried out by serial dilution spread plate techniques using Nutrient agar and Rose Bengal agar medium.

No. of colony forming units

$$\text{Per gram of sample} = \frac{\text{Total number of colony formed x Dilution factor}}{\text{Aliquot taken}}$$

3. 3. Statistical analysis

The data generated from the experiment were statistically analysed using Completely Randomised Design (CRD). The colour of jackfruit seed flour was statistically analysed using Kruskall-Wallis test (chi- square value) as described by Shamrez *et al*. (2013).

Results

4. RESULTS

The experimental data collected for the present study on "Standardisation of processing methods for production of jackfruit seed flour with functional properties" were analysed and the results are presented in this chapter under the following headings.

4.1. Effect of processing methods on jackfruit seed flour quality

4.2. Storage stability studies of jackfruit seed flour

4.1. EFFECT OF PROCESSING METHODS ON JACKFRUIT SEED FLOUR QUALITY

Jackfruit seed flour obtained through different processing methods were subjected to analyses for biochemical, functional and physical qualities.

4.1.1. Biochemical qualities of jackfruit seed flour

Biochemical parameters *viz.*, moisture content, protein, crude fat, crude fibre, total ash, vitamin C, starch of jackfruit seed flour were analysed and are depicted in Table 1a. and total soluble solids, titrable acidity, total sugar, reducing sugar, carotenoids and antioxidant activity are depicted in Table 1b.

4.1.1.1. Moisture content (%)

The processing methods for jackfruit seed flour influenced the moisture content and it ranged from 6.15% to 10.59%. The highest moisture content of 10.59% was observed for Pressure cooking+ Lye peeling of varikka (T_4V), which showed no significant difference with the treatments Pressure cooking of varikka (T_6V), Pressure cooking of koozha (T_{15}K), Pan roasting + Lye peeling of varikka (T_1V), Pressure cooking + Lye peeling of koozha (T_{13}K) and Pressure cooking+ Manual removal of spermoderm of koozha (T_{14}K). The lowest moisture content of 6.15% was recorded for the treatment Pan roasting + Manual removal of spermoderm of koozha seeds (T_{11}K).

4.1.1.2. Protein (%)

Protein content of jackfruit seed flour ranged from 11.76% to 21.13%. The highest protein content of 21.13% was observed for Pan roasting of koozha (T_{12}K) which showed no significant difference with varikka seed flour obtained through Pan roasting (T_3V). The lowest protein content of 11.76% was reported for koozha seed flour obtained through Pressure cooking+ Manual removal of spermoderm (T_{14}K) which showed no significant difference with Pressure cooking of koozha (T_{15}K).

Table 1a. Effect of processing methods on biochemical qualities of jackfruit seed flour

Treatments	Moisture content (%)	Protein (%)	Crude fat (%)	Crude fibre (%)	Total ash (%)	Vitamin C (mg $100g^{-1}$)	Starch (%)
T_1V (PR+LP)	10.32^{ab}	20.67^{b}	0.44^{bc}	3.38^{e}	2.88^{bc}	18.39^{g}	43.28^{e}
T_2V(PR+MR)	9.71^{e}	19.18^{c}	0.37^{e}	3.56^{c}	3.45^{a}	19.31^{e}	34.58^{g}
T_3V(PR)	9.32^{f}	21.02^{ab}	0.43^{c}	3.79^{b}	2.70^{d}	18.54^{fg}	34.71^{g}
T_4V (PC+LP)	10.59^{a}	19.27^{c}	0.28^{f}	3.46^{d}	1.55^{g}	19.19^{e}	67.06^{b}
T_5V (PC+MR)	10.10^{bc}	15.30^{e}	0.24^{g}	3.86^{ab}	1.94^{f}	18.71^{f}	63.60^{c}
T_6V (PC)	10.47^{a}	15.67^{e}	0.36^{e}	3.93^{a}	1.55^{g}	19.68^{d}	69.07^{a}
T_7V (LP)	9.70^{e}	19.45^{c}	0.76^{a}	1.54^{j}	2.83^{bcd}	21.23^{c}	42.34^{e}
T_8V(MR+OD)	9.73^{de}	19.17^{c}	0.46^{bc}	3.06^{g}	2.88^{b}	21.66^{b}	27.49^{i}
T_9V (OD)	7.94^{g}	19.20^{c}	0.37^{e}	2.35^{i}	2.85^{bcd}	22.11^{a}	24.88^{j}
T_{10}K (PR+LP)	10.07^{bcd}	15.47^{e}	0.45^{bc}	3.36^{e}	2.48^{e}	18.32^{g}	43.53^{e}
T_{11}K(PR+MR)	6.15^{h}	16.24^{d}	0.40^{d}	3.60^{c}	3.44^{a}	19.33^{e}	34.60^{g}
T_{12}K (PR)	7.85^{g}	21.13^{a}	0.45^{bc}	3.84^{b}	2.73^{cd}	18.81^{f}	38.30^{f}
T_{13}K (PC+LP)	10.28^{ab}	12.43^{f}	0.27^{f}	3.62^{c}	1.55^{g}	19.19^{e}	64.78^{c}
T_{14}K(PC+MR)	10.27^{ab}	11.76^{h}	0.26^{fg}	3.86^{ab}	1.88^{f}	18.77^{f}	60.69^{d}
T_{15}K (PC)	10.41^{ab}	11.86^{gh}	0.34^{e}	3.93^{a}	1.55^{g}	19.66^{d}	68.99^{a}
T_{16}K (LP)	10.08^{bcd}	12.67^{f}	0.73^{a}	1.54^{j}	2.78^{bcd}	21.27^{c}	43.33^{e}
T_{17}K(MR+OD)	9.76^{cde}	12.26^{fg}	0.47^{b}	3.15^{f}	2.71^{d}	21.52^{bc}	29.26^{h}
T_{18}K (OD)	7.62^{g}	12.47^{f}	0.35^{e}	2.85^{h}	2.90^{b}	22.32^{a}	25.71^{j}
SE (± mean)	0.125	0.145	0.01	0.026	0.057	0.103	0.51
CD (0.05)	0.358	0.416	0.029	0.075	0.164	0.295	1.463

V- Varikka K- Koozha

PR- Pan Roasting LP- Lye Peeling MR- Manual Removal

PC- Pressure Cooking OD-Oven Drying

4.1.1.3. Crude Fat (%)

The processing methods for jackfruit seed flour influenced the fat content and it ranged from 0.24% to 0.76%. The highest fat content of 0.76% was reported for Lye peeling of varikka (T_7V) which showed no significant difference with the treatment T_{16}K (Lye peeling of koozha). The lowest fat content of 0.24% was observed for the treatment T_5V (Pressure cooking + Manual removal of spermoderm of varikka) which showed no significant difference with the treatment T_{14}K (Pressure cooking+ Manual removal of spermoderm of koozha).

4.1.1.4. Crude fibre (%)

Crude fibre content of jackfruit seed flour ranged from 1.54% to 3.93%. The highest fibre content of 3.93% was recorded for koozha (T_{15}K) and varikka (T_6V) seed flour obtained through Pressure cooking which showed no significant difference with the treatment, Pressure cooking + Manual removal of spermoderm of varikka (T_5V) and koozha (T_{14}K) seed flour whereas, the lowest fibre content of 1.54% was recorded for Lye peeling of koozha (T_{16}K) and varikka (T_7V) seed flour.

4.1.1.5. Total ash (%)

Total ash content of jackfruit seed flour processed through different methods ranged from 1.55% to 3.45%. The highest ash content of 3.45% was observed for varikka seed flour obtained through Pan roasting+ Manual removal of spermoderm (T_2V) which showed no significant difference with the treatment, Pan roasting+ Manual removal of spermoderm (T_{11}K) of koozha seed flour. The lowest ash content of 1.55% was recorded for the varikka seed flour obtained through Pressure cooking (T_6V) and Pressure cooking + Lye peeling (T_4V) and also koozha seed flour obtained through Pressure cooking (T_{15}K) and Pressure cooking + Lye peeling (T_{13}K).

4.1.1.6. Vitamin C (mg $100g^{-1}$)

Vitamin C content of jackfruit seed flour ranged from 18.32 mg $100g^{-1}$ to 22.32 mg $100g^{-1}$. The highest Vitamin C content of 22.32 mg $100g^{-1}$ was observed for the treatment T_{18}K (Oven drying with spermoderm) of koozha which showed no significant difference with the treatment T_9V (Oven drying with spermoderm) of varikka. The lowest Vitamin C content of 18.32 mg $100g^{-1}$ was observed for the treatment T_{10}K (Pan roasting+ Lye peeling) of koozha, which showed no significant difference with the treatments T_1V (Pan roasting+ Lye peeling) of varikka and Pan roasting (T_3V) of varikka .

4.1.1.7. Starch (%)

Starch content of jackfruit seed flour ranged from 24.88% to 69.07% and the highest starch content of 69.07% was observed for the treatment T_6V (Pressure cooking) of varikka which showed no significant difference with the treatment T_{15}K (Pressure cooking) of koozha, whereas the lowest starch content of 24.88% was observed for the treatment T_9V (Oven drying with spermoderm) of varikka which showed no significant difference with the treatment T_{18}K (Oven drying with spermoderm) of koozha seed.

4.1.1.8. Total Soluble Solids (ºBrix)

Total soluble solid content of jackfruit seed flour ranged from 1.43ºBrix to 3.03ºBrix (Table 1b). The highest TSS content of 3.03ºBrix was observed for the treatment T_{18}K (Oven drying with spermoderm) of koozha seed flour which showed no significant difference with the treatment T_9V (Oven drying with spermoderm) of varikka and the lowest TSS content of 1.43ºBrix was observed for the treatment T_5V (Pressure cooking + Manual removal of spermoderm) of varikka which showed no significant difference with the treatments T_4V (Pressure cooking+ Lye peeling) of varikka, T_{10}K (Pan roasting+ Lye peeling) of koozha, Lye peeling of koozha (T_{16}K), T_7V (Lye peeling) of varikka, T_1V (Pan roasting+ Lye peeling) of varikka, T_{14}K (Pressure cooking+ Manual removal of spermoderm) of koozha.

4.1.1.9. Titrable acidity (%)

Titrable acidity of jackfruit seed flour processed through different methods ranged from 0.19% to 0.34%. The highest acidity of 0.34% was recorded for treatment T_{14}K (Pressure cooking+ Manual removal of spermoderm) for koozha which showed no significant difference with the treatments T_{17}K (Manual removal of spermoderm+ oven drying), T_{18}K (Oven drying with spermoderm) and T_{12}K (Pan roasting) of koozha seed flour. The lowest acidity of 0.19% was observed for the treatment T_{10}K (Pan roasting + Lye peeling) of koozha seed flour which showed no significant difference with the treatments T_4V (Pressure cooking+ Lye peeling), T_1V (Pan roasting+ Lye peeling) and T_7V (Lye peeling) of varikka, T_{13}K (Pressure cooking + Lye peeling) and T_{16}K (Lye peeling) of koozha seed flour.

4.1.1.10. Total sugar (%)

Total sugar content of jackfruit seed flour ranged from 0.57% to 5.59% and the highest total sugar of 5.59% was observed for koozha seed flour obtained through pan roasting (T_{12}K) which showed no significant difference with Pan roasting of varikka (T_3V) seeds. The lowest total sugar of 0.57% was observed for the treatment Pressure cooked varikka (T_6V) and koozha (T_{15}K) seed flour.

4.1.1.11. Reducing sugar (%)

Reducing sugar content of jackfruit seed flour ranged from 0.15% to 0.92%. The highest reducing sugar of 0.92% was observed for varikka (T_3V) and koozha (T_{12}K) seed flour obtained through Pan roasting. The lowest reducing sugar of 0.15% was observed for varikka seed flour obtained through Pressure cooking+ Lye peeling (T_4V) which showed no significant difference with the treatments T_5V (Pressure cooking + Manual removal of spermoderm) and T_6V (Pressure cooking) of varikka and koozha seed flour obtained through Pressure cooking + Lye peeling (T_{13}K).

4.1.1.12. Carotenoids (µg 100g^{-1})

Carotenoid content of jackfruit seed flour ranged from 1.30 to 5.64 µg 100g^{-1} and the highest carotenoid content of 5.64 µg 100g^{-1} was reported for the treatment T_9V (Oven drying with spermoderm) of varikka, which showed no significant difference with the treatment Oven drying with spermoderm of koozha seed flour (T_{18}K). The lowest carotenoid content of 1.30 µg 100g^{-1} was observed for the treatment T_{13}K (Pressure cooking + Lye peeling) of koozha seed flour which showed no significant difference with the treatments Pan roasting + Lye peeling of koozha (T_{10}K) seed flour and Pan roasting + Lye peeling (T_1V) and Pressure cooking + Lye peeling (T_4V) of varikka seed flour.

4.1.1.13. Antioxidant activity (%)

The processing methods for jackfruit seed flour influenced the antioxidant activity and it ranged from 63.50% to 77.77%. The highest antioxidant activity of 77.77% was reported for the treatment T_{11}K (Pan roasting+ Manual removal of spermoderm) for koozha seed flour which showed no significant difference with the treatments, and T_1V (Pan roasting+ Lye peeling) and T_2V *ie*., Pan roasting+ Manual removal of spermoderm of varikka seed flour. The lowest antioxidant activity of 63.50% was reported for the treatment T_{15}K (Pressure cooking) of koozha seed flour which showed no significant difference with the treatments T_{12}K (Pan roasting) and T_{18}K (Oven drying with spermoderm) T_{13}K (Pressure cooking + Lye peeling) of koozha seed flour and T_6V (Pressure cooking) and T_9V (Oven drying with spermoderm) of varikka seed flour.

Table 1b. Effect of processing methods on biochemical qualities of jackfruit seed flour

Treatments	TSS (°Brix)	Titrable Acidity (%)	Total sugar (%)	Reducing sugar (%)	Carotenoids (µg $100g^{-1}$)	Antioxidant activity (%)
T_1V (PR+LP)	1.60^{cde}	0.20^{g}	1.73^{c}	0.82^{b}	1.40^{h}	75.67^{abc}
T_2V(PR+MR)	1.77^{c}	0.28^{ef}	1.55^{de}	0.64^{c}	4.68^{b}	76.46^{ab}
T_3V(PR)	2.10^{b}	0.26^{f}	5.58^{a}	0.92^{a}	3.23^{ef}	65.83^{fgh}
T_4V (PC+LP)	1.50^{de}	0.20^{g}	0.83^{i}	0.15^{f}	1.34^{h}	67.21^{efg}
T_5V (PC+MR)	1.43^{e}	0.32^{abc}	0.85^{i}	0.19^{f}	2.23^{g}	68.87^{e}
T_6V (PC)	2.30^{b}	0.28^{ef}	0.57^{j}	0.16^{f}	3.67^{cde}	64.52^{hi}
T_7V (LP)	1.60^{cde}	0.21^{g}	1.22^{g}	0.26^{e}	3.98^{cd}	67.40^{ef}
T_8V(MR+OD)	1.77^{c}	0.29^{def}	1.03^{h}	0.25^{e}	2.23^{g}	73.51^{cd}
T_9V (OD)	3.00^{a}	0.30^{bcde}	1.59^{d}	0.43^{d}	5.64^{a}	64.56^{hi}
T_{10}K (PR+LP)	1.50^{de}	0.19^{g}	2.38^{b}	0.65^{c}	1.42^{h}	75.33^{bcd}
T_{11}K(PR+MR)	1.70^{cd}	0.30^{cde}	1.60^{cd}	0.46^{d}	4.31^{bc}	77.77^{a}
T_{12}K (PR)	2.17^{b}	0.31^{abcd}	5.59^{a}	0.92^{a}	3.26^{ef}	64.50^{hi}
T_{13}K (PC+LP)	1.67^{cd}	0.20^{g}	1.32^{fg}	0.16^{f}	1.30^{h}	65.08^{ghi}
T_{14}K(PC+MR)	1.63^{cde}	0.34^{a}	0.75^{i}	0.26^{e}	2.65^{fg}	66.39^{fgh}
T_{15}K (PC)	2.27^{b}	0.31^{bcd}	0.57^{j}	0.25^{e}	3.60^{de}	63.50^{i}
T_{16}K (LP)	1.57^{cde}	0.21^{g}	1.45^{ef}	0.26^{e}	3.99^{cd}	67.85^{ef}
T_{17}K(MR+OD)	1.67^{cd}	0.33^{ab}	1.36^{f}	0.26^{e}	2.23^{g}	73.45^{d}
T_{18}K (OD)	3.03^{a}	0.32^{abc}	1.57^{de}	0.27^{e}	5.63^{a}	65.08^{ghi}
SE (± mean)	0.08	0.01	0.047	0.017	0.237	0.754
CD (0.05)	0.229	0.03	0.136	0.049	0.68	2.162

V- Varikka K- Koozha

PR- Pan Roasting LP- Lye Peeling MR- Manual Removal

PC- Pressure Cooking OD-Oven Drying

4.1.2. Functional qualities of jackfruit seed flour

Functional qualities of jackfruit seed flour *viz*., water absorption capacity (mL $100g^{-1}$), oil absorption capacity (mL $100g^{-1}$) and swelling power (g g^{-1}) were analysed and depicted in Table 2.

4.1.2.1. Water absorption capacity (mL $100g^{-1}$)

Water absorption capacity of jackfruit seed flour ranged from 125 mL $100g^{-1}$ to 180 mL $100g^{-1}$. The highest water absorption capacity of 180 mL $100g^{-1}$ was recorded for the treatment T_2V(Pan roasting+ Manual removal of spermoderm) and T_3V (Pan roasting) of varikka and Pan roasting (T_{12}K) of koozha which showed no significant difference with the treatment T_{11}K (Pan roasting + Manual removal of spermoderm) of koozha. The lowest water absorption capacity of 125 mL $100g^{-1}$ was observed for the treatment T_{15}K (Pressure cooking) of koozha and T_6V (Pressure cooking of varikka).

4.1.2.2. Oil absorption capacity (mL $100g^{-1}$)

Oil absorption capacity of jackfruit seed flour ranged from 62.33 mL $100g^{-1}$ to 96.67 mL$100g^{-1}$. The highest oil absorption capacity of 96.67 mL $100g^{-1}$ was recorded for the treatment T_9V (Oven drying with spermoderm) and T_8V (Manual removal + Oven drying) of varikka seed flour which showed no significant difference with the treatments T_{17}K (Manual removal + Oven drying) and T_{18}K (Oven drying with spermoderm) of koozha seed flour whereas, the lowest oil absorption capacity of 62.33 mL $100g^{-1}$ was observed for the treatment (T_{11}K) Pan roasting + Manual removal of spermoderm of koozha seed flour which showed no significant difference with the treatments T_1V (Pan roasting + Lye peeling), T_2V (Pan roasting+ Manual removal of spermoderm) and T_3V (Pan roasting) of varikka, T_{12}K (Pan roasting), T_{10}K (Pan roasting + Lye peeling).

4.1.2.3. Swelling power (g g^{-1})

Swelling power of jackfruit seed flour ranged from 2.46 g g^{-1} to 5.44 g g^{-1} and the highest swelling power of 5.44 g g^{-1} was recorded for koozha seed flour obtained through Oven drying with spermoderm (T_{18}K) which showed no significant difference with the treatments T_{17}K (Manual removal + Oven drying) and T_9V (Oven drying with spermoderm) of varikka seed flour and the lowest swelling power of 2.46 g g^{-1} was observed for Pressure cooking + Manual removal of spermoderm (T_5V) of varikka seed flour which showed no significant difference with the treatments (T_6V) Pressure cooking of varikka, (T_{14}K) Pressure cooking + Manual removal of spermoderm and (T_{15}K) Pressure cooking of koozha seed flour.

Table 2. Effect of processing methods on functional qualities of jackfruit seed flour

Treatments	Water absorption capacity (mL $100g^{-1}$)	Oil absorption capacity (mL $100g^{-1}$)	Swelling power (g g^{-1})
T_1V (PR+LP)	165^{b}	64.67^{d}	5.25^{b}
T_2V(PR+MR)	180^{a}	63.67^{d}	4.24^{c}
T_3V(PR)	180^{a}	62.67^{d}	5.26^{b}
T_4V (PC+LP)	150^{de}	73.00^{c}	3.12^{e}
T_5V (PC+MR)	151.67^{de}	72.67^{c}	2.46^{f}
T_6V (PC)	125^{f}	74.33^{c}	2.65^{f}
T_7V (LP)	163.33^{b}	71.67^{c}	3.76^{d}
T_8V(MR+OD)	155^{cd}	96.67^{a}	3.78^{e}
T_9V (OD)	153.33^{cd}	96.67^{a}	5.42^{ab}
T_{10}K (PR+LP)	160^{bc}	64.67^{d}	5.23^{b}
T_{11}K(PR+MR)	175^{a}	62.33^{d}	4.24^{c}
T_{12}K (PR)	180^{a}	64.00^{d}	5.25^{b}
T_{13}K (PC+LP)	150^{de}	82.00^{b}	3.04^{e}
T_{14}K(PC+MR)	145^{e}	72.67^{c}	2.58^{f}
T_{15}K (PC)	125^{f}	82.67^{b}	2.65^{f}
T_{16}K (LP)	155^{cd}	73.33^{c}	3.67^{d}
T_{17}K(MR+OD)	163.33^{b}	96.66^{a}	5.43^{ab}
T_{18}K (OD)	153.33^{cd}	96.66^{a}	5.44^{ab}
SE (± mean)	2.606	1.192	0.087
CD (0.05)	7.474	3.418	0.249

V- Varikka K- Koozha

PR- Pan Roasting LP- Lye Peeling MR-Manual Removal

PC- Pressure Cooking OD-Oven Drying

4.1.3. Physical qualities of jackfruit seed flour

Jackfruit seed flour obtained through different processing methods were analysed for yield (%), bulk density (g cm^{-3}), tapped density (g cm^{-3}), hausner factor, carr index (%) and are depicted in Table 3 and the colour score in Table 4.

4.1.3.1. Yield (%)

Yield of jackfruit seed flour from different processing methods of jackfruit seeds ranged from 37.42% to 64.24%. The highest yield of 64.24% was recorded for the treatment T_9V (Oven drying with spermoderm) of varikka seed flour which showed no significant difference with $T_{18}K$ (Oven drying with spermoderm) of koozha whereas the lowest yield of 37.42% was observed for varikka seed flour obtained through Pressure cooking + Manual removal of spermoderm (T_5V) which showed no significant difference with ($T_{14}K$) Pressure cooking + Manual removal of spermoderm of koozha seed flour.

4.1.3.2. Bulk density (g cm^{-3})

Bulk density of jackfruit seed flour ranged from 0.70 g cm^{-3} to 0.82 g cm^{-3} with the highest bulk density of 0.82 g cm^{-3} for varikka seed flour obtained through Pressure cooking (T_6V) and the lowest bulk density of 0.70 g cm^{-3} was observed for Manual removal of spermoderm + Oven drying ($T_{17}K$) of koozha seed flour which showed no significant difference with the treatments T_1V (Pan roasting + Lye peeling), T_2V (Pan roasting+ Manual removal of spermoderm), T_3V (Pan roasting) of varikka seed flour and $T_{12}K$ (Pan roasting), $T_{13}K$ (Pressure cooking + Lye peeling), $T_{16}K$ (Lye peeling) and $T_{18}K$ (Oven drying with spermoderm) of koozha seed flour.

4.1.3.3. Tapped density (g cm^{-3})

Tapped density of jackfruit seed flour ranged from 0.84 g cm^{-3} to 0.98 g cm^{-3} and the highest tapped density of 0.98 g cm^{-3} was recorded for the treatment T_6V (Pressure cooking) of varikka seed flour whereas, the lowest tapped density of 0.84 g cm^{-3} was recorded for the treatment $T_{18}K$ (Oven drying with spermoderm) of koozha seed flour which showed no significant difference with the treatments $T_{17}K$ (Manual removal + Oven drying), $T_{16}K$ (Lye peeling) ,$T_{13}K$ (Pressure cooking + Lye peeling) of koozha seed flour and T_1V (Pan roasting + Lye peeling) of varikka seed flour.

Table 3. Effect of processing methods on physical qualities of jackfruit seed flour

Treatments	Yield (%)	Bulk density (g cm^{-3})	Tapped density (g cm^{-3})	Hausner factor	Carr index (%)
T_1V (PR+LP)	42.60^{f}	0.71^{e}	0.87^{de}	1.22^{ab}	17.99
T_2V(PR+MR)	40.76^{f}	0.71^{e}	0.86^{c}	1.21^{abc}	17.50
T_3V(PR)	54.32^{c}	0.73^{de}	0.90^{bc}	1.23^{a}	19.26
T_4V (PC+LP)	40.32^{fg}	0.77^{b}	0.93^{b}	1.20^{abcd}	16.55
T_5V (PC+MR)	37.42^{h}	0.75^{cd}	0.91^{b}	1.22^{ab}	17.96
T_6V (PC)	46.72^{e}	0.82^{a}	0.98^{a}	1.20^{bcd}	16.28
T_7V (LP)	56.42^{c}	0.78^{b}	0.93^{b}	1.18^{bcd}	15.47
T_8V(MR+OD)	51.62^{d}	0.77^{bc}	0.92^{b}	1.20^{bcd}	16.36
T_9V (OD)	64.24^{a}	0.77^{bc}	0.90^{bc}	1.17^{cd}	14.79
T_{10}K (PR+LP)	38.15^{g}	0.77^{bc}	0.93^{b}	1.20^{abc}	17.26
T_{11}K(PR+MR)	34.32^{i}	0.77^{bc}	0.91^{b}	1.19^{bcd}	15.69
T_{12}K (PR)	41.51^{f}	0.73^{de}	0.87^{cd}	1.20^{abcd}	16.77
T_{13}K (PC+LP)	41.52^{f}	0.73^{de}	0.87^{de}	1.20^{bcd}	16.12
T_{14}K(PC+MR)	37.54^{h}	0.76^{bc}	0.92^{b}	1.21^{abc}	17.33
T_{15}K (PC)	45.29^{e}	0.76^{bc}	0.93^{b}	1.22^{ab}	17.98
T_{16}K (LP)	51.92^{d}	0.73^{de}	0.85^{de}	1.17^{cd}	14.81
T_{17}K(MR+OD)	51.31^{d}	0.70^{e}	0.86^{de}	1.22^{ab}	18.20
T_{18}K (OD)	60.25^{ab}	0.73^{de}	0.84^{e}	1.16^{d}	13.82
SE (± mean)	0.806	0.009	0.011	0.015	1.022
CD (0.05)	2.312	0.027	0.027	0.042	NS

V- Varikka K- Koozha

PR- Pan Roasting LP- Lye Peeling MR- Manual Removal

PC- Pressure Cooking OD-Oven Drying

4.1.3.4. Hausner factor

Hausner factor of jackfruit seed flour which indicates the flowability of flour ranged from 1.16 to 1.23. The highest Hausner factor of 1.23 was recorded for the treatment T_3V (Pan roasting) of varikka which showed no significant difference with the treatments Pan roasting + Lye peeling (T_{10}K), Pan roasting (T_{12}K), Pressure cooking + Manual removal of spermoderm T_{14}K, Pressure cooking (T_{15}K) and Manual removal + Oven drying (T_{17}K) of koozha, Pan roasting + Lye peeling (T_1V), Pan roasting + Manual removal of spermoderm (T_2V), Pressure cooking + Lye peeling (T_4V) and Pressure cooking + Manual removal of spermoderm (T_5V) of varikka seed flour. The lowest Hausner factor of 1.16 was recorded for Oven drying with spermoderm of koozha (T_{18} K) seed flour which showed no significant difference with the treatments T_4V (Pressure cooking + Lye peeling), T_6V (Pressure cooking), T_7V (Lye peeling), T_8V (Manual removal of spermoderm + Oven drying), T_9V (Oven drying with spermoderm) of varikka and T_{11}K (Pan roasting + Manual removal of spermoderm), T_{12}K (Pan roasting), T_{13}K (Pressure cooking + Lye peeling) and T_{16}K (Lye peeling) of koozha seed flour.

4.1.3.5. Carr index (%)

The processing methods for jackfruit seed flour influenced the carr index and it ranged from 13.82 to 19.26% with no significant difference among the treatments.

4.1.3.6. Colour

Jackfruit seed flour processed thrrough different methods were analysed for the sensory attribute, colour and the scores are depicted in Table 4. Jackfruit seed flour processed through Lye peeling of varikka (T_7V) obtained a mean score of 4.1 which is creamish white in colour whereas, koozha (T_{16}K) obtained a mean score of 4 which is cream colour. Flour obtained through Pressure cooking of varikka (T_6V) and koozha (T_{15}K) resulted a mean score of 2.7 and 2.3 respectively which described as yellowish cream in colour. Pan roasting + Lye peeling and Pan roasting + Manual removal of spermoderm of varikka and koozha obtained a mean score of 3.25, 3.4 and 3.45, 3.6 respectively which also resulted as yellowish cream in colour. Pan roasting of varikka (T_3V) and koozha (T_{12}K) obtained a mean score of 1.9 and 1.85 respectively which is brownish cream colour. Jackfruit seed flour obtained through Oven drying of varikka (T_9V) and koozha (T_{18}K) resulted a mean score of 2 which resulted in creamish brown colour.

Table 4. Effect of processing methods on colour of jackfruit seed flour

Attributes		
Colour	Mean score	Mean rank
T_1V (PR+LP)	3.25	215.87
T_2V(PR+MR)	3.4	220.85
T_3V(PR)	1.9	40.42
T_4V (PC+LP)	2.5	11.80
T_5V (PC+MR)	3.85	269.72
T_6V (PC)	2.7	174.90
T_7V (LP)	4.1	280.30
T_8V(MR+OD)	3.4	230.20
T_9V (OD)	2.0	37.50
T_{10}K (PR+LP)	3.45	82.65
T_{11}K(PR+MR)	3.6	107.11
T_{12}K (PR)	1.85	95.52
T_{13}K (PC+LP)	2.5	161.95
T_{14}K(PC+MR)	3.75	261.90
T_{15}K (PC)	2.3	148.99
T_{16}K (LP)	4	274.92
T_{17}K(MR+OD)	3.55	246.00
T_{18}K (OD)	2.0	119.30
KW value	235.11	
χ^2	27.59	

Scores: White-5, Cream- 4, Creamish yellow- 3, Creamish brown- 2, Brown- 1

V- Varikka K- Koozha

PR- Pan Roasting LP- Lye Peeling MR- Manual Removal

PC- Pressure Cooking OD-Oven Drying

4.2. STORAGE STABILITY STUDIES OF JACKFRUIT SEED FLOUR

Based on biochemical, functional and physical qualities, jackfruit seed flour obtained from varikka and koozha types (with and without spermoderm) having superior quality were selected for the storage stability studies for two months. The selected jackfruit seed flour obtained from Pan roasting and Pressure cooking with spermoderm and Manual removal of spermoderm for varikka and koozha types were packed in polypropylene and stored under room temperature for storage stability analysis.

4.2.1. Biochemical qualities of jackfruit seed flour

4.2.1.1. Moisture content (%)

Table 5. Effect of storage on moisture content (%) of jackfruit seed flour

Treatments	Moisture content (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	9.71	9.71	9.77	9.72^{d}
S_2 (VPR)	9.32	9.16	9.25	9.24^{e}
S_3 (VPC+MR)	10.10	10.17	10.33	10.20^{c}
S_4 (VPC)	10.47	10.64	10.81	10.64^{a}
S_5 (KPR+MR)	6.15	6.16	6.57	6.29^{g}
S_6 (KPR)	7.85	7.86	8.09	7.94^{f}
S_7 (KPC+MR)	10.27	10.26	10.39	10.30^{bc}
S_8 (KPC)	10.41	10.40	10.48	10.43^{b}
Mean (M)	9.28^{b}	9.30^{b}	9.46^{a}	
SE(±m) T- 0.06 M-0.037 TXM-0.104				
CD (0.05) T- 0.171 M-0.105 TXM- NS				

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Moisture content of jackfruit seed flour increased with the storage period and is depicted in Table 5. At the time of storage, the moisture content was 9.28% which increased to 9.30% and 9.46% respectively after first and second month of storage. The highest moisture content of 10.64% was observed for varikka seed flour (S_4) obtained through Pressure cooking and the lowest moisture content of 6.29% was observed for koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm (S_5).

4.2.1.2. Protein (%)

Table 6. Effect of storage on protein content (%) of jackfruit seed flour

Treatments	Protein (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	19.18	19.00	18.99	19.06[b]
S_2 (VPR)	21.02	21.00	21.01	21.01[a]
S_3 (VPC+MR)	15.30	15.28	15.28	15.29[e]
S_4 (VPC)	15.67	15.65	15.63	15.65[d]
S_5 (KPR+MR)	16.24	16.23	16.22	16.22[c]
S_6 (KPR)	21.13	21.18	21.17	21.16[a]
S_7 (KPC+MR)	11.76	11.76	11.72	11.75[f]
S_8 (KPC)	11.86	11.84	11.83	11.84[f]
Mean (M)	16.52	16.49	16.48	
SE(±m) T- 0.098	M-0.06		TXM-0.17	
CD (0.05) T- 0.279	M-NS		TXM- NS	

V- Varikka
K- Koozha
PR- Pan Roasting
MR- Manual Removal
PC- Pressure Cooking

Protein content of jackfruit seed flour did not show any significant difference during the storage period and the interaction effects were also non-significant and is depicted in Table 6. The highest protein content of 21.16% was observed for Pan roasted koozha (S_6) which showed no significant difference with Pan roasted varikka (S_2) and the lowest protein content of 11.75% was observed for koozha seed flour obtained through Pressure cooking +Manual removal of spermoderm (S_7) which showed no significant difference with Pressure cooked koozha seed flour (S_8).

4.2.1.3. Crude fat (%)

Table 7. Effect of storage on crude fat content (%) of jackfruit seed flour

Treatments	Crude fat (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	0.37	0.37	0.36	0.36^c
S_2 (VPR)	0.43	0.43	0.42	0.43^a
S_3 (VPC+MR)	0.24	0.24	0.24	0.24^e
S_4 (VPC)	0.36	0.34	0.34	0.35^c
S_5 (KPR+MR)	0.40	0.39	0.41	0.40^b
S_6 (KPR)	0.45	0.44	0.44	0.44^a
S_7 (KPC+MR)	0.26	0.25	0.23	0.24^e
S_8 (KPC)	0.34	0.33	0.31	0.33^d
Mean (M)	0.35	0.35	0.34	
SE(±m) T- 0.227	M-0.139		TXM-0.004	
CD (0.05) T- 0.645	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Fat content of jackfruit seed flour did not show any significant difference during the storage period of two months (Table 7). The highest fat content of 0.44% was recorded for koozha seed flour obtained through Pan roasting (S_6) which showed no significant difference with Pan roasted varikka (S_2). The lowest fat content of 0.24% was recorded for Pressure cooking + Manual removal of spermoderm of varikka (S_3) and Pressure cooking + Manual removal of spermoderm of koozha (S_7) seed flour.

4.2.1.4. Crude fibre (%)

Table 8. Effect of storage on crude fibre content (%) of jackfruit seed flour

Treatments	Crude fibre (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	3.56	3.56	3.60	3.57^d
S_2 (VPR)	3.79	3.75	3.72	3.76^c
S_3 (VPC+MR)	3.86	3.86	3.88	3.87^b
S_4 (VPC)	3.93	3.95	3.97	3.95^a
S_5 (KPR+MR)	3.60	3.61	3.62	3.61^d
S_6 (KPR)	3.84	3.85	3.87	3.85^b
S_7 (KPC+MR)	3.86	3.84	3.84	3.84^b
S_8 (KPC)	3.93	3.94	3.97	3.95^a
Mean (M)	3.80	3.79	3.80	
SE(±m) T- 0.015 M-0.009 TXM-0.026				
CD (0.05) T- 0.043 M-NS TXM- NS				

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

The jackfruit seed flour did not show any significant difference in crude fibre content on storage and is depicted in Table 8. The highest fibre content of 3.95% was observed for Pressure cooked varikka (S_4) and Pressure cooked koozha (S_8) seed flour and the lowest fibre content of 3.57% was observed for varikka seed flour obtained through Pan roasting+ Manual removal of spermoderm (S_1) which showed no significant difference with Pan roasting+ Manual removal of spermoderm (S_5) of koozha seed flour.

4.2.1.5. Total ash (%)

Table 9. Effect of storage on total ash content (%) of jackfruit seed flour

Treatments	Total ash (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	3.45	3.43	3.40	3.43[a]
S_2 (VPR)	2.70	2.69	2.67	2.69[c]
S_3 (VPC+MR)	1.94	1.93	1.91	1.93[d]
S_4 (VPC)	1.55	1.53	1.51	1.53[g]
S_5 (KPR+MR)	3.44	2.87	2.85	3.05[b]
S_6 (KPR)	2.73	2.71	2.67	2.70[c]
S_7 (KPC+MR)	1.88	1.86	1.83	1.86[de]
S_8 (KPC)	1.55	1.77	1.75	1.69[f]
Mean (M)	2.37	2.35	2.32	
SE(±m) T- 0.034	M-0.021		TXM-0.06	
CD (0.05) T- 0.098	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

The highest ash content of 3.43% was recorded for varikka seed flour obtained through Pan roasting+ Manual removal of spermoderm (S_1) and the lowest ash content of 1.53% was recorded for Pressure cooked (S_4) varikka seed flour (Table 9). Total ash content of jackfruit seed flour did not show any significant difference on storage.

4.2.1.6. Vitamin C (mg 100g^{-1})

Table 10. Effect of storage on vitamin C content (mg100g^{-1}) of jackfruit seed flour

Treatments	Vitamin C (mg100g^{-1})			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	19.31	19.32	19.15	19.26^b
S_2 (VPR)	18.54	18.50	18.27	18.43^d
S_3 (VPC+MR)	18.71	18.68	18.49	18.63^c
S_4 (VPC)	19.68	19.65	19.52	19.62^a
S_5 (KPR+MR)	19.33	19.31	19.17	19.27^b
S_6 (KPR)	18.81	18.80	18.66	18.76^c
S_7 (KPC+MR)	18.77	18.75	18.55	18.69^c
S_8 (KPC)	19.66	19.63	19.50	19.60^a
Mean (M)	19.10^a	19.08^a	18.91^b	
SE(±m) T- 0.051	M-0.031		TXM-0.089	
CD (0.05) T- 0.145	M-0.089		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Vitamin C content of jackfruit seed flour decreased on storage and the interaction effects were found non-significant (Table 10). At the time of storage, Vitamin C content was 19.10 mg 100g^{-1} and did not show significant difference after first month of storage which decreased to 18.91 mg 100g^{-1} after the second month of storage. The highest Vitamin C content of 19.62 mg 100g^{-1} was reported for Pressure cooked varikka seed flour (S_4) which showed no significant difference with Pressure cooked koozha seed flour (S_8) and the lowest Vitamin C content of 18.43 mg 100g^{-1}

was reported for varikka seed flour obtained through Pan roasting (S_2).

4.2.1.7. Starch (%)

Table 11. Effect of storage on starch content (%) of jackfruit seed flour

Treatments	Starch (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	34.58	34.56	34.53	34.56[e]
S_2 (VPR)	34.71	34.69	34.66	34.69[e]
S_3 (VPC+MR)	63.60	63.59	63.57	63.59[b]
S_4 (VPC)	69.07	69.06	69.04	69.05[a]
S_5 (KPR+MR)	34.60	34.58	34.56	34.58[e]
S_6 (KPR)	38.30	38.29	38.27	38.29[d]
S_7 (KPC+MR)	60.69	60.67	60.65	60.67[c]
S_8 (KPC)	68.99	68.98	68.96	68.98[a]
Mean (M)	50.57	50.55	50.53	
SE(±m) T- 0.267	M-0.164	TXM-0.463		
CD (0.05) T- 0.76	M-NS	TXM- NS		

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Jackfruit seed flour did not show any change in starch content during the storage period of two months and the interaction effects were also non- significant, but it varied among the treatments (Table 11). Pressure cooked varikka seed flour (S_4) recorded a higher starch content of 69.05% which showed no significant difference with Pressure cooked koozha (S_8) seed flour and the lowest starch content of 34.56% for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm (S_1) which showed no significant difference with Pan roasted varikka (S_2) and Pan roasting + Manual removal of spermoderm of koozha (S_5) seed flour.

4.2.1.8. Total Soluble Solids (^{0}Brix)

Table 12. Effect of storage on Total Soluble Solids (TSS) content (^{0}Brix) of jackfruit seed flour

Treatments	TSS (°Brix)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	1.77	1.77	1.77	1.77^c
S_2 (VPR)	2.10	2.13	2.10	2.11^b
S_3 (VPC+MR)	1.43	1.44	1.43	1.44^d
S_4 (VPC)	2.30	2.31	2.31	2.31^a
S_5 (KPR+MR)	1.70	1.72	1.71	1.71^c
S_6 (KPR)	2.17	2.20	2.17	2.18^{ab}
S_7 (KPC+MR)	1.63	1.64	1.65	1.64^c
S_8 (KPC)	2.27	2.30	2.31	2.29^a
Mean (M)	1.92	1.94	1.93	
SE(±m) T- 0.047	M-0.029 TXM-0.082			
CD (0.05) T- 0.135	M-NS TXM- NS			

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Total Soluble Solid (TSS) content of jackfruit seed flour did not show any significant change during the storage period and the interaction effects were also non-significant as depicted in Table 12. The highest TSS content of 2.31^{0}Brix was recorded for Pressure cooking of varikka (S_4) which showed no significant difference with Pan roasting of koozha (S_6) and Pressure cooking of koozha (S_8). The lowest TSS content of 1.44 ^{0}Brix was observed for varikka seed flour processed through Pressure cooking + Manual removal of spermoderm (S_3).

4.2.1.9. Titrable acidity (%)

Table 13. Effect of storage on titrable acidity (%) of jackfruit seed flour

Treatments	Acidity (%)			Mean (T)
	Months after storage (M)			
	At the time of storage	1	2	
S_1 (VPR+MR)	0.28	0.26	0.22	0.25^{cd}
S_2 (VPR)	0.26	0.22	0.18	0.22^{e}
S_3 (VPC+MR)	0.32	0.21	0.18	0.23^{de}
S_4 (VPC)	0.28	0.24	0.18	0.23^{de}
S_5 (KPR+MR)	0.30	0.25	0.20	0.25^{cd}
S_6 (KPR)	0.31	0.27	0.20	0.26^{bc}
S_7 (KPC+MR)	0.34	0.30	0.29	0.31^{a}
S_8 (KPC)	0.31	0.28	0.23	0.27^{b}
Mean (M)	0.29^{a}	0.25^{b}	0.21^{c}	
SE(±m) T-0.007	M-0.004	TXM-0.012		
CD (0.05) T- 0.02	M 0.012	TXM- NS		

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Titrable acidity of jackfruit seed flour decreased on storage whereas the interaction effects were non-significant as described in Table 13. At the time of storage, acidity was 0.29% and decreased to 0.25% and 0.21% after first and second month of storage respectively. The highest titrable acidity of 0.31% was observed for koozha seed flour with Pressure cooking + Manual removal of spermoderm (S_7) and the lowest acidity of 0.22% for varikka seed flour obtained through Pan roasting (S_2) which showed no significant difference with Pressure cooking + Manual removal of spermoderm of varikka (S_3) and Pressure cooked varikka seed flour (S_4).

4.2.1.10. Total sugar (%)

Table 14. Effect of storage on total sugar (%) of jackfruit seed flour

Treatments	Total sugar (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	1.55	1.53	1.50	1.53^c
S_2 (VPR)	5.58	2.83	2.80	3.73^b
S_3 (VPC+MR)	0.85	0.83	0.80	0.83^d
S_4 (VPC)	0.57	0.54	0.51	0.54^f
S_5 (KPR+MR)	1.60	1.59	1.54	1.58^c
S_6 (KPR)	5.59	5.56	5.54	5.56^a
S_7 (KPC+MR)	0.75	0.74	0.71	0.73^e
S_8 (KPC)	0.57	0.55	0.51	0.54^f
Mean (M)	1.79	1.77	1.74	
SE(±m) T- 0.027	M-0.016		TXM-0.046	
CD (0.05) T- 0.076	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Total sugar content of jackfruit seed flour did not show any significant difference during the storage period and the interaction effects were also found non-significant. The highest total sugar of 5.56% was observed for Pan roasting of koozha seed flour (S_6) and the lowest total sugar content of 0.54% for Pressure cooking of varikka (S_4) and koozha (S_8) seed flour (Table 14).

4.2.1.11. Reducing sugar (%)

Table 15. Effect of storage on reducing sugar (%) of jackfruit seed flour

Treatments	Reducing sugar (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1`	2	
S_1 (VPR+MR)	0.64	0.66	0.68	0.66^c
S_2 (VPR)	0.92	0.95	0.98	0.95^a
S_3 (VPC+MR)	0.19	0.20	0.22	0.20^f
S_4 (VPC)	0.16	0.18	0.20	0.18^f
S_5 (KPR+MR)	0.46	0.48	0.50	0.48^d
S_6 (KPR)	0.92	0.76	0.77	0.81^b
S_7 (KPC+MR)	0.26	0.27	0.29	0.27^e
S_8 (KPC)	0.25	0.26	0.28	0.26^e
Mean (M)	0.45^c	0.47^b	0.49^a	
SE(±m) T- 0.009	M-0.006		TXM-0.016	
CD (0.05) T- 0.026	M-0.016		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Reducing sugar of jackfruit seed flour gradually increased with storage as depicted in Table 15. At the time of storage, the reducing sugar was 0.45% which increased to 0.47% after the first month and 0.49% after second month of storage respectively. The highest reducing sugar of 0.95% was observed for Pan roasting of varikka seed flour (S_2) and the lowest reducing sugar of 0.18% was observed for Pressure cooking of varikka seed flour (S_4) which showed no significant difference with Pressure cooking + Manual removal of spermoderm (S_3) of varikka seed flour.

4.2.1.12. Carotenoids (µg 100g^{-1})

Table 16. Effect of storage on carotenoid content (µg 100g^{-1}) of jackfruit seed flour

Treatments	Carotenoids (µg 100g^{-1})			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1(VPR+MR)	4.68	4.67	4.67	4.67^a
S_2 (VPR)	3.23	3.23	3.26	3.24^f
S_3 (VPC+MR)	2.23	2.22	2.23	2.22^h
S_4 (VPC)	3.67	3.66	3.66	3.66^c
S_5 (KPR+MR)	4.31	4.30	4.31	4.31^b
S_6 (KPR)	3.26	3.26	3.26	3.26^e
S_7 (KPC+MR)	2.65	2.65	2.65	2.65^g
S_8 (KPC)	3.60	3.60	3.61	3.61^d
Mean (M)	3.45	3.45	3.46	
SE(±m) T- 0.005	M-0.003		TXM-0.010	
CD (0.05) T- 0.016	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Carotenoid content of jackfruit seed flour did not show any significant difference on storage (Table 16). The highest carotenoid content of 4.67 µg 100g^{-1} was reported for the treatment S_1 (Pan roasting + Manual removal of spermoderm) of varikka seed flour and the lowest carotenoid content of 2.22 µg 100g^{-1} was recorded for S_3 (Pressure cooking + Manual removal of spermoderm) of varikka seed flour.

4.2.1.13. Antioxidant activity (%)

Table 17. Effect of storage on antioxidant activity (%) of jackfruit seed flour

Treatments	Antioxidant activity (%)			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	76.46	76.44	76.42	76.44[a]
S_2 (VPR)	65.83	65.81	65.78	65.80[cd]
S_3 (VPC+MR)	68.87	68.86	68.77	68.83[b]
S_4 (VPC)	64.52	64.50	64.48	64.50[de]
S_5 (KPR+MR)	77.77	77.76	77.74	77.76[a]
S_6 (KPR)	64.50	64.49	64.47	64.49[de]
S_7 (KPC+MR)	66.39	66.40	66.38	66.39[c]
S_8 (KPC)	63.50	63.49	63.47	63.48[e]
Mean (M)	68.48	68.47	68.44	
SE(±m) T- 0.515	M-0.315		TXM-0.891	
CD (0.05) T- 1.463	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Antioxidant activity of jackfruit seed flour showed no significant change during the storage period of two months and the interaction effects were also non- significant as depicted in Table 17. The highest antioxidant activity of 77.76% was recorded for koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm (S_5) which did not show any significant difference with varikka seed flour from Pan roasting+ Manual removal of spermoderm (S_1) whereas the lowest antioxidant activity of 63.48% was recorded for koozha seed flour obtained through Pressure cooking (S_8) which showed no significant difference with the treatments Pressure cooking of varikka (S_6) and Pan roasting of koozha (S_4) after two months of storage.

4.2.1.14. Peroxide value (meq kg^{-1})

Table 18. Effect of storage on peroxide value of jackfruit seed flour

Treatments	Peroxide value (meq kg^{-1})		
	Months after storage (M)		
	At the time of storage	1	2
S_1 (VPR+MR)	0.013	0.013	0.013
S_2 (VPR)	0.017	0.017	0.018
S_3 (VPC+MR)	0.013	0.013	0.013
S_4 (VPC)	0.017	0.017	0.018
S_5 (KPR+MR)	0.013	0.013	0.013
S_6 (KPR)	0.017	0.017	0.018
S_7 (KPC+MR)	0.013	0.013	0.013
S_8 (KPC)	0.017	0.017	0.018
SE(±m)	0.003	0.003	0.003
CD (0.05)	NS	NS	NS

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

The jackfruit seed flour recorded a peroxide value of 0.013- 0.017 meq kg^{-1} which showed no significant difference between the treatments (Table 18). The peroxide value of jackfruit seed flour did not show any changes after one month of storage which increased slightly after the storage of two months in treatments with spermoderm even though the changes were negligible.

4.2.2. Functional qualities of jackfruit seed flour

4.2.2.1. Water absorption capacity (mL 100g^{-1})

Table 19. Effect of storage on water absorption capacity (mL 100g^{-1}) of jackfruit seed flour

Treatments	Water absorption capacity (mL 100g^{-1})			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	180.00	180.02	180.00	180.01^{a}
S_2 (VPR)	180.00	180.02	180.00	180.00^{a}
S_3 (VPC+MR)	151.67	151.68	151.68	151.67^{c}
S_4 (VPC)	125.00	125.00	125.00	125.00^{e}
S_5 (KPR+MR)	175.00	175.04	175.00	175.01^{b}
S_6 (KPR)	180.00	180.00	180.00	180.00^{a}
S_7 (KPC+MR)	145.00	145.05	145.00	145.02^{d}
S_8 (KPC)	125.00	125.05	125.00	125.02^{e}
Mean (M)	157.70	157.72	157.71	
SE(±m) T- 1.522	M-0.932		TXM-2.635	
CD (0.05) T- 4.327	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Water absorption capacity of jackfruit seed flour obtained through different processing methods did not show significant difference during the storage period and the interaction effects were also non- significant (Table 19). The highest water absorption capacity of 180.01 mL 100g^{1} was recorded for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm (S_1) which showed no significant difference with Pan roasting of varikka (S_2) and koozha (S_6). The lowest water absorption capacity of 125.00 mL 100g^{-1} was recorded for varikka seed flour obtained through Pressure cooking (S_4) which showed no significant difference with Pressure cooking of koozha (S_8) seed flour after two months of storage.

4.2.2.2. Oil absorption capacity (mL 100g^{-1})

Table 20. Effect of storage on oil absorption capacity (mL 100g^{-1}) of jackfruit seed flour

Treatments	Oil absorption capacity (mL 100g^{-1})			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	63.67	63.63	63.64	63.65^c
S_2 (VPR)	62.67	62.67	62.62	62.62^c
S_3 (VPC+MR)	72.67	72.71	72.69	72.69^b
S_4 (VPC)	74.33	74.38	74.34	74.35^b
S_5 (KPR+MR)	62.33	62.89	63.07	62.77^c
S_6 (KPR)	64.00	64.30	64.23	64.17^c
S_7 (KPC+MR)	72.67	72.71	72.68	72.69^b
S_8 (KPC)	82.67	82.71	82.69	82.69^a
Mean (M)	69.37	69.50	69.50	
SE(±m) T-0.665	M-0.407		TXM-1.152	
CD (0.05) T- 1.891	M-NS		TXM- NS	

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Oil absorption capacity of jackfruit seed flour did not show significant difference during the storage period and the interaction effects were also non-significant. Oil absorption capacity of jackfruit seed flour recorded the highest value of 82.69 mL 100g^{-1} for Pressure cooked koozha seed flour (S_8) (Table 20). The lowest oil absorption capacity of 62.62 mL 100g^{1} was recorded for varikka seed flour obtained through Pan roasting (S_2) which showed no significant difference with Pan roasted koozha (S_6), Pan roasting+ Manual removal of spermoderm of varikka (S_1) and koozha (S_5) seed flour.

4.2.2.3. Swelling power (g g^{-1})

Table 21. Effect of storage on swelling power (gg^{-1}) of jackfruit seed flour

Treatments	Swelling power (gg^{-1})			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	4.24	4.15	4.33	4.24^b
S_2 (VPR)	5.26	5.24	5.24	5.25^a
S_3 (VPC+MR)	2.46	2.43	2.43	2.44^d
S_4 (VPC)	2.67	2.82	2.66	2.72^c
S_5 (KPR+MR)	4.24	4.15	4.33	4.24^b
S_6 (KPR)	5.25	5.26	5.25	5.25^a
S_7 (KPC+MR)	2.58	2.85	2.81	2.75^c
S_8 (KPC)	2.68	2.62	2.70	2.67^c
Mean (M)	3.67	3.69	3.72	
SE(±m) T- 0.038	M-0.023			TXM-0.065
CD (0.05) T- 0.107	M-NS			TXM- NS

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Swelling power of jackfruit seed flour did not show any significant difference during the storage period and the interaction effects were also non- significant as depicted in Table 21. Swelling power of jackfruit seed flour differed significantly among the treatments and the highest swelling power of 5.25 g g^{-1} was recorded for Pan roasted varikka (S_2) and koozha (S_6) seed flour and the lowest swelling power of 2.44g g^{-1} was recorded for Pressure cooking + Manual removal of spermoderm of varikka (S_3) seed flour.

4.2.2.4. Bulk density (g cm^{-3})

Table 22. Effect of storage on bulk density (g cm^{-3}) of jackfruit seed flour

Treatments	Bulk density (g cm^{-3})			
	Months after storage (M)			Mean (T)
	At the time of storage	1	2	
S_1 (VPR+MR)	0.71	0.67	0.68	0.68^f
S_2 (VPR)	0.73	0.67	0.68	0.69^f
S_3 (VPC+MR)	0.75	0.74	0.75	0.75^d
S_4 (VPC)	0.82	0.81	0.82	0.82^a
S_5 (KPR+MR)	0.77	0.77	0.76	0.77^b
S_6 (KPR)	0.73	0.71	0.73	0.72^e
S_7 (KPC+MR)	0.76	0.77	0.77	0.76^c
S_8 (KPC)	0.76	0.75	0.76	0.76^c
Mean (M)	0.75	0.73	0.74	
SE(±m) T- 0.003	M-0.002			TXM-0.005
CD (0.05) T- 0.009	M-NS			TXM- NS

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

Bulk density of jackfruit seed flour did not show any significant difference during the storage period and the interaction effects were also non-significant. The highest bulk density of 0.82 g cm^{-3} was recorded for Pressure cooking of varikka seed flour (S_4) and the lowest bulk density of 0.68 g cm^{-3} was recorded for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm (S_1) which showed no significant difference with Pan roasted (S_2) varikka seed flour (Table 22).

4.2.2.5. Colour

Table 23. Effect of storage on colour of jackfruit seed flour

Attributes	Months after storage					
Colour	At the time of storage		1		2	
	Mean score	Mean rank	Mean score	Mean rank	Mean score	Mean rank
S_1 (VPR+MR)	3.4	43.35	3.4	43.35	3.4	43.35
S_2 (VPR)	1.9	11.92	1.9	11.92	1.9	11.92
S_3 (VPC+MR)	3.85	54.97	3.85	54.97	3.85	54.97
S_4 (VPC)	2.7	34.42	2.7	34.42	2.7	34.42
S_5 (KPR+MR)	3.6	49.55	3.6	49.55	3.6	49.55
S_6 (KPR)	1.85	13.97	1.85	13.97	1.85	13.97
S_7 (KPC+MR)	3.75	53.67	3.75	53.67	3.75	53.67
S_8 (KPC)	2.3	29.32	2.3	29.32	2.3	29.32
KW value	47.89					
χ^2	9.49					

White-5, Cream- 4, Creamish yellow- 3, Creamish brown- 2, Brown- 1

V- Varikka K- Koozha

PR- Pan Roasting MR- Manual Removal

PC- Pressure Cooking

The colour score for jackfruit seed flour obtained through different processing methods did not show any changes during the storage period of two months (Table 23). The treatments, Pan roasting + Manual removal of spermoderm (S_1), Pressure cooking + Manual removal of spermoderm (S_3) of varikka seed flour, Pan roasting + Manual removal of spermoderm (S_5) and Pressure cooking + Manual removal of spermoderm (S_7) of koozha seed flour obtained a mean score of 3.4, 3.85, 3.6 and 3.75 respectively which is creamish yellow to cream in colour.

4.2.2.6. Microbial analysis

The jackfruit seed flour obtained through different processing methods were analysed for bacteria and fungi during the storage period of two months. No microbial load was detected during the storage period.

Discussion

5. DISCUSSION

The results obtained from the investigation on "Standardisation of processing methods for production of jackfruit seed flour with functional properties" are discussed in this chapter under the following headings.

1. Effect of processing methods on jackfruit seed flour quality
2. Storage stability studies of jackfruit seed flour

5.1. EFFECT OF PROCESSING METHODS ON JACKFRUIT SEED FLOUR QUALITY

The jackfruit seeds extracted from ripe jackfruits (varikka and koozha types) were washed thoroughly with clean water and were subjected to different processing treatments *viz*., roasting, pressure cooking, lye peeling, and oven drying with and without spermoderm. The jackfruit seeds after the treatments were finally dried in hot air oven at 60^0C and milled to get fine flour. Biochemical, functional and physical qualities of jackfruit seed flour were analysed and observed that flour qualities were influenced by different processing methods.

5.1.1. Biochemical qualities of jackfruit seed flour

Jackfruit seed flour obtained through different processing methods were analysed for moisture content (%), protein (%), crude fat (%), crude fibre (%), total ash (%) and vitamin C (mg $100g^{-1}$), starch (%), Total Soluble Solids ($^{\circ}$Brix), acidity (%), total sugar (%), reducing sugar (%), carotenoids (μg $100g^{-1}$), and antioxidant activity (%).

The moisture content of jackfruit seed flour ranged from 6.15% to 10.59% and was influenced by the processing methods. The highest moisture content (10.59%) was recorded for the treatment Pressure cooking of varikka and koozha, Pan roasting + Lye peeling of varikka and Pressure cooking+ Lye peeling of koozha. The lowest moisture content of 6.15% was observed for Pan roasting + Manual removal of spermoderm for koozha seeds. The pressure cooking and lye peeling treatments increased the moisture content of both varikka and koozha seed flour. The results are in accordance with the findings of Borgis *et al*. (2018) who reported that lower moisture content in jackfruit seed flour was obtained through processing methods of baking, pan roasting and microwave roasting of seeds. Sultana *et al*. (2015) reported that jackfruit seed flour with spermoderm contain a moisture content of 8.1% and seed flour without spermoderm contain 9.1% moisture. A higher moisture content of 11.84% was reported in pressure cooked jackfruit seeds whereas pan roasted seeds possessed lower moisture content of 9.72% which might be due to the removal of moisture and volatile compounds during roasting process (Borgis and Bharati, 2020).

In the present study, the protein content of jackfruit seed flour ranged from 11.76% to 21.13% (Fig. 1) and the highest protein content (21.13%) was recorded for Pan roasted varikka and koozha seed flour. The lowest protein content (11.76%) was observed for Pressure cooking+ Manual removal of spermoderm as well as pressure cooking method for koozha seed flour. Pan roasting of jackfruit seeds significantly increased the protein content of varikka and koozha seed flour. These results are in line with the findings of Ejiofor *et al.* (2014), who recorded a protein content of 12.25% to 16.80% for jackfruit seed flour obtained through different methods of processing of which roasted jackfruit seed flour had the highest protein content (16.80%) whereas, autoclaved jackfruit seed flour recorded the lowest protein content (12.25%). Islam *et al.* (2015) reported that seed flour obtained from lye peeled jackfruit seeds from Bangladesh had a protein content of 5.78% and is used for the preparation of biscuits. Thermally processed jackfruit seed flour recorded the highest protein content due to denaturation of protein followed by protein aggregation (Zuwariah *et al*., 2018) and Borgis and Bharati (2020) stated that increase in protein content in pan roasting might be due to the release of bound nitrogen as compared to raw seeds.

The fat content of jackfruit seed flour ranged from 0.24% to 0.76% and was influenced by the processing methods. The highest fat content (0.76%) was reported for Lye peeled varikka and koozha jackfruit seeds and the lowest fat content (0.24%) was observed for the treatment Pressure cooking + Manual removal of spermoderm of varikka and koozha seed flour. The ability to absorb oil is a critical feature in food formulations because fat enhances the flavour and mouth feel of foods, also high oil absorption suggest that protein subunits have hydrophobic characteristics (Kinsella,

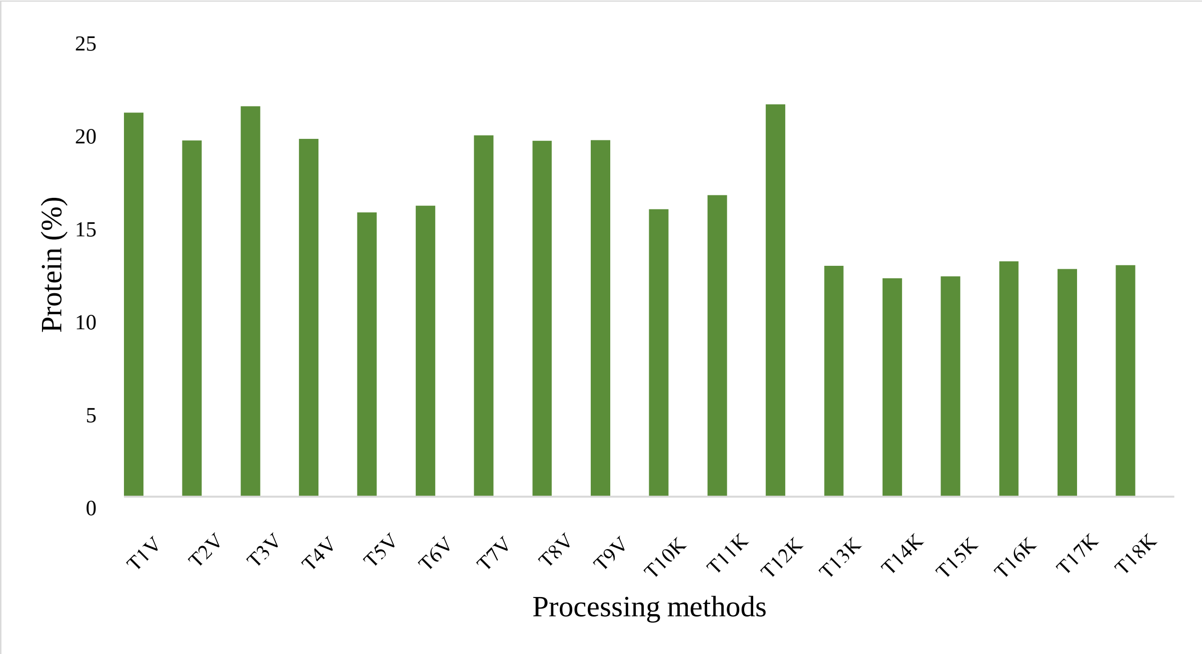


Fig 1. Protein content (%) of jackfruit seed flour obtained from different processing methods

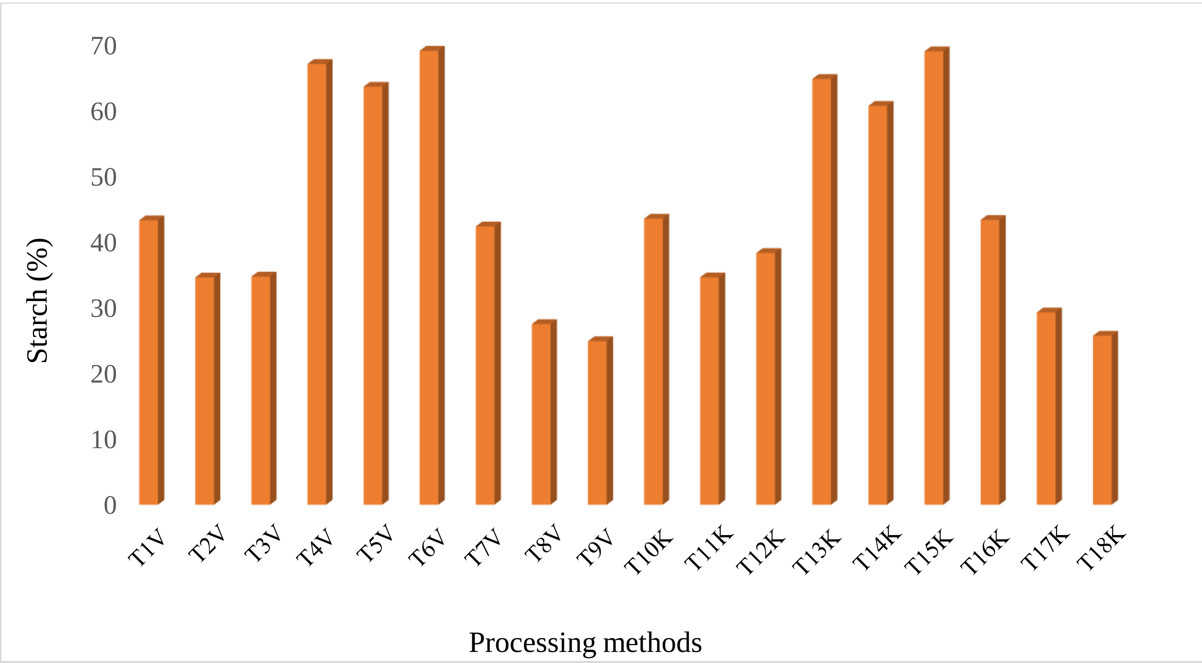


Fig 2. Starch content (%) of jackfruit seed flour obtained from different processing methods

1976). Okafor *et al*. (2015) stated that, the loss of fat in wet processed seeds can be attributed to the evaporation of volatile fatty acids and the leaching out of oil during the processing. Borgis and Bharati (2020) also reported that boiling and pressure cooking reduced fat content considerably, however baked, microwave roasted, and pan roasted seed flour did not differ significantly.

The crude fibre content of jackfruit seed flour ranged from 1.54% to 3.93% and was influenced by the processing methods. The highest crude fibre (3.93%) was recorded for Pressure cooking and Pressure cooking + manual removal of spermoderm methods for varikka and koozha seed flour and the lowest crude fibre (1.54%) was recorded for lye peeled varikka as well as koozha seed flour. This result is similar to the findings of Ejiofor *et al*. (2014) who reported the highest crude fibre in jackfruit seed flour was obtained through autoclaving and the present result is in conformity with Borgis and Bharati (2020). Zuwariah *et al*. (2018) stated that, the filtration of insoluble dietary fibre to concentrate the protein content resulted in a loss of dietary fibre in thermally processed jackfruit seed flour. Pandey (2005) reported a crude fibre content of 1.40% for varikka as well as koozha seeds.

The highest ash content (3.45%) was observed for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm whereas, the lowest ash content (1.55%) was recorded for the varikka and koozha seed flour obtained through Pressure cooking and Pressure cooking + Lye peeling methods. Pressure cooking of both varikka and koozha seed flour recorded the lowest ash content which is comparable with the findings of Borgis and Bharati, (2020) who reported a lower ash content of 2.93% for pressure cooked seed flour. This might be due to the leaching of soluble minerals like calcium chloride, sodium chloride, and potassium chloride during pressure cooking as reported by Okafor *et al*. (2015).

Vitamin C content of jackfruit seed flour ranged from 18.32 mg $100g^{-1}$ to 22.32 mg $100g^{-1}$ and was influenced by the processing methods. The highest vitamin C content of 22.32 mg $100g^{-1}$ was observed for oven drying with spermoderm of varikka as well as koozha seed flour and the lowest vitamin C content of 18.32 mg $100g^{-1}$ was observed for the treatments, Pan roasting+ Lye peeling of varikka and koozha and also for Pan roasted varikka seed flour. The processing method at higher temperature recorded lower vitamin C in jackfruit seed flour as vitamin C loss increases with temperature. Zuwariah *et al*. (2018) reported that germinated jackfruit seed flour had the highest vitamin C (78.78 mg100 g^{-1}) , followed by raw jackfruit seed flour (31.98 mg 100 g^{-1}) and thermal jackfruit seed flour recorded the lowest vitamin C content of 21.71 mg 100 g^{-1}.

The starch content of jackfruit seed flour was observed highest for the treatment Pressure cooked varikka (69.07%) as well as koozha seed flour (Fig. 2) The lowest starch content was recorded for the treatment Oven drying with spermoderm of varikka (24.88%) and koozha seed flour. The processing method of pressure cooking increased the starch content in both varikka and koozha seed flour and the results are in accordance with the findings of Ejiofor *et al.* (2014) who reported a higher starch content for autoclaved jackfruit seed flour (36.03%) and lowest starch content for dried jackfruit seed flour (26.55%). They also stated that starch content in jackfruit seed flour might vary with variety, maturity period, regional differences and processing methods used for flour preparation. Thermal treatment of jackfruit seeds increased the solubility of seed flour which indicated that the starch had been removed by the gelatinization process (Zuwariah *et al*., 2018). Kushwaha *et al*. (2020) also reported that starch content of jackfruit seeds vary with varieties and it increased with fruit maturity.

Total Soluble Solids is an important factor with respect to quality of food products (Morshed *et al*., 2019). The highest TSS content (3.03ºBrix) was observed for the treatment Oven drying with spermoderm for varikka and koozha seed flour and the lowest Total Soluble Solid (1.43%) was observed for the treatments Pressure cooking + Manual removal of spermoderm, Pan roasting+ Lye peeling, Lye peeling of varikka and koozha seed flour.

Titrable acidity of jackfruit seed flour processed through different methods ranged from 0.19% to 0.34%. The highest acidity (0.34%) was recorded for the treatments Pressure cooking + Manual removal of spermoderm, Manual removal of spermoderm+ oven drying, Oven drying with spermoderm and Pan roasting for koozha seed flour and the lowest acidity (0.19%) was observed for the treatments Pan roasting + Lye peeling, Pressure cooking+ Lye peeling and Lye peeling of varikka and koozha seed flour. In the present study, processing methods which include lye peeling step, recorded the lowest titratable acidity of jackfruit seed flour. Varikka seeds recorded an acidity of 0.03% whereas, koozha seeds had an acidity of 0.08% as reported by Pandey (2005). However, Airani, (2007) reported an acidity of 5.78% and Morshed *et al*. (2019) reported an acidity of 0.08% in jackfruit seed flour. The highest total sugar (5.59%) was observed for varikka and koozha seed flour obtained through pan roasting and the lowest total sugar (0.57%) was recorded for Pressure cooking of varikka and koozha seed flour. The results are in conformation with the findings of Ejiofor *et al.* (2014) who reported the highest sugar content of 2.48% for roasted jackfruit seed flour and lowest sugar content of 0.50% was recorded for autoclaved jackfruit seed flour.

The highest reducing sugar (0.92%) was observed for pan roasted varikka and koozha seed flour and the lowest reducing sugar (0.15%) was recorded for varikka and koozha seed flour obtained through Pressure cooking+ Lye peeling. The wet processing methods reduced the reducing sugar content in jackfruit seed flour. Leite *et al*. (2020) reported a reducing sugar of 1.85% in jackfruit seed flour.

Carotenoid content of jackfruit seed flour ranged from 1.30 to 5.64 µg $100g^{-1}$. The highest carotenoid content (5.64 µg $100g^{-1}$) was reported for the treatment Oven drying with spermoderm of varikka and koozha seed flour and the lowest carotenoid content (1.30 µg $100g^{-1}$) was observed for the treatments Pressure cooking + Lye peeling and Pan roasting + Lye peeling of varikka and koozha seed flour. Pandey (2005) reported a higher beta carotene for koozha bulbs as compared to varikka and the pulp of jackfruit is cream in colour due to the presence of carotenoids (Faria *et al*., 2009).

The processing methods for jackfruit seed flour influenced the antioxidant activity and it ranged from 63.50% to 77.77%. The highest antioxidant activity (77.77%) was reported for the treatments Pan roasting+ Manual removal of spermoderm for varikka and koozha seed flour and the lowest antioxidant activity (63.50%) was reported for the treatments Pressure cooking and Oven drying with spermoderm of varikka and koozha seed flour. The antioxidant activity of jackfruit seed flour ranged from 7.00 to 53.78% as reported by Kushwaha *et al*. (2020), and it was affected by the maturity stage of jackfruit. However, Sivaranjini *et al.* (2020)

reported an antioxidant activity of 14 mg g^{-1} in jackfruit seed flour and the variation was observed with variety and maturity.

5.1.2. Functional qualities of jackfruit seed flour

The physical behaviour of foods or their constituents during preparation, processing and storage is also influenced by their functional characteristics (Chowdhury *et al*., 2012). The functional qualities *viz.*, water absorption capacity (mL $100g^{-1}$), oil absorption capacity (mL $100g^{-1}$) and swelling power (g g^{-1}) were analysed for the jackfruit seed flour.

Water absorption capacity of jackfruit seed flour ranged from 125 mL $100g^{-1}$ to 180 mL $100g^{-1}$ (Fig. 3). The highest water absorption capacity of 180 mL $100g^{-1}$ was recorded for the treatments Pan roasting+ Manual removal of spermoderm and Pan roasting of varikka and koozha seed flour, and the lowest water absorption capacity was observed for Pressure cooking of varikka as well as koozha seed flour. The results are in accordance with the findings of Ejiofor *et al*. (2014) who reported the highest water absorption capacity for roasted jackfruit seed flour. Jackfruit seed flour with higher water absorption capacity is useful for baking industries which is important in viscosity and bulking quality of the products (Kushwaha *et al*., 2020).

Oil absorption capacity of jackfruit seed flour ranged from 62.33 mL $100g^{-1}$ to 96.67 mL$100g^{-1}$. The highest oil absorption capacity (96.67 mL $100g^{-1}$) was recorded for Oven drying with spermoderm and Manual removal + Oven drying of varikka and koozha seed flour and the lowest oil absorption capacity (62.33 mL $100g^{-1}$) was observed for the treatments Pan roasting + Manual removal of spermoderm, Pan roasting + Lye peeling and Pan roasting of varikka and koozha seed flour. Similar findings was observed by Ejiofor *et al*. (2014) who reported the highest oil absorption capacity for dried jackfruit seed flour whereas roasted jackfruit seed flour had lowest oil absorption capacity. Lye peeled jackfruit seed flour recorded an oil absorption capacity of 86 mL $100g^{-1}$ as reported by Islam *et al.* (2015). Kushwaha *et al*. (2020) reported an oil absorption capacity of jackfruit seed flour which ranged between 67.91 and 102.42%.

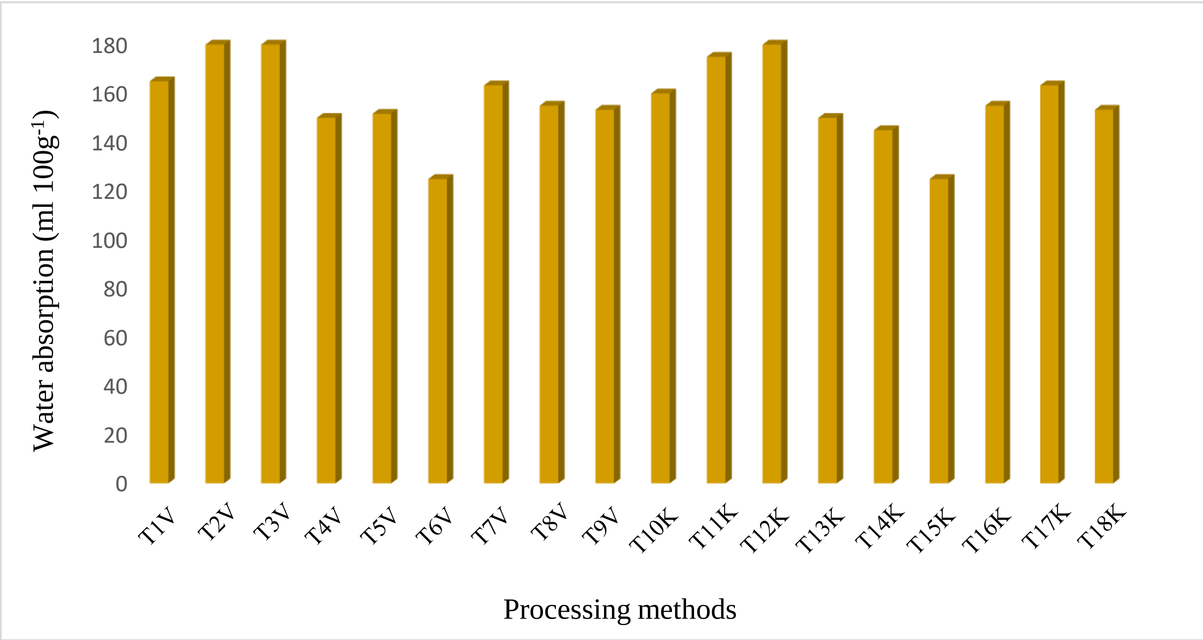


Fig 3. Water absorption capacity (ml $100g^{-1}$) of jackfruit seed flour obtained from different processing methods

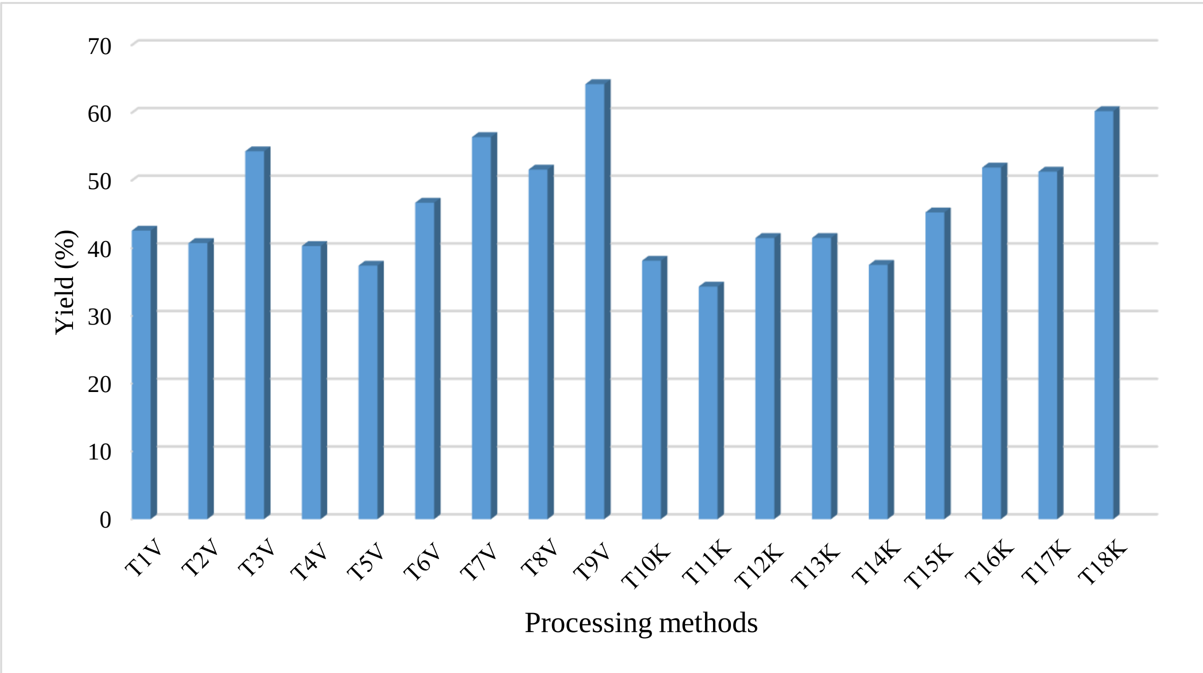


Fig 4. Yield (%) of jackfruit seed flour obtained from different processing methods

Swelling power of jackfruit seed flour ranged from 2.46 g g^{-1} to 5.44 g g^{-1} and the highest swelling power (5.44 g g^{-1}) was recorded for koozha and varikka seed flour obtained through Oven drying with spermoderm and the lowest swelling power (2.46 g g^{-1}) was observed for Pressure cooking + Manual removal of spermoderm and Pressure cooking of varikka and koozha seed flour. This results are in accordance with the findings of Ejiofor *et al*. (2014) who reported the highest swelling power (8.41%) for dried jackfruit seed flour, and autoclaved jackfruit seed flour had the lowest swelling power of 6.58%. A swelling power of 3.62 g g^{-1} was recorded for jackfruit seed flour obtained through lye peeling as reported by Butool and Butool (2013) whereas Islam *et al*. (2015) reported a swelling power of 1.46 g g^{-1} for lye peeled jackfruit seed flour.

5.1.3. Physical qualities of jackfruit seed flour

Physical property is characteristic of a substance that can be observed or measured without changing the identity of the substance and it determines the quality of flour and the subsequent product obtained from the flour. The physical qualities were analysed *viz*., yield (%), bulk density (g cm^{-3}), tapped density (g cm^{-3}), hausner factor and carr index (%).

Yield of jackfruit seed flour from different processing methods of jackfruit seeds ranged from 37.42% to 64.24% (Fig. 4) The highest yield (64.24%) was recorded for varikka and koozha seed flour obtained through Oven drying with spermoderm and the lowest yield (37.42%) was recorded for varikka and koozha seed flour obtained through Pressure cooking + Manual removal of spermoderm. Airani (2007) reported a yield of 46% for heat processed jackfruit seed flour and for mechanical processing it was 43% and jackfruit seed flour obtained by manual removal of spermoderm reported a yield of 48.25% (Hossain *et al*., 2014). Borgis and Bharati (2020) stated that jackfruit seed flour obtained through moist processing recorded lower yield because of the removal of spermoderm or leaching of solids along with water soluble components whereas, ovendried seed flour recorded higher flour yield.

The bulk density of flour is a measurement of its weight and is crucial for identifying packaging needs, material handling and application in food industry (Ocloo *et al*., 2010).

Bulk density of jackfruit seed flour ranged from 0.70 g cm^{-3} to 0.82 g cm^{-3} and the highest bulk density of 0.82 g cm^{-3} was recorded for varikka seed flour obtained through Pressure cooking and the lowest bulk densitywas observed for Manual removal of spermoderm + Oven drying of koozha seed flour and Pan roasting of varikka as well as koozha seed flour. Bulk density of jackfruit seed flour was reduced by 11.5% as a result of heat processing and it indicated the heaviness of flour and is important in deciding handling of materials and packaging requirements (Odoemelam, 2005). Results of the present study are comparable with the findings of Ejiofor *et al*. (2014) who reported the highest bulk density (0.30 g cm^{-3}) for autoclaved jackfruit seed flour.

Tapped density of jackfruit seed flour ranged from 0.84 g cm^{-3} to 0.98 g cm^{-3} and the highest tapped density was recorded for Pressure cooked varikka seed flour whereas, the lowest tapped density was recorded for Oven drying with spermoderm of koozha seed flour. Tapped density decreased with increase in drying temperature as reported by Leite *et al*. (2020).

Hausner factor indicates the flowability of flour and a value smaller than 1.25 indicate good flow whereas greater than 1.50 denote poor flowability of the flour (Leite *et al*., 2020). The highest Hausner factor (1.23) was recorded for Pan roasting, Pressure cooking + Manual removal of spermoderm and Pan roasting + Lye peeling of varikka and koozha seed flour and the lowest Hausner factor was recorded for Oven drying with spermoderm of varikka seed flour, Pressure cooking + Lye peeling, Lye peeling for varikka and koozha seed flour. Hausner factor of jackfruit seed flour obtained through different processing methods in the present study ranged from 1.16 to 1.23 indicating that all flour had a good flowability. Leite *et al.* (2020) reported a Hausner factor of 1.049 to 1.049 in thermally processed jackfruit seed flour as compared to other processing methods.

Carr index indicates the compressibility of the flour and the value between 15 to 20% denotes good flowability whereas 20 to 35% indicate poor flowability (Santhalakshmy *et al*., 2015). The processing methods for jackfruit seed flour influenced the carr index and it ranged from 13.82 to 19.26 with no significant difference among the treatments. The result is in conformation with the findings of

Leite *et al*. (2020) who reported that carr index of jackfruit seed flour was not influenced by the processing temperature.

The colour of jackfruit seed flour plays an important role in its usage in food products as it affects the colour and acceptance of the final food product. Jackfruit seed flour processed through Lye peeling of varikka obtained a mean score of 4.1 which is creamish white in colour whereas pan roasting of varikka and koozha obtained a mean score of 1.9 and 1.85 respectively which is brownish cream colour. Lye peeled seed flour recorded more whitish colour flour and the flour with spermoderm yield brownish colour seed flour. Mukprasirt and Sajjaanantakul (2004) reported that jackfruit seed flour obtained through wet milling had a lighter colour when compared to dry milled jackfruit seed flour and the difference in colour might be due to the washing out of pigments in wet processing. The colour of jackfruit seed flour was influenced by the method of processing and roasted jackfruit seed flour scored less value (74.76%) for colour score than the dried jackfruit seed flour has the highest value (82.59%) which is pure white in colour (Ejiofor *et al*., 2014).

5.2. STORAGE STABILITY STUDIES OF JACKFRUIT SEED FLOUR

The shelf life quality of any food ingredient is significant since it affects the suitability for product development and shelf life studies can provide valuable information to product developers, allowing them to ensure high quality product to consumers with safety. Based on biochemical, functional and physical qualities, jackfruit seed flour obtained from varikka and koozha types (with and without spermoderm) having superior quality were selected for the storage stability studies for two months. The selected jackfruit seed flour obtained from Pan roasting and Pressure cooking with spermoderm and Manual removal of spermoderm for varikka and koozha types were packed in polypropylene and stored under room temperature for storage stability analyse of biochemical, functional, physical and microbial qualities.

Biochemical qualities *viz* ., protein, crude fat, crude fibre, total ash, starch, Total Soluble Solids, total sugar, reducing sugar, carotenoids, antioxidant activity and peroxide value of jackfruit seed flour did not show any significant difference during the storage period. But it differed depending on the type of processing methods used.

5.2.1. Biochemical qualities of jackfruit seed flour

At the time of storage, the moisture content was 9.28% and increased to 9.30% and 9.46% respectively after first and second month of storage (Fig. 5). The highest moisture content (10.64%) was observed for varikka seed flour obtained through Pressure cooking and the lowest moisture content (6.29%) was observed for koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm. During storage of jackfruit seed flour, moisture content slightly increased from 9.28% to 9.46% and Airani (2007) also recorded an increase in moisture content from 7.16% to 11.03% at 6 months of storage. The moisture content of jackfruit seed flour increased from 8.1% to 9.35% under room temperature and to 8.57% under refrigerated condition as reported by Sultana *et al*. (2015) during a storage period of 3 months. Similar result was observed by Saha *et al.* (2016) who reported that moisture content of jackfruit seed flour increased with the advancement of storage period. The results are in accordance with the findings of Borgis *et al*. (2018) who reported a higher moisture content for jackfruit seed flour obtained through pressure cooking.

Protein content of jackfruit seed flour did not show any significant difference during the storage period and the highest protein content (21.16%) was observed for Pan roasted varikka and koozha seed flour and the lowest protein content of 11.75% was observed for koozha seed flour obtained through Pressure cooking +Manual removal of spermoderm and Pressure cooking. The crude protein content of jackfruit seed flour decreased during the storage period of 180 days and the decrease in protein might be due to the structural changes that inhibited the amino acid solubility and proteolysis (Baruah, 2014). Morshed *et al*. (2019) observed a slight reduction in protein content of jackfruit seed flour as the storage period advanced which was 12.57% at the time of storage and decreased to 12.52% after 336 days of storage.

Fat content of jackfruit seed flour did not show any significant difference during a storage period of two months. The highest fat content (0.44%) was recorded for varikka and koozha seed flour obtained through Pan roasting and the lowest fat content (0.24%) was recorded for Pressure cooking + Manual removal of spermoderm of varikka and koozha seed flour. Baruah (2014) stated that a decline in crude fat in

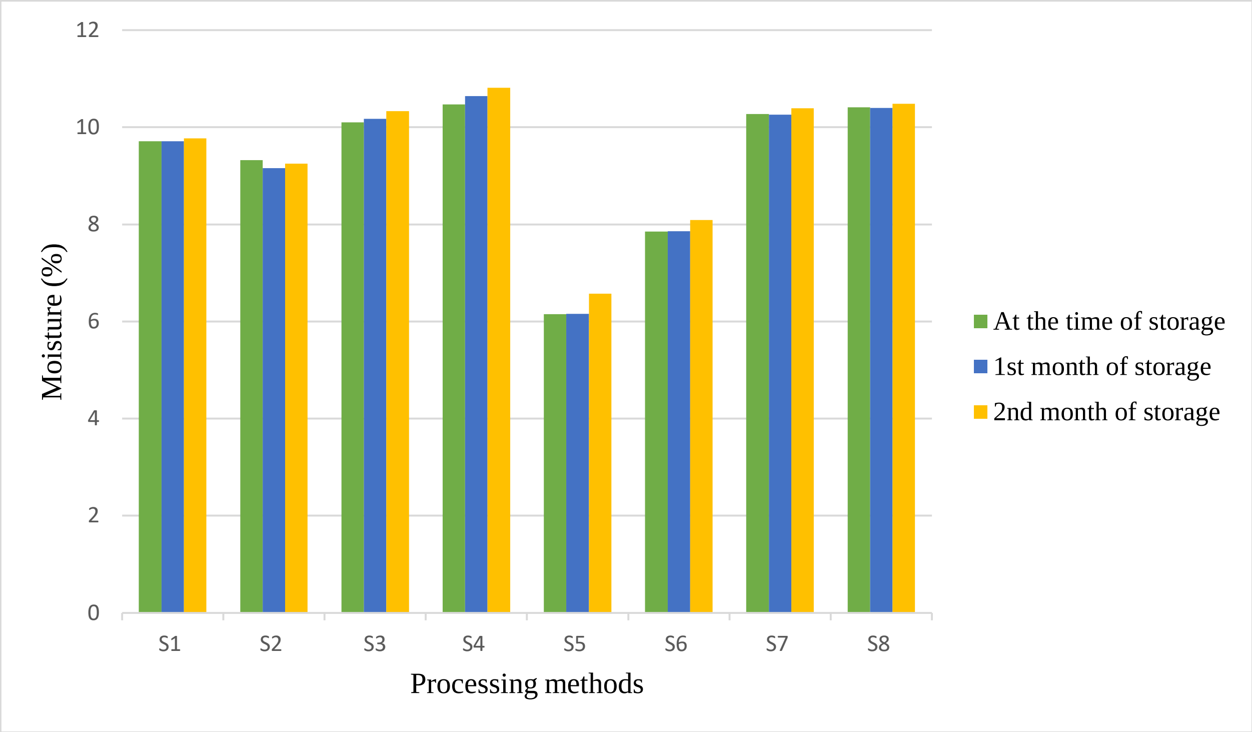


Fig 5. Effect of storage on moisture content (%) of jackfruit seed flour

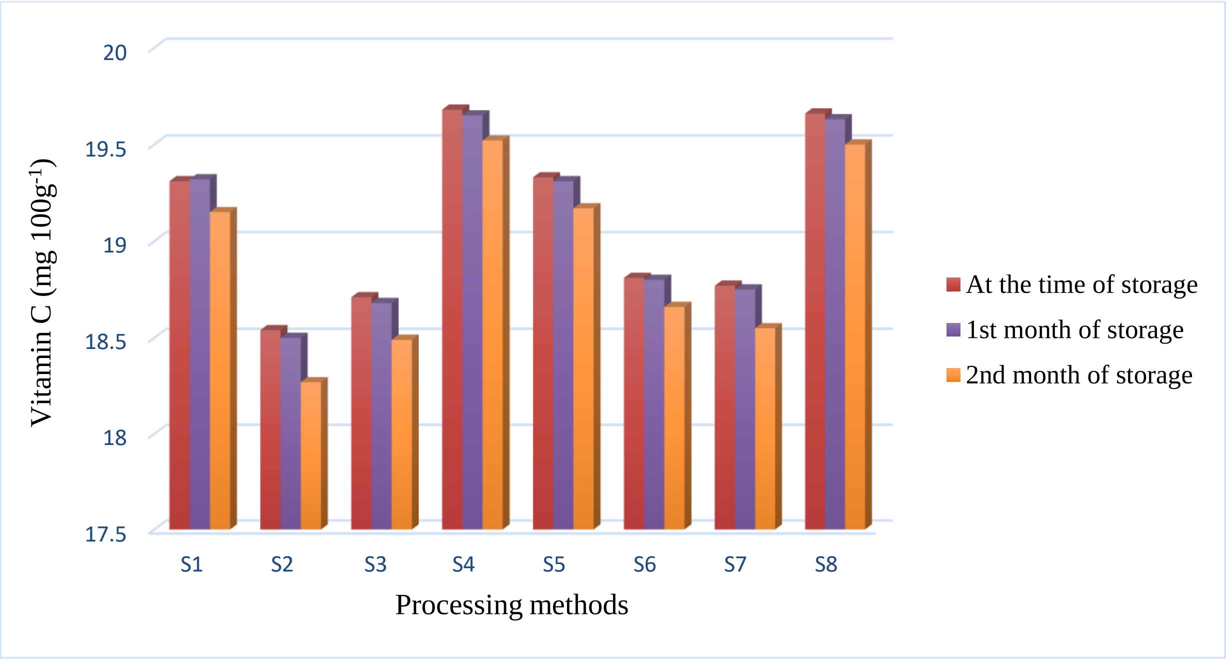


Fig 6. Effect of storage on vitamin C (mg $100g^{-1}$) of jackfruit seed flour

jackfruit seed flour was observed from the 30th day to 180 days of storage and might be due to lipolytic activity of lipase and lipoxidase enzymes. Similar findings was observed by Saha *et al*. (2016) who reported that jackfruit seed flour did not show any changes in fat content during a storage period of 4 months.

The jackfruit seed flour did not show any significant difference in crude fibre content on storage. The highest fibre content of 3.95% was observed for Pressure cooked varikka and koozha seed flour and the lowest fibre content was observed for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm. The crude fibre content of jackfruit seed flour decreased slightly with the advancement of storage period of 180 days as reported by Baruah (2014) and Saha *et al.* (2016) reported that fibre content of jackfruit seed flour did not show any significant changes during the storage period of 4 months.

The highest ash content (3.43%) was recorded for varikka seed flour obtained through Pan roasting+ Manual removal of spermoderm and the lowest ash content (1.53%) was recorded for Pressure cooked varikka seed flour. Total ash content of jackfruit seed flour did not show any significant difference on storage treatments. The ash content of jackfruit seed flour do not showed any significant difference during the storage period of 180 days (Baruah, 2014). The result is in conformity with finding of Saha *et al*. (2016) who reported that there was no significant changes for ash content of jackfruit seed flour during a storage period of 4 months. Morshed *et al*. (2019) reported that there was a slight decrease in ash content of jackfruit seed flour during a storage period of 336 days.

Vitamin C content of jackfruit seed flour decreased on storage and it was 19.10 mg 100g^{-1} and did not show significant difference after first month of storage which decreased to 18.91 mg 100g^{-1} after the second month of storage (Fig. 6). Among the treatments, the highest Vitamin C content (19.10 mg 100g^{-1}) was reported for Pressure cooked varikka and koozha seed flour and the lowest Vitamin C content (18.91 mg 100g^{-1}) was reported for varikka seed flour obtained through Pan roasting both decreased slightly during the storage. Esteve *et al*. (2005) reported that vitamin C gradually decreased with storage in orange juices. Vitamin C in jackfruit seed flour at the time of storage was 55.82 mg $100g^{-1}$ and it gradually decreased to 50.03 mg 100 g^{-1} at the end of storage period of 336 days reported by Morshed *et al*. (2019).

Jackfruit seed flour did not show any change in starch content during the storage period of two months, but it varied among the treatments. Pressure cooked varikka and koozha seed flour recorded a higher starch content (69.05%) and the lowest starch content (34.56%) was observed for varikka and koozha seed flour obtained through Pan roasting + Manual removal of spermoderm and Pan roasted varikka seed flour. Morshed *et al*. (2019) reported a slight decrease in starch content during storage from 41.63% to 41.28% after a storage period of 336 days.

Total Soluble Solid (TSS) content of jackfruit seed flour did not show any significant change during the storage period and the highest TSS content (2.31^0Brix) was recorded for Pressure cooking method of varikka and koozha seed flour and Pan roasted koozha seed flour. According to Morshed *et al*. (2019), Total Soluble Solids of jackfruit seed flour slightly increased during the storage period of 336 days.

Titrable acidity of jackfruit seed flour decreased on storage. At the time of storage, acidity was 0.29% and it decreased to 0.25% and 0.21% after first and second month of storage respectively (Fig. 7). The result is in accordance with the reports of Morshed *et al*. (2019) who observed reduction in acidity of jackfruit seed flour during storage.

Total sugar content of jackfruit seed flour did not show any significant difference during the storage period. The highest total sugar (5.56%) was observed for Pan roasting of koozha seed flour and the lowest total sugar content was observed for Pressure cooking of varikka and koozha seed flour. Decrease in total sugar content was observed higher in oven dried jackfruit seed flour as compared to heat processed jackfruit seed flour during a storage period of 180 days (Baruah, 2014). Total sugar of jackfruit seed flour decreased at the rate of 0.30% during the storage period of 336 days as reported by Morshed *et al*. (2019).

Reducing sugar of jackfruit seed flour gradually increased with storage (Fig. 8). At the time of storage, the reducing sugar was 0.45% which increased to 0.47% after the first month and 0.49% after second month of storage respectively. The highest

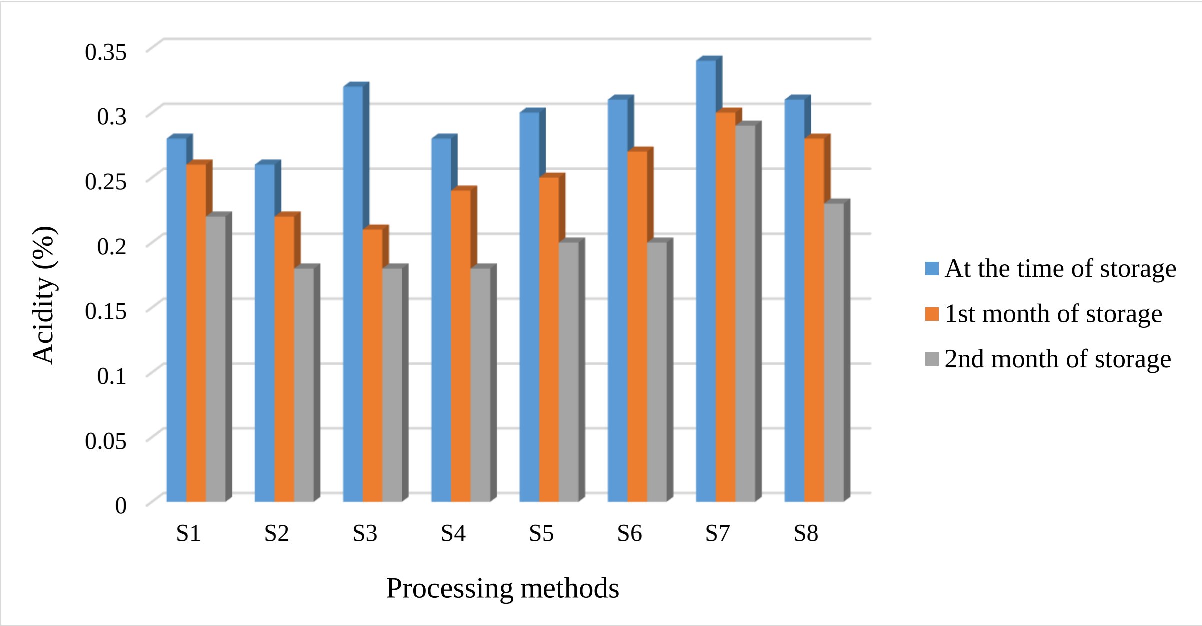


Fig 7. Effect of storage on titrable acidity (%) of jackfruit seed flour

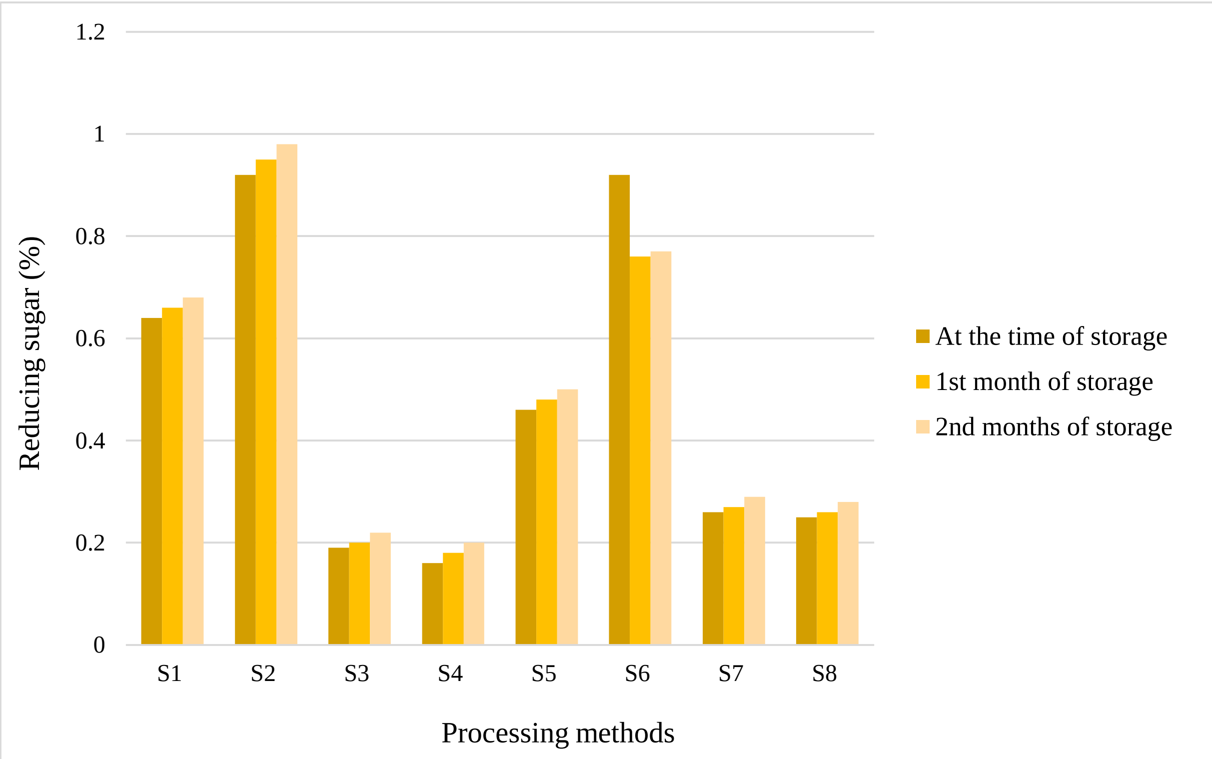


Fig 8. Effect of storage on reducing sugar (%) of jackfruit seed flour

reducing sugar (0.95%) was observed for Pan roasting of varikka seed flour and the lowest reducing sugar (0.18%) was observed for Pressure cooking and Pressure cooking + Manual removal of spermoderm of varikka seed flour. A gradual increase in reducing sugar of jackfruit seed flour was observed during the storage period of 336 days due to the acid hydrolysis of total sugar (Morshed *et al*., 2019).

Carotenoid content of jackfruit seed flour did not show any significant difference on storage. The highest carotenoid content (4.67 μg $100g^{-1}$) was reported for Pan roasting + Manual removal of spermoderm) of varikka seed flour and the lowest carotenoid content (2.22 μg $100g^{-1}$) was recorded for Pressure cooking + Manual removal of spermoderm of varikka seed flour.

Antioxidant activity of jackfruit seed flour showed no significant change during the storage period of two months. The highest antioxidant activity (77.76%) was recorded for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm and the lowest antioxidant activity (63.48%) was recorded for varikka and koozha seed flour obtained through Pressure cooking and Pan roasted koozha seed flour. An antioxidant content of 9.84 mg g^{-1} for jackfruit seeds was recorded by Kamath *et al*. (2015).

The jackfruit seed flour recorded a peroxide value of 0.013 to 0.017 meq kg^{-1} which showed no significant difference between the treatments. The peroxide value of jackfruit seed flour did not show any changes after one month of storage which increased slightly after the storage of two months in treatments with spermoderm even though the changes were negligible. Ajayi (2008) reported a peroxide value of 15 mg g^{-1} for oil extracted from jackfruit seeds. Akter *et al.* (2020) claimed that the peroxide value of cake enriched with jackfruit seed flour decreased with an increase in concentration of jackfruit seed flour.

5.2.2. Functional qualities of jackfruit seed flour

Water absorption capacity of jackfruit seed flour obtained through different processing methods did not show any significant difference during the storage period. The highest water absorption capacity (180.01 mL $100g^{1}$) was recorded for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm and Pan roasting of varikka and koozha seeds. The lowest water absorption capacity (125 mL $100g^{-1}$) was recorded for varikka and koozha seed flour obtained through Pressure cooking. In oven dried jackfruit seed flour, the water absorption capacity at the time of storage was 3.12 mL g^{-1} which decreased to 2.6 mL g^{-1} at the end of storage period of 180 days and found that heat processed jackfruit seed flour had better keeping quality in terms of water absorption capacity (Baruah, 2014).

Oil absorption capacity of jackfruit seed flour did not show significant difference during the storage period. Oil absorption capacity of jackfruit seed flour recorded the highest value (82.69 mL $100g^{-1}$) for Pressure cooked koozha seed flour and the lowest oil absorption capacity was recorded for varikka and koozha seed flour obtained through Pan roasting and Pan roasting + Manual removal of spermoderm. Baruah (2014) reported that oil absorption capacity of raw jackfruit seed flour decreased by 12.6% during storage and also heat processed jackfruit seed flour showed a higher oil absorption capacity.

Swelling power of jackfruit seed flour did not show any significant difference during the storage period. Swelling power of jackfruit seed flour differed significantly among the treatments and the highest swelling power of 5.25 g g^{-1} was recorded for Pan roasted varikka and koozha seed flour and the lowest swelling of power of 2.44 g g^{-1} was recorded for Pressure cooking + Manual removal of spermoderm of varikka seed flour. Swelling power of jackfruit seed flour reported a value of 3.62 g g^{-1} by (Airani, 2007) and 4.77 g g^{-1} reported by Ocloo *et al*. (2010).

Bulk density of jackfruit seed flour did not show any significant difference during the storage period. The highest bulk density of 0.82 g cm^{-3} was recorded for Pressure cooking of varikka seed flour and the lowest bulk density was recorded for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm and Pan roasting. According to Baruah (2014), the bulk density at the time of storage was 0.721 g mL^{-1} in oven dried jackfruit seed flour which increased during a storage period of 180 days.

Colour is an important quality aspect in processed foods, which influence the consumer acceptance. The colour score for jackfruit seed flour obtained through different processing methods did not show any changes during the storage period of two months. The treatments Pan roasting + Manual removal of spermoderm and Pressure cooking + Manual removal of spermoderm of varikka seed flour, Pan roasting + Manual removal of spermoderm and Pressure cooking + Manual removal of spermoderm of koozha seed flour obtained a mean score of 3.4, 3.85, 3.6 and 3.75 respectively which is creamish yellow to cream in colour. According to Baruah (2014), the colour of oven dried jackfruit seed flour was deteriorated during the storage period of 180 days. Borgis *et al*. (2018) stated that jackfruit seed flour did not showed any change in colour during a storage period of 180 days.

The jackfruit seed flour obtained through different processing methods were analysed for bacteria and fungi during the storage period of two months. No microbial load was detected during the storage period indicating good storage stability of jackfruit seed flour. Jackfruit seed flour obtained through higher processing temperature killed the microorganisms in the flour when compared to moist processing *ie*., bacterial and fungal count were lower in pan roasted seed flour was reported by Borgis *et al*. (2018). According to Morshed *et al*. (2019), jackfruit seed flour had a storage period of 11 months at room temperature, even though presence of microorganisms was recorded towards the end of storage period but was within a permissible limit.

Summary

6. SUMMARY

The study entitled “Standardisation of processing methods for production of jackfruit seed flour with functional properties” was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani during the period 2019-2021 with the objective of quality evaluation of jackfruit seeds of varikka and koozha types, standardisation of processing methods for jackfruit seed flour with functional properties and assessment of storage stability. The study was conducted as two continuous experiments, effect of processing methods on jackfruit seed flour quality and storage stability studies of jackfruit seed flour and are summerized below.

Jackfruit seeds were separated from fully ripened jackfruits of varikka and koozha types. The jackfruit seeds extracted from ripe jackfruits (varikka and koozha types) were washed thoroughly with clean water and were subjected to different processing treatments like Pan roasting, Pressure cooking, Lye peeling, and Oven drying. The jackfruit seeds after the treatments were finally dried in hot air oven at 60^0C and milled to get fine flour and were subjected to analysis for biochemical, functional and physical qualities.

Biochemical parameters *viz*., moisture content (%), protein (%), crude fat (%), crude fibre (%), total ash (%), vitamin C (mg $100g^{-1}$), starch (%), Total Soluble Solids (°Brix), acidity (%), total sugar (%), reducing sugar (%), carotenoids (μg 100 g^{1}) and antioxidant activity (%) were analysed for jackfruit seed flour obtained through different processing methods. The moisture content of jackfruit seed flour obtained through different processing methods ranged from 6.15% to 10.59%. The highest moisture content (10.59%) was recorded for the treatment Pressure cooking of varikka and koozha, Pan roasting + Lye peeling of varikka and Pressure cooking+ Lye peeling of koozha. The lowest moisture content (6.15%) was observed for Pan roasting + Manual removal of spermoderm of koozha seeds. The protein content of jackfruit seed flour ranged from 11.76% to 21.13% and the highest protein content (21.13%) was recorded for Pan roasted varikka and koozha seed flour. The lowest protein content (11.76%) was observed for Pressure cooking+ Manual removal of spermoderm as well as Pressure cooking method for koozha seed flour. Pan roasting of jackfruit seeds significantly increased the protein content of varikka and koozha seed flour. The fat content of jackfruit seed flour ranged between 0.24% and 0.76% and was influenced by the processing methods. The highest fat content (0.76%) was reported for Lye peeled varikka and koozha jackfruit seeds and the lowest fat content (0.24%) was observed for the treatment Pressure cooking + Manual removal of spermoderm of varikka and koozha seed flour. The crude fibre content of jackfruit seed flour ranged from 1.54% to 3.93% and the highest crude fibre (3.93%) was recorded for Pressure cooking and Pressure cooking + Manual removal of spermoderm methods for varikka and koozha seed flour and the lowest crude fibre (1.54%) was recorded for lye peeled varikka as well as koozha seed flour. The highest ash content (3.45%) was observed for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm whereas, the lowest ash content (1.55%) was recorded for the varikka and koozha seed flour obtained through Pressure cooking and Pressure cooking + Lye peeling methods. Vitamin C content of jackfruit seed flour ranged between 18.32 mg $100g^{-1}$ and 22.32 mg $100g^{-1}$ and was influenced by the processing methods. The highest vitamin C content of 22.32 mg $100g^{-1}$ was recorded for the treatment Oven drying with spermoderm method for varikka as well as koozha seed flour and the lowest vitamin C content of 18.32 mg $100g^{-1}$ was observed for the treatments Pan roasting+ Lye peeling of varikka and koozha and also for Pan roasted varikka seed flour. The starch content of jackfruit seed flour was observed highest for the treatment Pressure cooked varikka (69.07%) as well as koozha seed flour. The lowest starch content was observed for the treatment Oven drying with spermoderm of varikka (24.88%) and koozha seed flour. The highest TSS content (3.03ºBrix) was observed for the treatment Oven drying with spermoderm of varikka and koozha seed flour and the lowest TSS (1.43%) was observed for the treatments Pressure cooking + Manual removal of spermoderm, Pan roasting+ Lye peeling, Lye peeling of varikka and koozha seed flour.

Titrable acidity of jackfruit seed flour processed through different methods ranged from 0.19% to 0.34%. The highest acidity (0.34%) was recorded for the treatments Pressure cooking + Manual removal of spermoderm, Manual removal of spermoderm + Oven drying, Oven drying with spermoderm and Pan roasting for koozha seed flour and the lowest acidity (0.19%) was observed for the treatments Pan roasting + Lye peeling, Pressure cooking+ Lye peeling and Lye peeling of varikka and koozha seed flour. The highest total sugar (5.59%) was observed for varikka and koozha seed flour obtained through Pan roasting and the lowest total sugar (0.57%) was recorded for Pressure cooking of varikka and koozha seed flour. Reducing sugar content of jackfruit seed flour ranged from 0.15% to 0.92% and the highest reducing sugar (0.92%) was observed for pan roasted varikka and koozha seed flour and the lowest reducing sugar (0.15%) was recorded for varikka and koozha seed flour obtained through Pressure cooking+ Lye peeling. Carotenoid content of jackfruit seed flour ranged between 1.30 and 5.64 µg $100g^{-1}$ and the highest carotenoid content (5.64 µg $100g^{-1}$) was reported for the treatment Oven drying with spermoderm of varikka and koozha seed flour and the lowest carotenoid content (1.30 µg $100g^{1}$) was observed for the treatments Pressure cooking + Lye peeling and Pan roasting + Lye peeling of varikka and koozha seed flour. The processing methods for jackfruit seed flour influenced the antioxidant activity and it ranged from 63.50% to 77.77%. The highest antioxidant activity (77.77%) was reported for the treatments Pan roasting+ Manual removal of spermoderm for varikka and koozha seed flour and the lowest antioxidant activity (63.50%) was reported for the treatments Pressure cooking and Oven drying with spermoderm of varikka and koozha seed flour.

Functional qualities *viz.*, water absorption capacity (mL $100g^{-1}$), oil absorption capacity (mL $100g^{-1}$) and swelling power (g g^{-1}) were analysed for jackfruit seed flour obtained through different processing methods. Water absorption capacity of jackfruit seed flour ranged between 125 mL $100g^{-1}$ and 180 mL $100g^{-1}$ and the highest water absorption capacity of 180 mL $100g^{-1}$ was recorded for the treatments Pan roasting+ Manual removal of spermoderm and Pan roasting of varikka and koozha seed flour, and the lowest water absorption capacity was observed for Pressure cooking of varikka as well as koozha seed flour. Oil absorption capacity of jackfruit seed flour ranged from 62.33 mL $100g^{-1}$ to 96.67 mL$100g^{-1}$. The highest oil absorption capacity (96.67 mL $100g^{-1}$) was recorded for Oven drying with spermoderm and Manual removal + Oven drying of varikka and koozha seed flour and the lowest oil absorption capacity (62.33 mL $100g^{-1}$) was observed for the treatments Pan roasting + Manual removal of spermoderm, Pan roasting + Lye peeling and Pan roasting of varikka and koozha seed flour. Swelling power of jackfruit seed flour ranged from 2.46 g g^{-1} to 5.44 g g^{-1} for the seed flour obtained by different methods of processing. The highest swelling power

(5.44 g g^{-1}) was recorded for koozha and varikka seed flour obtained through Oven drying with spermoderm and the lowest swelling power (2.46 g g^{-1}) was observed for Pressure cooking + Manual removal of spermoderm and Pressure cooking of varikka and koozha seed flour.

Jackfruit seed flour obtained through different processing methods were analysed for physical qualities *viz.*, yield (%), bulk density (g cm^{-3}), tapped density (g cm^{-3}), hausner factor and carr index (%).

Yield of jackfruit seed flour from different processing methods of jackfruit seeds ranged between 37.42% and 64.24% and the highest yield (64.24%) was recorded for varikka and koozha seed flour obtained through Oven drying with spermoderm and the lowest yield (37.42%) was recorded for varikka and koozha seed flour obtained through Pressure cooking + Manual removal of spermoderm. The highest bulk density of 0.82 g cm^{-3} was recorded for varikka seed flour obtained through Pressure cooking and the lowest bulk density was observed for Manual removal of spermoderm + Oven drying of koozha seed flour and Pan roasting of varikka as well as koozha seed flour. The highest tapped density was recorded for Pressure cooked varikka seed flour whereas, the lowest tapped density was recorded for Oven drying with spermoderm of koozha seed flour. The highest Hausner factor (1.23) was recorded for Pan roasting, Pressure cooking + Manual removal of spermoderm and Pan roasting + Lye peeling of varikka and koozha seed flour and the lowest Hausner factor was recorded for Oven drying with spermoderm of varikka seed flour, Pressure cooking + Lye peeling, Lye peeling for varikka and koozha seed flour. The processing methods for jackfruit seed flour did not influence the carr index and it ranged from 13.82 to 19.26 with no significant difference among the treatments. The processing methods of jackfruit seeds showed significant difference in colour of the jackfruit seed flour. Jackfruit seed flour processed through Lye peeling of varikka obtained a mean score of 4.1 which is creamish white in colour whereas Pan roasting of varikka and koozha obtained a mean score of 1.9 and 1.85 respectively which is brownish cream colour.

Based on biochemical, functional and physical qualities of jackfruit seed flour obtained from varikka and koozha types (with and without spermoderm) having superior quality were selected for the storage stability studies for two months. The selected jackfruit seed flour obtained from Pan roasting and Pressure cooking with spermoderm and Manual removal of spermoderm were packed in polypropylene and stored under room temperature and were analysed for biochemical, functional, physical and microbial qualities.

Storage stability studies revealed that biochemical parameters *viz* ., protein, crude fat, crude fibre, total ash, starch, TSS, total sugar, reducing sugar, carotenoids, antioxidant activity and peroxide value of jackfruit seed flour did not show any significant difference during the storage period of two months.

At the time of storage, the moisture content was 9.28% which increased to 9.30% and 9.46% respectively after first and second month of storage. The highest moisture content (10.64%) was observed for varikka seed flour obtained through Pressure cooking and the lowest moisture content (6.29%) was observed for koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm. Protein content of jackfruit seed flour did not show any significant difference during the storage period and the highest protein content (21.16%) was observed for Pan roasted varikka and koozha seed flour and the lowest protein content of 11.75% was observed for koozha seed flour obtained through Pressure cooking +Manual removal of spermoderm and Pressure cooking. Fat content of jackfruit seed flour did not show any significant change during the storage period of two months. The highest fat content (0.44%) was recorded for varikka and koozha seed flour obtained through Pan roasting and the lowest fat content (0.24%) was recorded for Pressure cooking + Manual removal of spermoderm of varikka and koozha seed flour. The jackfruit seed flour did not show any significant difference in crude fibre content on storage. The highest fibre content of 3.95% was observed for Pressure cooked varikka and koozha seed flour and the lowest fibre content was observed for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm. The highest ash content (3.43%) was recorded for varikka seed flour obtained through Pan roasting+ Manual removal of spermoderm and the lowest ash content (1.53%) was recorded for Pressure cooked varikka seed flour. No change in total ash content was recorded for the treatments during the storage. Vitamin C content of jackfruit seed flour decreased on storage and it was 19.10 mg $100g^{-1}$ and did not show significant difference after first month of storage which decreased to 18.91 mg $100g^{-1}$ after the second month of storage. Among the treatments, the highest Vitamin C content (19.10 mg $100g^{-1}$) was reported for Pressure cooked varikka and koozha seed flour and the lowest Vitamin C content (18.91 mg $100g^{-1}$) was reported for varikka seed flour obtained through Pan roasting both decreased slightly during the storage. Jackfruit seed flour did not show any change in starch content during the storage period of two months. Pressure cooked varikka and koozha seed flour recorded a higher starch content (69.05%) and the lowest starch content (34.56%) was observed for varikka and koozha seed flour obtained through Pan roasting + Manual removal of spermoderm and Pan roasted varikka seed flour.

Total Soluble Solid (TSS) content of jackfruit seed flour did not show any significant change during the storage period and the highest TSS content (2.31^0Brix) was recorded for Pressure cooking method for varikka and koozha seed flour and Pan roasted koozha seed flour. Titrable acidity of jackfruit seed flour decreased on storage. At the time of storage, acidity was 0.29% and decreased to 0.25% and 0.21% after first and second month of storage respectively. Total sugar content of jackfruit seed flour did not show any significant difference during the storage period. The highest total sugar (5.56%) was observed for Pan roasting of koozha seed flour and the lowest total sugar content was observed for Pressure cooking of varikka and koozha seed flour. Reducing sugar of jackfruit seed flour gradually increased with storage. At the time of storage, the reducing sugar was 0.45% which increased to 0.47% after the first month and 0.49% after second month of storage respectively. The highest reducing sugar (0.95%) was observed for Pan roasting of varikka seed flour and the lowest reducing sugar (0.18%) was observed for Pressure cooking and Pressure cooking + Manual removal of spermoderm of varikka seed flour.

Antioxidant activity of jackfruit seed flour showed no significant change during the storage period of two months. The highest antioxidant activity (77.76%) was recorded for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm and the lowest antioxidant activity (63.48%) was recorded for varikka and koozha seed flour obtained through Pressure cooking and Pan roasted koozha seed flour. The jackfruit seed flour recorded a peroxide value of 0.013 to 0.017 meq kg^{-1} which showed no significant difference between the treatments. The peroxide value of jackfruit seed flour did not show any changes after one month of storage which increased slightly after the storage of two months in treatments with spermoderm even though the changes were negligible.

Water absorption capacity of jackfruit seed flour obtained through different processing methods did not show any significant difference during the storage period. The highest water absorption capacity (180.01 mL $100g^{1}$) was recorded for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm and Pan roasting of varikka and koozha. The lowest water absorption capacity (125 mL $100g^{1}$) was recorded for varikka and koozha seed flour obtained through Pressure cooking. Oil absorption capacity of jackfruit seed flour did not show significant difference during the storage period with the highest value (82.69 mL $100g^{-1}$) for Pressure cooked koozha seed flour and the lowest for varikka and koozha seed flour obtained through Pan roasting and Pan roasting + Manual removal of spermoderm. Swelling power of jackfruit seed flour did not show any significant difference during the storage period. Bulk density of jackfruit seed flour did not show any significant difference during the storage period. The highest bulk density of 0.82 g cm^{-3} was recorded for Pressure cooking of varikka seed flour and the lowest bulk density was recorded for varikka seed flour obtained through Pan roasting + Manual removal of spermoderm and Pan roasting. The colour score for jackfruit seed flour obtained through different processing methods did not show any changes during the storage period of two months. Jackfruit seed flour processed through Pan roasting + Manual removal of spermoderm and Pressure cooking + Manual removal of spermoderm of varikka seed flour, Pan roasting + Manual removal of spermoderm and Pressure cooking + Manual removal of spermoderm of koozha seed flour were creamish yellow to cream in colour. The jackfruit seed flour obtained through different processing methods were analysed for bacteria and fungi during the storage period of two months. No microbial load was detected during the storage period indicating good storage stability of jackfruit seed flour.

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Appendix

APPENDIX-1

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Post Harvest Technology

Title: Standardisation of processing methods for production of jackfruit seed flour with functional properties

Score card for assessing the colour of jackfruit seed flour obtained through different processing methods

Instructions: You are given 18 samples of jackfruit seed flour. Evaluate them and give scores for each criteria

Criteria	Scores																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Colour																		

Scores

White	5
Cream	4
Creamish yellow	3
Creamish brown	2
Brown	1

Date:

Name:

Signature:

STANDARDISATION OF PROCESSING METHODS FOR PRODUCTION OF JACKFRUIT SEED FLOUR WITH FUNCTIONAL PROPERTIES

by

SREELEKSHMI S. KUMAR

(2019-12-049)

Abstract of the thesis
Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY
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2021

ABSTRACT

The present study entitled “Standardisation of processing methods for production of jackfruit seed flour with functional properties” was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani during the period 2019-2021 with the objective of quality evaluation of jackfruit seeds of varikka and koozha types, standardisation of processing methods for jackfruit seed flour with functional properties and assessment of storage stability.

Jackfruit seeds of varikka and koozha types were subjected to different processing methods viz., Pan roasting, Pressure cooking, Lye peeling and Oven drying for the development of jackfruit seed flour. The jackfruit seed flour obtained through different processing methods were subjected to analyses for biochemical, functional and physical qualities.

The processing methods for jackfruit seed flour influenced the biochemical, physical and functional qualities of the seed flour. The moisture content of jackfruit seed flour ranged from 6.15% to 10.59% and the highest moisture content of 10.59% was observed for jackfruit seed flour processed by the methods of pressure cooking, pressure cooking+ lye peeling of varikka and koozha seeds. The lowest moisture content of 6.15% was recorded for the treatment Pan roasting + Manual removal of spermoderm of koozha seeds. The highest protein content of 21.13% was observed for Pan roasted koozha as well as varikka seed flour. The highest fat content of 0.76% was reported for Lye peeled varikka and koozha seed flour and fibre content was the highest (3.93%) for Pressure cooking and Pressure cooking + Manual removal of spermoderm of varikka and koozha types. The highest ash content of 3.45% was observed for varikka and koozha seed flour obtained through Pan roasting+ Manual removal of spermoderm. Vitamin C content of jackfruit seed flour ranged from 18.32 mg $100g^{-1}$ to 22.32 mg $100g^{-1}$ and the highest Vitamin C content of 22.32 mg $100g^{-1}$ was observed for the treatment oven drying with spermoderm for varikka and koozha seeds.

The highest starch content of 69.07% was observed for pressure cooking method of varikka as well as koozha seed flour. The highest TSS content of 3.03ºBrix and carotenoid content of 5.64 µg $100g^{-1}$ was observed for the treatment Oven drying with spermoderm for varikka and koozha seed flour and the treatment Pressure cooking+ Manual removal of spermoderm for koozha seeds recorded the highest acidity of 0.34%. The highest total sugar of 5.59% and reducing sugar of 0.92% was observed for varikka and koozha seed flour obtained through pan roasting.

Functional qualities of jackfruit seed flour *viz*., water absorption capacity was the highest (180 mL $100g^{-1}$) for pan roasted seeds whereas oven dried seeds recorded the highest oil absorption capacity (96.67 mL $100g^{-1}$) and swelling power (5.44 g g^{-1}).

The highest yield of 64.24% was recorded for oven dry method of jackfruit seed flour for both the types (varikka and koozha) and the highest bulk density (0.82 g cm^{-3}) and tapped density of 0.98 g cm^{-3} were recorded for pressure cooked varikka seed flour. Pan roasting method recorded the highest value of Hausner factor and the processing methods did not show any significant difference for carr's index. Jackfruit seed flour obtained through lye peeling of varikka and koozha seeds recorded more whitish flour with highest mean score and oven dried method with spermoderm recorded the lowest score indicates the brownish colour of the flour.

Jackfruit seed flour did not show any quality changes during a storage period of two months. During storage, there was no significant changes in biochemical and functional parameters of jackfruit seed flour except moisture content and reducing sugar which showed a slight increase, whereas titrable acidity and vitamin C slightly decreased with the storage. No microbial load was detected during the storage period and the storage studies revealed good storage stability of jackfruit seed flour.

സംഗ്രഹം

ഗുണമേന്മയുള്ള ചക്കക്കുരുപൊടിയുടെ വിവിധ സംസ്കരണ രീതികൾ ക്രമീകരിക്കൽ എന്ന വിഷയത്തെ ആസ്പദമാക്കി വെള്ളായണി കാർഷിക കോളേജിലെ വിളവെടുപ്പാനന്തര സാങ്കേതിക വിദ്യാവിഭാഗത്തിൽ 2019-2021 വർഷക്കാലയളവിൽ പഠനം നടത്തുകയുണ്ടായി. വരിക്കചക്കയുടെയും കൂഴച്ചക്കയുടെയും ചക്കകുരുവിന്റെ ഗുണനിലവാരം വിലയിരുത്തുക, ഗുണമേന്മയുള്ള ചക്കക്കുരുപൊടിയുടെ സംസ്കരണ രീതികൾ ക്രമീകരിക്കൽ, സംഭരണ സ്ഥിരത എന്നീ കാര്യങ്ങളാണ് പഠനവിധേയമാക്കിയത്.

ചക്കക്കുരു പൊടി തയ്യാറാക്കുന്നതിന്റെ ഭാഗമായി വരിക്കച്ചക്കയുടെയും കൂഴചക്കയുടെയും വിത്തുകൾ പാൻ റോസ്റ്റിങ്, പ്രഷർ കുക്കിംഗ്, ലൈപീലിംഗ്, ഓവൻ ഡ്രയിങ് എന്നീ രീതികൾ അവലംബിച്ചു തയ്യാറാക്കുകയുണ്ടായി. അപ്രകാരം പ്രത്യേകമായി ഓരോ സംസ്കരണ രീതിയിലും തയ്യാറാക്കിയ ചക്കക്കുരു പൊടിയുടെ ജൈവരാസ ഘടനയും ഭൗതികവും നിർവഹകണപരവുമായ പ്രത്യേകതകളും ഗുണനിലവാരവും വിശകലനം ചെയ്യുകയുണ്ടായി.

പ്രഷർ കുക്കിംഗ്, ലൈപീലിംഗ് രീതിയിൽ വരിക്കച്ചക്കയുടെയും കൂഴചക്കയുടെയും വിത്തുകൾ സംസ്ക്കരിച്ച പൊടിയിൽ 10.59 ശതമാനം ജലാംശം നിലനിൽക്കുന്നതായി കണ്ടെത്തി. ഏറ്റവും കുറഞ്ഞ തോതിലുള്ള 6.15% ജലാംശം കണ്ടെത്തിയത് തവിട്ടുതൊലി നീക്കിയ കൂഴചക്കയുടെ വിത്തുകൾ പാൻറോസ്റ്റിങ് ചെയ്ത് തയ്യാറാക്കിയ പൊടിയിലാണ്. വലിയ തോതിലുള്ള 21.13% പ്രോട്ടീന്റെ അളവ് കണ്ടെത്തിയത് പാൻറോസ്റ്റ് ചെയ്ത കൂഴ-വരിക്ക ചക്കക്കുരു പൊടിയിലാണ്. ലൈപീലിംഗ് നടത്തിയ വരിക്ക-കൂഴ ചക്കവിത്തുകളിൽനിന്നുള്ള പൊടിയിൽ 0.76% കൊഴുപ്പും തവിട്ടുതൊലി നീക്കം ചെയ്ത വരിക-കൂഴ ചക്കവിത്തുകൾ പ്രഷർ കുക്കിംഗ് മുഖേന സംസ്കരിച്ച പൊടിയിൽ 3.93% നാരും കണ്ടെത്തിയിട്ടുണ്ട്. തവിട്ടുതൊലി നീക്കം ചെയ്തു പാൻ റോസ്റ്റിങ് നടത്തി തയ്യാറാക്കിയ ചക്കക്കുരു പൊടിയിൽ 3.45% ക്ഷാരം, 18.32 മില്ലിഗ്രാം/100 ഗ്രാം മുതൽ 22.32 മില്ലിഗ്രാം/100 ഗ്രാം വരെ വിറ്റാമിൻ സി കണ്ടെത്തിയതിൽ, 22.32 മില്ലിഗ്രാം/100 ഗ്രാം ഉണ്ടെന്ന് കണ്ടത് വരിക്ക-കൂഴ ചക്കക്കുരു ഓവൻ ഡ്രയിങ് ചെയ്തു തയ്യാറാക്കിയ പൊടിയിലാണ്.

വരിക്ക-കൂഴ വിത്തുകൾ പ്രഷർകുക്കിംഗ് നടത്തി സംസ്കരിച്ച പൊടിയിലാണ് 69.07% അന്നജം കണ്ടെത്തിയത്. വരിക്ക-കൂഴ വിത്തുകൾ തവിട്ടുതൊലി നീക്കാതെ ഓവൻ ഡ്രയിങ് നടത്തി തയ്യാറാക്കിയ പൊടിയിൽ വലിയതോതിൽ ടി എസ് എസ് ഘടകവും (3.03 ഡിഗ്രീ ബ്രിക്സ്സും), 5.64 മൈക്രോ ഗ്രാം/100ഗ്രാം കരോട്ടിനോയ്ഡും കണ്ടെത്തി. പാൻ റോസ്റ്റ്റ്റിങ്ങിലൂടെ വരിക്ക-കൂഴ ചക്ക വിത്തുകൾ സംസ്കരിച്ച് പൊടി തയ്യാറാക്കിയതിന്റെ ടോട്ടൽ ഷുഗർ 5.59%, 0.92% റെഡ്യൂസിംഗ് ഷുഗറും, വലിയതോതിലുള്ള ജല ആഗിരണ ശേഷിയും (180 മില്ലിലിറ്റർ / 100 ഗ്രാം), ഓവൻ ഡ്രൈഡ് ചക്കവിത്തിനു വലിയതോതിലുള്ള എണ്ണ ആഗിരണ ശേഷിയും (96.67 മില്ലിലിറ്റർ/100 ഗ്രാം), സ്വെല്ലിങ് പവർ (5.44 ഗ്രാം/ഗ്രാം) ഉള്ളതായി കണ്ടെത്തി.

ഓവൻഡ്രൈ രീതി പ്രകാരം വരിക്ക-കൂഴ ചക്കക്കുരുകളിൽ നിന്നും 64.24% പൊടിയുടെ കൂടിയ ലഭ്യത രേഖപ്പെടുത്തിയപ്പോൾ വരിക്ക ചക്കക്കുരു പ്രഷർകുക്കർ ചെയ്തപ്പോൾ ഉള്ള പൊടിക്ക് 0.82 ഗ്രാം/സെൻറിമീറ്റർ ക്യൂബ് ബൾക് ഡെന്സിറ്റി, 0.98 ഗ്രാം/സെൻറിമീറ്റർ ക്യൂബ് ടാപിഡ് ഡെന്സിറ്റി ഉണ്ടെന്നും രേഖപ്പെടുത്തുന്നു. ഹൌസ്നർ ഘടകത്തിന്റെ ഏറ്റവും വലിയ മൂല്യം രേഖപ്പെടുത്തിയിരിക്കുന്നത് പാൻ റോസ്റ്റ്റ്റിംഗ് രീതിയിലെ ചക്കക്കുരു സംസ്കരണത്തിനാണ്. വ്യത്യസ്തമായ നിർമ്മാണ രീതികളിൽ കാർഴ്സ് സൂചികയെ സംബന്ധിച്ച് സാരവത്തായ വ്യത്യാസങ്ങൾ കണ്ടെത്തിയില്ല. ലൈപീലിംഗിലൂടെ ലഭ്യമായ ചക്കക്കുരു പൊടി (വരിക്ക, കൂഴ) കൂടുതൽ വെള്ള നിറത്തിൽ കാണപ്പെടുമ്പോൾ തവിട്ടുതൊലി നീക്കാതെയുള്ള ഓവൻ ഡ്രൈഡ് രീതിയിൽ ലഭ്യമാകുന്ന പൊടി കുറഞ്ഞ തവിട്ടു നിറത്തിലും കാണപ്പെടുന്നു.

ചക്കക്കുരു പൊടിയുടെ രണ്ടുമാസത്തെ സംഭരണം ഗുണമേന്മയിൽ മാറ്റമൊന്നും ഉണ്ടാക്കുന്നില്ല എന്ന് കണ്ടെത്തി. പൊടിയുടെ ജൈവരാസ ഘടനയിലോ നിർവ്വഹകണ സ്വഭാവത്തിലോ സാരവത്തായ മാറ്റങ്ങൾ സംഭരണകാലയളവിൽ സംഭവിച്ചില്ല. എന്നാൽ ഈർപ്പത്തിന്റെ തോതും റെഡ്യൂസിംഗ് ഷുഗറിന്റെ അളവും ചെറിയതോതിൽ വർദ്ധിക്കുന്നതായി കാണുന്നു. എന്നാൽ സംഭരണത്തിൽ അമ്ലസാന്ദ്രതയും വിറ്റാമിൻ സി യും ചെറിയ തോതിൽ കുറയുന്നതായും കാണുന്നു. സംഭരണ കാലയളവിൽ സൂക്ഷ്മാണു ബാധ കണ്ടെത്തിയിട്ടില്ലെന്നും ചക്കക്കുരുപൊടി നല്ല രീതിയിൽ സംഭരണ ക്ഷമത ഉറപ്പാക്കുന്നതതായും സംഭരണത്തെ സംബന്ധിച്ച പഠനങ്ങൾ വെളിപ്പെടുത്തുന്നു.