PROCESS STANDARDISATION FOR JACKFRUIT SEED FLOUR WITH CHOCOLATE AROMA AND PREPARATION OF JACKFRUIT COOKIES

by

Hiba K

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THESIS

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VELLAYANI, THIRUVANANTHAPURAM 695 522

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2023

DECLARATION

I, hereby declare that this thesis entitled "**PROCESS STANDARDISATION FOR JACKFRUIT SEED FLOUR WITH CHOCOLATE AROMA AND PREPARATION OF JACKFRUIT COOKIES**" is 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.

Place: Vellayani

Date: 20-02-2023

Hiba K

(2020-12-007)

CERTIFICATE

Certified that this thesis entitled "**PROCESS STANDARDISATION FOR JACKFRUIT SEED FLOUR WITH CHOCOLATE AROMA AND PREPARATION OF JACKFRUIT COOKIES**" is a record of research work done independently by Ms. Hiba K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani

Date: 20-02-2023

Dr. P.R. Geetha Lekshmi
(Major advisor, Advisory committee)
Assistant Professor (Hort.)
Department of Postharvest Management
College of Agriculture, Vellayani
Thiruvananthapuram- 695 522

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Hiba K (2020-12-007), a candidate for the degree of Master of Science in Horticulture with the major in Postharvest Management, agree that the thesis entitled **"PROCESS STANDARDISATION FOR JACKFRUIT SEED FLOUR WITH CHOCOLATE AROMA AND PREPARATION OF JACKFRUIT COOKIES"** may be submitted by Ms. Hiba K. (2020-12-007), in partial fulfilment of the requirement for the degree.

Geetha 20/02/2023

Dr. P.R. Geetha Lekshmi
(Major Advisor, Advisory Committee)
Assistant Professor
Department of Postharvest Management
College of Agriculture, Vellayani
Thiruvananthapuram- 695 522

20/2/23

Dr. Mini C.
(Member, Advisory committee)
Professor and Head
Department of Postharvest Management
College of Agriculture, Vellayani
Thiruvananthapuram- 695 522

20/2/23

Dr. Suma Divakar
(Member, Advisory committee)
Professor
Department of Community Science
College of Agriculture, Vellayani
Thiruvananthapuram- 695 522

20/2/23

Ms. Athulya S. Kumar
(Member, Advisory committee)
Assistant Professor
Department of Postharvest Management
College of Agriculture, Vellayani
Thiruvananthapuram- 695 522

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LIST OF ABBREVIATIONS

et al.	Co-workers/ Co-authors
%	Per cent
@	At the rate of
μg	Micro gram
CRD	Completely Randomised Design
CD	Critical difference
DPPH	2, 2-diphenyl-1-picrylthydrazyl
g	Gram
g cm^{-3}	Gram per centimetre cube
g g^{-1}	Gram per gram
kg	Kilogram
AJSF	Aromatic jackfruit seed flour
DJSF	Dried jackfruit seed flour
WF	Refined wheat flour
mg	Milligram
min	minute
mL	Millilitre
mm	Millimetre
cm	Centimetre
No.	Number
NS	Not significant
SEm	Standard error of mean
Viz.,	Namely
	Chi-square
KW	Kruskall- Wallis

INTRODUCTION

1. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam) is the largest edible fruit with the highest yield which remains underutilised. As a fruit, jackfruit bulbs are used and seeds are often wasted which contributes to about 10 to 15 per cent of the total weight of the fruit. Jackfruit seeds are abundant in starch, protein, dietary fibre, minerals, phytonutrients and jackfruit seed flour could be a novel functional ingredient with promising nutraceutical potential. The food processing industry has recognised jackfruit seed as a novel food ingredient with desirable functional properties due to its high content of phytonutrients. Blending jackfruit seed flour and wheat flour without adversely affecting the sensory profile of the final product could improve the nutritional quality of the processed product (Akter and Haque, 2018). There are several challenges in the processing of jackfruit seeds and the processing methods influence the nutritional, functional and sensory characteristics of jackfruit seed flour (Waghmare *et al*., 2019).

Cocoa powder is used as an ingredient to impart chocolate aroma to food products. As cocoa plants are extremely sensitive to climatic changes and in order to meet its rising demand, novel alternate sources of chocolate aroma are necessary that provide farmers new sources of income. By utilising various pre-treatments such as fermentation, acidification, and processing techniques jackfruit seeds can develop chocolate aroma (Spada *et al*., 2017). Due to the lower lipid contents of jackfruit seeds (0.7%–2.2%) compared to cocoa beans (53%–39%), jackfruit seed flour has added benefits in increasing the nutritional value of processed products.

Food products containing functional ingredients are the major thrust of food industry to meet the nutritional requirement of people for a healthy diet. Cookies are widely consumed as a snack food, especially in developing nations. Therefore, by modifying their nutritional composition, cookies can act as a vehicle for delivering important nutrients. With suitable pre-treatment and processing techniques, chocolate aroma in jackfruit seed flour could be developed, which is an inventive substitute for cocoa powder in food preparations (Spada *et al*., 2018). The baking industry in India is growing at a very faster rate and the demand for healthy bakery products is increasing. Biscuits and cookies generally prepared from refined wheat flour are deficient in proteins, vitamins, minerals and fibre. Jackfruit seed flour can be utilised for the preparation of nutrient dense cookies (Varghese *et al*., 2020) as jackfruit seed flour had higher levels of protein, ash, fibre and other nutrients. The jackfruit seed flour with chocolate aroma developed through various pre-treatments and processing methods can be utilised for the preparation of cookies with chocolate flavour it is a novel process to improve the acceptability of jackfruit seed flour cookies with better nutritional and sensory qualities.

Hence the present study entitled "Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies" was conducted with the objective of standardisation of processing methods for the development of chocolate aroma in jackfruit seed flour and assessment of its suitability for jackfruit cookies with functional properties.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Jackfruit seed is an underutilized fruit in many tropical countries even though the jackfruit seed are rich in phytonutrients are often discarded. The present study focused on the pre-processing treatments of jackfruit seeds to develop chocolate aroma and to utilise it for the preparation of jackfruit cookies. The literature on the qualities of jackfruit seed, processing of jackfruit seed to seed flour and studies on jackfruit seed flour-based cookies are reviewed in this chapter.

2.1. HEALTH BENEFITS OF JACKFRUIT SEED

Jackfruit (*Artocarpus heterophyllus*) belongs to the family Moraceae (Mulberry family). It is native to India and can be found across Southeast Asia and also grown in West Africa's evergreen forest zone (Berry and Kalra, 1988). Jackfruit seed contains lignans, isoflavones, saponins, and other phytonutrients, and its health benefits range from anti-cancer to antihypertensive, anti-ageing, antioxidant, and antiulcer (Fardet *et al.*, 1998).

The fresh jackfruit seed contains 6.06 g of crude protein, 0.4g fat, 38.4g carbohydrates, 1.5g fibre, 1.25g to 1.50 g of ash, and 51.6g to 57.77g of moisture in 100g seed weight and the presence of antinutritional factors such as tannin and trypsin inhibitors had also been reported, resulting in digestive problems (Morton, 1987). The jackfruit tree produces more yield than any other fruit tree (Haque, 1993). Jackfruit seeds are currently underutilized in human and animal diets and majority of people are unaware of the benefits of jackfruit seed flour. Lack of knowledge about nutrient content and adequate methods for incorporating jackfruit seeds into food formulations are significant factors leading to jackfruit seed wastage (Gunasena, 1996).

Jackfruit is a seasonal fruit and seeds have a shorter shelf life and are usually discarded during the season. The seeds can be processed into intermediate products such as flour, which can be stored for an extended period of time. This flour can also be used alone or in combination with other grains to make novel foods like cake, bread, and biscuits while keeping the final product's functional and sensory profiles (Babitha *et al.*, 2004). Jackfruit seeds are high in starch (22%), as well as dietary fibre (3.19%) (Guria, 2006).

Essential fatty acids such as linoleic acid and alpha-linolenic acid which are not synthesized by the body and must be obtained through diet are abundant in jackfruit seed. These fatty acids aid in forming healthy cell membranes, proper brain and nervous system development and functioning, proper thyroid and adrenal activity, hormone production, blood circulation regulation, and healthy hair and skin promotion (Nagala *et al*., 2013).

Oxalate and phytate content of raw jackfruit seed kernel was 6.37 mg $100g^{-1}$ and 48.08 mg $100g^{-1}$ respectively as reported by Ajay (2008). To reduce calorie intake, jackfruit seed flour, which is high in protein and carbohydrates and has good water and oil absorption abilities, is used as an alternative to wheat flour (Prakash *et al*., 2009).

Jackfruit seeds are valuable by-products that account for more than 15% of the total weight of the fruit (Prathima, 2008). The protein and carbohydrate composition of jackfruit seeds are reported as 13.50% and 79.34%, respectively (dry basis), and also contain high amount of calcium (3087 mg kg^{-1}), iron (130.74 mg kg^{-1}), potassium (1478 mg kg^{-1}), sodium (60.66 mg kg^{-1}), copper (10.45 mg kg^{-1}) and manganese (1.12 mg kg^{-1}). However, nutrient content may vary according to the variety and growing location (Ocloo *et al*., 2010).

Abedin *et al*. (2012) reported the nutritional composition of jackfruit seeds and discovered that the protein content ranged from 13% to 18% crude fibre content as 1.56% to 2.60% and the starch content as 12.86% to 17.90%. Alkaloids, phenols, tannins, saponins, steroids, and other compounds were also present in jackfruit seeds (Swami *et al*., 2012). According to Islam *et al*. (2015), jackfruit seeds had 15.88% moisture, 2.49% crude fibre, 5.78% protein, and 1.77% fat content.

Miah *et al*. (2017) reported that jackfruit seeds recorded a moisture content of 39.2%, 1.3% ash, 16.01% crude protein, 0.980% of crude lipid, 3.56% crude fibre and a total carbohydrate content of 42.49%. In another study, jackfruit seeds recorded an approximate moisture content of 71.92%, crude fibre of 3.92%, ash content of 0.89%, protein of 10.9%, fat of 4.29%, and carbohydrate content of 7.89% (Amadi *et al*., 2018). Khan *et al.* (2021) reported that jackfruit seeds contain 0.40g to 0.43g of fat, 25.80g to 38.40 g of carbohydrates, 11mg of vitamin C, 50mg of calcium, 63mg of potassium, and 1.50mg of iron. The jackfruit seed flour prepared from soft and firm Brazilian varieties recorded a protein content varying from 13.43% to 16.28%, insoluble fibre in the range 4.16% to 4.68% and a good source of magnesium (200mg $100g^{-1}$), oleic and linoleic acid (Hajj *et al*., 2022).

2.2. PRE-TREATMENT OF JACKFRUIT SEEDS

Jackfruit seed flour was reported as a cheap source of protein (13.49%), ash (2.47%), carbohydrate (70.73%), potassium (6466 ppm), magnesium (4582 ppm) and sodium (8906 ppm) with a higher water absorption capacity of 2.91 mL g^{-1}, oil absorption capacity of 0.884 mL g^{-1}, bulk density of 0.873 g mL^{-1} and gelation capacity of 17% (Anjaly *et al*., 2018).

According to Tulyathan *et al*. (2002), jackfruit seed flour prepared using lye peeling method contain 8.57% moisture, 11.17% crude protein, 0.99% crude lipid, 1.67% crude fibre, 3.92% ash, 82.25% total carbohydrates, and 77.76% starch. Airani (2007) studied the percentage recovery of jackfruit seed flour from jackfruit seeds in a comparative study from lye peeling, boiling, and mechanical peeling methods and estimated as 50%, 46%, and 43%, respectively. It was reported that the starch extracted from jackfruit seed flour had 80% amylopectin and 20% amylose, titratable acidity and lactic acid concentrations were also determined as 5.78% and 1.12%, respectively, with a fibre content of 5.19%. In the food industry, jackfruit seed flour has enormous potential, particularly as a thickener and binding agent in a variety of food processes (Samatarini, 2007).

The fibre content, sugars, fat, proteins, pectin, organic acids, antioxidants, phenols, vitamins, minerals, flavours, and other bioactive substances of jackfruit seed flour were all affected by the jackfruit seed treatment process (Reis *et al*., 2012). According to Swami *et al*. (2012), physiochemical composition of jackfruit seed was reported as moisture (6.09%), crude fat (1.27%), ash (2.70%), protein (13.50%), fibre (3.19%), energy (382.79 kcal 100 g^{-1}), titratable acidity as lactic acid (1.12%), pH 5.78, bulk density (0.80 g cm^{-1}), carbohydrate (79.34%) and functional properties include water absorption capacity (25%), fat absorption capacity (17%), foaming capacity (25%), foam stability (34%) and swelling power (4.77g g^{-1}).

Proteins, carbohydrates, and minerals were found to be abundant in jackfruit seed flour (Abedin *et al*., 2012). The total sugar, starch and carbohydrate of jackfruit seed powder gradually decreased during storage at a rate of 0.30%, 0.35%, and 0.53%, respectively (Rahman *et al*., 2012). According to Nair *et al*. (2013), jackfruit seed recorded a total phenolic of 4.06mg GAE g^{-1} and tannin content of 1.98mg GAE g^{-1}. Jackfruit seed flour is a nutritious ingredient for various food applications. The jackfruit seed starch composition in soft and firm fleshed varieties was recorded as 92.8% and 94.5% respectively (Madruga *et al*., 2014).

According to Shaiful *et al*. (2015), jackfruit seed had 5.78% protein and 2.49% crude fibre and the biochemical composition of roasted jackfruit seed flour was influenced by different processing methods. Dried jackfruit seed recorded a moisture content of 5.88%, lipid content of 0.48%, protein content of 11.2%, ash content of 2.9%, insoluble fibre content of 10.34%, and soluble fibre content of 3.88% without any pre-treatment. Acidified jackfruit seeds recorded 1.38% moisture, 0.3% lipids, 11.16% protein, 2.44% ash, 9.29% insoluble fibre and 2.68% soluble fibre whereas fermented jackfruit seeds recorded 5.1% moisture, 0.5% lipids, 14.82% protein, 4.7% ash, 18.9% insoluble fibre and 3.34% soluble fibre (Spada *et al*., 2017).

The biochemical composition of jackfruit seed flour obtained through different types of processing, including raw, germinated, and thermally processed was studied by Zuwariah *et al*. (2018). Raw jackfruit flour had an energy value of 429.5 kcal, 3.21 g of moisture, 2.75 g of ash, 9.780 g of protein, 25.43 g of dietary fibre, 83.68 g of carbohydrate, and 55.90 g of starch for 100 g of seed flour. The corresponding values for 100 g of germinated jackfruit seed flour were 429.5 kcal of energy value, 2.92g of moisture, 2.56g of ash, 10.41 g of protein, 24.48 g of fibre, 83.63 g of carbohydrate, 64.98g of starch. The thermally processed jackfruit seed flour had 5.98 g $100g^{-1}$ moisture, 2.43 g $100g^{-1}$ ash, 24.94 g $100g^{-1}$ protein, 14.33 g $100g^{-1}$ dietary fibre, 76.03 g $100g^{-1}$ carbohydrate, 50.97 g $100g^{-1}$ starch, and 434.5 kcal $100g^{-1}$ energy value. Processing treatments also influenced the chemical composition of jackfruit seed flour. The protein content of thermally processed jackfruit seed flour had the most significant increase (61%) compared to that of raw jackfruit seed flour. The increase in protein content of thermally treated jackfruit seeds may be a result of protein denaturation, followed by aggregation of either soluble or insoluble complexes of protein.

Borgis *et al.* (2020) reported that jackfruit seed flour contain nutrients as well as non-nutritive substances such as antioxidants that are essential for growth, development and overall health. Jackfruit seed flour had a calcium content of 234.24 mg, 105.93 mg phosphorus, 162.51 mg magnesium, 12.55 mg iron, 4.25% copper, 2.03% zinc, 2.02% manganese, and it also had phenolic content of 4.52 mg GAE g^{-1}, and tannin content of 2.12mg TAE g^{-1} which increased its nutritional value and health benefits. The jackfruit seed processing techniques enhanced the proximate and mineral contents and reduced the anti-nutritional factors and toasting was found as the best method of processing Eyoh (2020).

Nisar *et al.* (2021) studied the chemical composition of processed dried jackfruit seeds and reported that sun dried jackfruit powder had 5.16% moisture, 2.6% ash, 1.71% crude fat, 20.71% protein, 2.46% crude fibre, and 67.70% carbohydrate content. While the tray dried jackfruit powder had 4.79% moisture, 2.69% ash, 1.86% crude fat, 21.49% protein, 2.47% crude fibre and 66.70% carbohydrate content, and the dried jackfruit seed powder produced by tray drying method was found superior to that by sun drying.

According to Kumar (2021), processing methods influenced the biochemical, functional, and physical properties of jackfruit seed flour and jackfruit seed flour recorded 6.15% to 10.59% of moisture, 11.76% to 21.13% of protein, 0.24% to 0.76% of fat, 1.55% to 3.45% of ash, 18.32 mg 100 g^{-1} to 22.32 mg 100 g^{-1} of vitamin C, 24.88% to 69.07% of starch and 24.88% to 69.07% of TSS. Functional properties of jackfruit seed flour *viz.*, water absorption capacity (180 mL $100g^{-1}$) was highest 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 jackfruit seed flour swelling power and solubility increased with temperature stimulation as the other starch flour (Madrigal-Aldana *et al*., 2011) and hence had the potential in food formulation as blended flour. Functional properties of jackfruit seed flour were influenced by heating, pH, and milling operations and jackfruit seed flour blended with wheat flour up to 15% was suggested to use in bread preparation with a comparable sensory nutritional quality (Chowdhury *et al.*, 2012). They also reported that jackfruit seed flour blend could be used as a protein supplement and functional ingredient in bakery products.

According to Ocloo *et al*. (2010) jackfruit seed flour had a high flavour retention rate due to its oil absorption capacity and good water absorption capacity. This suggested that jackfruit seed flour might be utilised in the bakery industry and could be used as thickeners due to high bulk density in food industry. Kaushal *et al*. (2012) reported that the increase in amylose solubility and leaching the loss of starch crystalline structure had been linked to an increase in the water absorption capacity and the flour with high water absorption might contain more hydrophilic ingredients like polysaccharides. According to Ejiofor *et al*. (2014) the composition, functional and pasting qualities of jackfruit seed flour were influenced by the processing techniques. The higher water absorption capacity of the roasted jackfruit seed flour indicated essential processing factor that had an impact on viscosity. Islam *et al*. (2015) reported that the functional properties of jackfruit flour include 72 ml 100 g^{-1} capacity for water absorption, 86 ml 100 g^{-1}capacity for oil absorption and 33% dispersibility of flour. The swelling power of seed flour was measured at a higher rate (1.46 g g^{-1}) than its per cent solubility (2.31%). Kusumayanti *et al*. (2015) stated that the hydrodynamic characteristics of the food are affected by swelling capacity, which had effect on texture, consistency and appearance of food products. Proteins could interact with water in food because they are both hydrophilic and hydrophobic. Jackfruit seed flour good ability to bind with both water and oil with functional qualities required in the food industry and reported 200% water absorption capacity and 90% oil absorption capacity (Mahanta and Kalita, 2015).

The ratio between the bulk and tapped densities was used to develop the Hausner Factor, which analyse the fluidity of materials. The values between 1.25 and 1.5 require the addition of adjuvants to improve flow; values less than 1.25 indicate good flow, while values greater than 1.5 indicate poor flow (Quispe-Condori *et al.*, 2011). Santhalakshmy *et al.* (2015) reported that increases in temperature or air velocity had no effect on the Carr's Index, which also indicate the fluidity of powder and flour.

The relative volume of packaging materials required is determined by bulk density and differences in starch content reflected in variation of bulk density. The bulk density of the flour was also influenced by maturity and which ranged from 0.72 to 0.92 g/cm^3. The sample with the highest water absorption capacity is best for baking industries as it influenced product bulking and viscosity. The water absorption capacity of jackfruit seed flour ranged from 147.85% to 233.72% and oil absorption capacity of jackfruit seed flour was in the range 67.91% to 102.42% (Kushwaha *et al*., 2020).

The flour yield from dried jackfruit seed flour, acidified jackfruit seed flour, and fermented jackfruit seed flour was 48%, 45%, and 40%, respectively and the sensory assessment proved that roasted jackfruit seeds could produce a chocolate aroma and showed that the aroma can be affected by both seed processing and roasting conditions (Spada *et al*., 2017).

Jackfruit seeds subjected to soaking, boiling and fermentation reduced their tannin and oxalate contents by 85% (Ndyomugyenyi *et al.*, 2014). According to Lai *et al*. (2017) other than heat processing, effective methods for reducing the presence of antinutritional factor in plants included fermentation and enzyme treatment. The proximate analysis of jackfruit seed flour obtained through fermentation and roasting process revealed that the raw sample had the highest carbohydrate content (65.31%), followed by flour through fermentation (62.75%) and the roasting process (61.44%). The roasted sample had the highest protein value (29.59%), crude fat (1.68%) and ash content (3.67%). The fermentation process of seeds recorded a carbohydrate content of 26.92% as compared to 24.90% of raw seed flour and the crude fat was 1.63% for raw and 1.28% for the fermented. The ash content was 3.56% and 3.35% for seed flour of raw and fermented jackfruit seed respectively and the moisture content was the highest in the fermented sample (3.48%) followed by raw (2.56%) and roasted (2.48%). The roasted samples had the highest percentage reduction in all the anti-nutrient factors (tannin, phytate, oxalate, saponin) as compared to the fermented sample (Abiola *et al.*, 2018).

The effect of processing methods *viz*., fermentation, boiling and roasting on micronutrients and antinutrient composition of jackfruit seed flour was evaluated by (Attaugwu *et al.*, 2018) and found that roasting process had increased potassium (from

10.26 to 11.80 mg kg^{-1}) and sodium content (0.69 to 0.72 mg kg^{-1}). A reduction in oxalate, phytate, tannin, trypsin inhibitor and haemagglutinin was reported in jackfruit seed flour processed through fermentation, boiling and roasting and reported the values for oxalate as 94.13%, 93.42% and 93.00%, phytate as 65, 43.85, 28.58%, tannin as 44.10%, 59.18%, 57.66%, trypsin inhibitor as 17.92%, 80.59%, 71.06 % and haemagglutinin 50.42%, 25.16%, 27.88% respectively.

Pre-treatments such as germination and roasting could decrease the levels of tannin and phytic acid and possibility of using jackfruit seeds as a food ingredient arises from the effectiveness of both treatments in reducing tannin and phytic acid content in jackfruit seeds. The lowest level of tannin and phytic acid was found in roasted jackfruit seed (0.1039% and 0.0159 g $100g^{-1}$, respectively) (Bakri *et al*., 2021).

2.3. JACKFRUIT SEED FLOUR AS AN ALTERNATIVE SOURCE OF CHOCOLATE AROMA AND FLAVOUR IN FOOD PRODUCTS

Roasted jackfruit seeds contain high levels of trimethylpyrazine (malty cocoa aroma) and 2,3-diethyl-5-methyl-pyrazine (cocoa, green, and roast aroma), both of which had low threshold values and important in chocolate aroma production (Wagner *et al*., 1999). Cocoa is traditionally fermented in tropical regions to produce chocolate flavour and Maillard precursors such as free sugars and amino acids generate pyrazines during roasting. (Oyekale *et al.*, 2009).

According to Afoakwa (2010) due to the lower lipid composition of jackfruit seeds (0.7%-2.2%) in comparison to Forastero cocoa beans (53%-39%), jackfruit seed flour has the additional benefit of having fewer calories than cocoa. The hydrophobic amino acids released by proteinase activities during fermentation were significant precursors to the Maillard reaction which increased during the processes of fermentation and acidification. The sucrose hydrolysis byproducts of reducing sugars, fructose and glucose, were found also important precursors. Leucine and glucose in cocoa produce aroma notes referred to as sweet chocolate. Pyrazines, which are similar to fermented and roasted cocoa beans, were the dominant odour-active volatile compounds found in roasted jackfruit seeds (Tran *et al*., 2015). More specifically, phenylacetaldehyde from phenylalanine yielded notes of malty cocoa, honey, and green, floral notes from 3-

methylbutanal, 2-methylbutanal, and 2-methylpropanal. Leucine, isoleucine, and valine, respectively, were degraded by the Strecker process. And development of cocoa flavor, these amino acids were found crucial (Kongor *et al*., 2016).

It has been reported that roasted jackfruit seed powder can be used as a partial replacement for cocoa in cappuccinos (Spada *et al*., 2018). Ravindran *et al.* (2020) reported that for the preparation of diet chocolate by substituting 10% of the cocoa powder with jackfruit seed powder this reduced the glycemic index without significantly changing the proximate composition. Spada *et al.* (2020) reported that jackfruit seed flour could be used as a substitute for cocoa because its solubility was unaffected by fermentation, drying, or roasting temperatures and could replace more highly priced gums that are currently used in many food applications for food coatings.

When jackfruit seeds were subjected to temperatures similar to roasting produced pyrazines substituted with their respective carbon chains in the presence of glucose and glycine. Similarly, those with a 2-methylbutyl side chain were derived from isoleucine, while those with a 2-methylpropyl side chain were derived from valine. All pyrazines with a 3-methylbutyl side chain can be derived from 3-methylbutanal from the Strecker degradation of leucine (Spada *et al*., 2021)

Viscosity, solubility and swelling power or water uptake are the most significant functional properties in chocolate products (Dogan *et al*., 2016). Spada *et al*. (2020) reported that even under different moisture, temperature, and exposure time conditions, the water uptake values for all jackfruit seed flours were close to the values for cocoa powder. Compared to jackfruit seed flours, the apparent densities of cocoa powder were significantly lower and the highest apparent density values increase wettability because of the higher granule porosity and surface area that can expose particles. Jackfruit seed flour was found to have a higher wettability than cocoa powder that yielded powders with less lump formation which was more in cocoa powder.

Spada *et al*. (2017) studied the usage of jackfruit seeds, an underutilized tropical waste product and reported that by acidifying or fermenting the seeds prior to drying and roasting under various time or temperature combinations, twenty-seven distinct roasted jackfruit seed flours were generated. The findings revealed that fermentation and acidification had a considerable and favourable impact on the development of chocolate aroma. According to SPME/GC-MS analysis of the flours, important aroma compounds such as 2,3-diethyl-5-methylpyrazine and 2-phenylethyl acetate were significantly higher in the fermented product, and the more severe roasting conditions produced 2-3 times more 2,3-diethyl-5-methylpyrazine but less 3-methylbutanal. Based on the report of Solid phase extraction (SPE) GC–MS method although phenylacetaldehyde was much higher in cocoa, strecker aldehydes and aldol condensates were discovered in jackfruit seed flours at levels comparable to those in cocoa powder. Jackfruit seed flour obtained from fermented and roasting had much higher pyrazine levels closer to cocoa. In addition to the pyrazines already found in chocolate, jackfruit seed flours contain many more pyrazines than have been found in cocoa, coffee, nuts, etc. (Spada *et al*., 2021).

2.4. FUNCTIONAL COOKIES

Consumer demand for novel foods that are rich in nutrition with acceptable organoleptic qualities and those which have traditional values is increasing. Today, cookies have become one of the most popular and well-accepted snacks worldwide among all age groups. This is because cookies are a good source of energy and are 'ready-to-eat' products. The low manufacturing cost as well as stable shelf life renders the cookies to serve as a valuable source of instant nutrition. Moreover, cookies could be produced in large quantities with minimal time requirements and enable widespread distribution (Zucco *et al*., 2011). Nowadays consumers are becoming more and more interested in low-calorie functional cookies, which lead to an increased demand for such products in the market (Mir *et al*., 2017). The pulp, seed, and leaves of jackfruit were rich in flavonoids, that support health and had low concentrations of phytic acid, oxalates, tannin, and alkaloids (Amadi *et al*., 2018).

Jackfruit seeds could be processed into seed flour and used in familiar bakery products (bread, cookies, and cake), extruded products (snacks, noodles, and breakfast cereals), baby foods, etc. based on the nutritional values, functional properties, and general acceptability (Akter and Haque, 2018).

Munishamanna *et al*. (2010) studied the potential use of jackfruit seeds as food ingredient. Jackfruit seed flour was reported a potential substitute for wheat flour that could be used in foods like vada, chapatti, bread, cake, buttered biscuits, pancakes, and noodles (Hema, 2015).

David *et al*. (2016) reported that to increase dietary fibre and to produce a low-calorie cake, jackfruit seed flour could be added to common flour. As per the sensory evaluation, 5% jackfruit seed flour with 95 % wheat flour was found as the best treatment combination. It was observed that as the percentage of jackfruit seed flour increased, the amount of antioxidant activity and dietary fibre in the chocolate cake increased.

Airani (2007) incorporated 10% to 50% jackfruit seeds flour blended with wheat flour (maida and whole wheat flour) to prepare cookies. The product with 20% and 30% incorporation was acceptable with an excellent sensory profile, whereas 50% incorporation resulted in a hard texture. The approximate composition of cookies with 12.5% jackfruit seed flour reported a moisture content of 3.14%, protein 12.80%, crude fat 26.39%, fibre 2.78%, and total ash 1.43%. The studies on suitability of jackfruit seed flour to be used in the preparation of biscuits found that biscuit made up of 50% wheat flour and 50% jackfruit seed flour had the highest level of overall acceptance. Different jackfruit seed preparation and processing techniques had an impact on the proximate composition, mineral content, anti-nutritional content, and baking qualities of jackfruit seed flour (Hasan *et al.*, 2010). According to Okpala (2010), the effects of substitution of wheat flour with fermented jackfruit seed flour enhanced the baking quality of the bread and cookies due to its high protein content. The cookies made from jackfruit flour alone had the lowest spread ratio and different processing treatments of jackfruit seeds improved the spread ratio slightly. Cookies made with fermented jackfruit seed flour had a high spread ratio, similar to those made with 100% wheat flour. Sensory evaluation of the composite flour cookies indicated that all cookies made with a 30% substitution of wheat flour 20% jackfruit pulp flour and 10% jackfruit seed flour were acceptable.

Due to the higher levels of carbohydrates, dietary fibre, protein, and minerals in jackfruit seeds, conversion of raw seeds into flour could significantly increase their use in food products. With the ability to absorb both water and oil well, jackfruit seed flour combine well with wheat flour could be used in processed food products. Cereal bars with good sensory and nutritional qualities were successfully made with jackfruit seed flour at a level of 11% and 27% jackfruit dehydrated pulp (Santos *et al*., 2011).

The diameter of cookies was reduced as a result of the increase in water-absorbing fibre content (Hasan *et al*., 2010). The spread factor might have decreased as a result of reduced gluten due to increased levels of wheat flour replacement (Chowdhury *et al*., 2012). According to Maurya (2017) when the amount of jackfruit seed flour increased, the percentage expansion of cookies decreased. It had been noted that the competition between ingredients for the available water had an impact on the spread factor of cookies; flour or any other ingredient that absorbs water during dough mixing reduced the spread ratio (Suriya *et al*., 2017). As a result, the presence of more water-absorbing ingredients like protein and fibre could be responsible for the reduced spread ratios of cookies made with jackfruit seed flour. Maskey *et al*. (2020) reported that when the proportion of jackfruit seed flour in cookies increased, physical characteristics like diameter, thickness, and spread ratio was affected.

Faridah and Aziah (2012) reported that in the preparation of low-calorie chocolate cake, the jackfruit seed starch had effectively replaced up to 16% of the wheat flour, along with the substitution of sucrose with polydextrose at a level of 11%. The jackfruit seed flour's fat content was negligible, making it a good constituent in functional foods that can be consumed safely and performed better in terms of water absorption, oil absorption, and swelling power so that it could be used in a variety of food preparations (Abraham and Jayamuthunagai, 2014). Islam *et al*. (2015) found that biscuits made with 10, 20, and 30% jackfruit seed flour did not significantly differ from the control in terms of their sensory qualities. Different blends of refined flour, jackfruit seed flour, and coconut milk residue flour were used to make biscuits. The biscuit with a 50:20:30 and 50:30:20 ratio of refined flour, coconut flour, and jackfruit seed flour resulted in high sensory attributes (Barge and Divekar, 2018).

Hidayati (2019) reported that in order to make cookies, jackfruit seed flour was substituted at levels of 10%, 20%, and 30% and 30% substitution produced the crispiest cookies with good sensory qualities.

Maskey *et al*. (2020) reported that combining 12.5% jackfruit seed flour with 87.5% wheat flour resulted in higher sensory scores for cookies with significantly higher protein, fat, fibre, and ash contents than wheat flour cookies. Cookies made with jackfruit seed flour had good printability and quality for 3D printed cookies (Varghese *et al*., 2020).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

This chapter provides a description of the materials used and methodologies selected in the investigation of the “Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies”.

3.1 STANDARDISATION OF PROCESSING METHODS FOR THE DEVELOPMENT OF CHOCOLATE AROMA IN JACKFRUIT SEED FLOUR

The experiment was carried out at the Department of Postharvest Management, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram during the year 2020-2022.

3.1.1 Selection of Raw Materials

Fully matured jackfruits of varikka type collected from the Instructional farm, Vellayani were ripened and used for the study.

3.1.2 Pre-treatments of Jackfruit Seeds for the Development of Chocolate Aroma

Jackfruit bulbs with seeds from fully ripened fruits (varikka type) were subjected to different pre-treatments like fermentation and acidification. The jackfruit seeds after the pre-treatments were cleaned, dried, roasted and milled. The processing pre-treatments were

T_1- Fermentation process for 8 days
T_2- Fermentation process for 10 days
T_3- Acidification process for 5 days
T_4 – Acidification process for 8 days
T_5- Control (Without pre-treatments)

After the pre-treatments, the seeds were washed and dried after removing the spermoderm in a hot air oven at 60^{o}C for 2 hours. The seeds were then roasted (170^{o}C, 30 minutes) and milled to obtain jackfruit seed flour. The jackfruit seeds without any treatment were dried in hot air oven at 60^{o}C for 2 hours after removing the spermoderm and then roasted at 170^{o}C for 30 minutes and milled to get the control treatment. The biochemical, functional, physical and sensory qualities of jackfruit seed flour were analysed using standard procedure.

Fermented jackfruit seed (8 days) without spermoderm

Fermented (8 days) jackfruit seed flour

Plate 1. Jackfruit seed processing pre-treatment fermentation for 8 days

Fermented jackfruit seed (10 days) without spermoderm

Fermented (10 days) jackfruit seed flour

Plate 2. Jackfruit seed processing pre-treatment fermentation for 10 days

3.1.3 Biochemical Parameters of Jackfruit Seed Flour

Biochemical parameters of jackfruit seed flour *viz*., total soluble solids, titrable acidity, starch, total sugar, reducing sugar, protein, crude fibre, total ash, crude fat, vitamin C, carotenoid, and antioxidant activity were analysed using the following procedures.

3.1.3.a. Total Soluble Solids (^{0}Brix)

Total soluble solids (TSS) were recorded directly using a digital refractometer and expressed in degree brix (^{0}Brix).

3.1.3.b. Titrable Acidity (%)

The method described by Ranganna (1986) was used to estimate titrable acidity.

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

3.1.3.c. Starch (%)

The Lane and Eynon titrimetric method was used to estimate starch content and expressed in percentage.

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

3.1.3.d. Total Sugar (%)

The total sugar was expressed in terms of the inverted sugar described by Ranganna (1986) using the following formula

$$\text{Total sugar (\%)} = \frac{\text{Glucose Eq. x Total volume made up (mL) x Volume made up after inversion (mL) x100}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (mL)}}$$

Acidified jackfruit seeds
(5 days) without

Acidified (5days) jackfruit
seed flour

Plate 3. Jackfruit seed processing pre-treatment acidification for 5 days

Acidified jackfruit seed
(8 days) without spermoderm

Acidified (8days) jackfruit seed
flour

Plate 4. Jackfruit seed processing pre-treatment acidification for 8 days

Jackfruit seed without
pre-treatments

Jackfruit seed flour without
pre-treatments

3.1.3.e. Reducing Sugar (%)

The titrimetric method of Lane and Eynon was used to estimate reducing sugar as described by (Ranganna, 1986).

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

3.1.3.f. Protein (%)

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

3.1.3.g. Crude Fibre (%)

The crude fibre was determined by the method described by Sadasivam and Manickam (1992).

$$\text{Crude fibre (\%)} = \frac{\text{Loss in weight in ignition } [(W_2-W_1) - (W_3-W_1)] \text{ x 100}}{\text{Sample weight (g)}}$$

W_1- Weight of crucible

W_2- Weight of crucible and sample after ignition

W_3-Final weight of crucible

3.1.3.h. Total Ash (%)

Total ash content was determined by the method described by Ranganna (1986) in the manual of analysis of fruits and vegetables.

3.1.3.i. Crude Fat (%)

The crude fat was extracted using solvent extraction by Soxhlet apparatus with petroleum ether as solvent and expressed in percentage.

$$\text{Crude Fat (\%)} = \frac{\text{Initial weight of flask (g) - Weight of flask with extracted fat (g) x 100}}{\text{Weight of sample (g)}}$$

T_1

T_2

T_3

T_4

T_5

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

The 2, 6-dichlorophenol indophenol (DCPIP) dye was used to estimate ascorbic acid content using the titrimetric method described by Ranganna (1986).

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

3.1.3.k. Carotenoids (mg 100 g^{-1})

The total amount of carotenoids was estimated according to the method described by Saini *et al.* (2015).

3.1.3.l. Antioxidant Activity (%)

The total antioxidant activity of jackfruit seed flour was assessed using the DPPH radical scavenging assay (2, 2, diphenyl-1-picrylhydrazyl). The method described by Sharma and Bhat (2009) was used to measure the scavenging activity.

3.1.4. Functional Properties of Jackfruit Seed Flour

The following procedures were used to analyse the functional properties of jackfruit seed flour *viz.*, water absorption capacity (mL 100g^{-1}), oil absorption capacity (mL 100g^{-1}), and swelling power (g g^{-1}).

3.1.4.a. Water Absorption Capacity (mL 100g^{-1})

The method described by Ejiofor *et al.* (2014), was followed to determine the water absorption capacity of jackfruit seed flour.

3.1.4.b. Oil Absorption Capacity (mL 100g^{-1})

Oil absorption capacity of jackfruit seed flour was calculated according to the method described by Islam *et al*. (2015).

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

The swelling power of jackfruit seed flour was assessed using the method described by Islam *et al.* (2015).

3.1.5. Physical Parameters of Jackfruit Seed Flour

Physical characteristics of jackfruit seed flour *viz*., yield, bulk density, tapped density, hausner factor, and carr's index were analysed.

3.1.5.a. Yield (%)

The percentage recovery of jackfruit seed flour was determined using the following formula.

$$\text{Yield (\%)} = \frac{\text{Weight of jackfruit seed flour}}{\text{Weight of raw jackfruit seed}} \times 100$$

3.1.5.b. Moisture content (%)

Moisture content of one gram of jackfruit seed flour was calculated using a moisture analyzer (Essae, AND MAX 50) that dries the sample using a halogen bulb and provides the moisture content in percentage based on the principle of thermo gravimetric analysis.

3.1.5.c. Bulk Density (g cm^{-3})

Bulk density of jackfruit seed flour was determined according to the method described by Narayana and Rao (1984).

3.1.5.d. Tapped Density (g cm^{-3})

The process described by Leite *et al*. (2020) was used to determine the tapped density of jackfruit seed flour.

3.1.5.e. Hausner Factor

The ratio of the bulk density to the tapped density was used to calculate the Hausner factor (Leite *et al*., 2020).

3.1.5.f. Carr's Index (%)

The Carr's index of jackfruit seed flour was calculated according to the methods described by Bhusari *et al*. (2014).

3.1.5.h. Aroma Profiling

Headspace analysis of the jackfruit seed flour were carried out on Shimadzu Gas Chromatograph Mass Spectrometer- QP2020C NX attached to Shimadzu HS 20 Head Space autosampler. The Headspace analysis was done by static method and the aroma compounds were detected and the chromatograms were plotted.

3.1.6. Sensory Analysis

The sensory analysis was carried out by a 30 member semi-trained panel comprising of research students from the College of Agriculture, Vellayani. The sensory qualities (colour, appearance, flavour, overall acceptability) of jackfruit seed flour processed after various pre-treatments were scored based on a 9-point hedonic scale (Ranganna, 1986), the panel was asked to rate the sample in the following order of preference

1-Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 5-Neither like or dislike, 6-Like slightly, 7-Like moderately, 8-like very much, 9-Like extremely

For the preparation of jackfruit cookies, the best jackfruit seed flour was selected based on nutritional, functional, physical, and sensory qualities.

3.2. DEVELOPMENT OF JACKFRUIT SEED FLOUR COOKIES

Jackfruit seed flour selected with chocolate aroma, processed after the pre-treatment of jackfruit seeds from the first part of the experiment was used for the preparation of aromatic jackfruit seed flour cookies. The jackfruit seed flour obtained without any pre-treatments (Dried Jackfruit Seed Flour) of jackfruit seeds was also used for cookie preparation. The refined wheat flour (WF) was replaced with aromatic jackfruit seed flour (AJSF) as well as jackfruit seed flour (DJSF) at different proportions for the preparation of cookies and were compared with cookies from refined wheat flour with and without addition of cocoa powder.

The treatment combinations were

T_1 – Aromatic jackfruit seed flour (AJSF 5%) + Refined wheat flour (WF 95%)

T_2 – Aromatic jackfruit seed flour (AJSF 10%) + Refined wheat flour (WF 90%)

T_3 – Aromatic jackfruit seed flour (AJSF 15%) + Refined wheat flour (WF 85%)

T_4 – Aromatic jackfruit seed flour (AJSF 20%) + Refined wheat flour (WF 80%)

T_5 – Aromatic jackfruit seed flour (AJSF 25%) + Refined wheat flour (WF 75%)

T_6– Dried jackfruit seed flour (DJSF 5%) + Refined wheat flour (WF 95%)

T_7 – Dried jackfruit seed flour (DJSF 10%) + Refined wheat flour (WF 90%)

T_8 – Dried jackfruit seed flour (DJSF 15%) + Refined wheat flour (WF 85%)

T_9 – Dried jackfruit seed flour (DJSF 20%) + Refined wheat flour (WF 80%)

T_{10} – Dried jackfruit seed flour (DJSF 25%) + Refined wheat flour (WF 75%)

T_{11}- Refined wheat flour (WF 100%) with cocoa powder

T_{12}- Refined wheat flour (WF100%) without cocoa powder

The cookies prepared were analysed for biochemical, physical, anti-nutritional and sensory parameters based on which the best combination was selected

3.3.1. Biochemical Parameters of Jackfruit Cookies

Biochemical parameters of jackfruit seed cookies *viz.,* carbohydrate, crude protein, crude fibre, crude fat and total ash were analysed using the following procedures.

3.3.1.a. Carbohydrate (%)

Carbohydrate content of jackfruit seed flour cookies was estimated as per the method described by Dubois *et al*. (1956) and expressed as percentage.

3.3.1.b. Crude Protein (g 100g^{-1})

Crude protein content of jackfruit cookies was calculated as described in 3.1.3.f.

3.3.1.c. Crude Fibre (%)

Crude fibre content of jackfruit cookies was calculated as described in 3.1.3.g.

3.3.1.d. Crude Fat (%)

Crude fat content of jackfruit cookies was calculated as described in 3.1.3.i.

3.3.1.e. Total Ash (%)

Total ash of jackfruit cookies was calculated as described in 3.1.3.h.

3.3.2. Physical Parameters of Jackfruit Cookies

Physical parameters of jackfruit seed flour cookies *viz.*, yield, diameter, thickness and spread ratio were analysed using the following procedure.

3.3.2.a. Yield (%)

The yield was calculated as the rate of weight of the baked cookies to the weight of raw cookies and expresses in percentage.

3.3.2.b. Thickness (cm)

The thickness of cookies was measured using a vernier caliper and expressed in cm.

3.3.2.c. Diameter (cm)

The diameter of cookies was measured using a vernier caliper and expressed in cm.

3.3.2.d. Spread Ratio

The spread ratio was calculated as the diameter to thickness ratio (Nandeesh *et al*., 2011).

3.3.3. Anti-nutritional Factors of Jackfruit Cookies

3.3.3.a. Oxalate (mg g^{-1})

One gram of the sample was weighed into a 100 mL conical flask, to which 75 mL of 3M H_2SO_4 was added, and the mixture was stirred for one hour with a magnetic stirrer using the titration method. This was filtered using a Whatman No 1 filter paper and 25mL filtrate was taken and titrated while still hot against a 0.05M $KMnO_4$ solution until a pale pink colour persisted for at least 30 seconds. The oxalate content was determined using 1mL of 0.05M $KMnO_4$ as equivalent to 2.2mg oxalate (Chinma and Igyor, 2007).

3.3.3.b. Phytate (mg $100g^{-1}$)

Phytic acid content was determined as described by Wheeler and Ferrel (1971) using the following formula.

$$\text{Phytate (mg } 100g^{-1}) = \frac{6/4 \times A \times C \times 20 \times 10 \times 50 \times 100}{1000 \times S}$$

A = Optical density

C = Concentration corresponding to optical density

S = Weight of sample

3.3.4. Sensory Analysis of Jackfruit Cookies

Sensory attributes of developed cookies were analysed by a 30-member semi-trained panel of research students from the College of Agriculture, Vellayani. The panel was asked to rate the sample using a 9-point hedonic scale for appearance, cracking, crumb colour, texture, mouth feel, flavour and overall acceptability (Ranganna, 1986) in the following order of preference.

1-Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 5-Neither like or dislike, 6-Like slightly, 7-Like moderately, 8-like very much and 9-Like extremely for all parameters except for cracking. For the cracking attributes, 1- No cracking, 2- very less cracking, 3- Less cracking, 4- Moderate cracking, 5- Slight cracking, 6- High cracking, 7- Very high cracking, 8- Extreme cracking and 9- Full cracking.

3.3.5. Statistical Analysis

Completely Randomized Design (CRD) was used for the statistical analysis of the experimental data. The Kruskall-Wallis test (chi-square value) was used to analyse the sensory attribute score to check the statistical difference between the treatments (Shamrez *et al*., 2013).

RESULTS

4. RESULT

The results of the analysis of the experimental data recorded for the current study on “Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies” are presented in this chapter under the following headings.

4.1. Standardisation of processing methods for the development of chocolate aroma in jackfruit seed flour

4.2. Development of jackfruit seed flour cookies

4.1. STANDARDISATION OF PROCESSING METHODS FOR THE DEVELOPMENT OF CHOCOLATE AROMA IN JACKFRUIT SEED FLOUR

Jackfruit seeds after being subjected to different processing pre-treatments of fermentation and acidification processes were roasted and milled. The jackfruit seed flour was analysed for biochemical, functional, physical and sensory qualities.

4.1.1. Biochemical Parameters of Jackfruit Seed Flour

Biochemical parameters *viz*., total soluble solids, starch, titrable acidity, total sugar, reducing sugar, protein, crude fibre, total ash, crude fat, vitamin C, carotenoid and antioxidant activity were analysed.

The effect of pre-treatments on TSS (^{0}Brix), titrable acidity (%) and starch (%) content of jackfruit seed flour is depicted in Table 1.

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

The processing methods influenced the total soluble solids (TSS) of jackfruit seed flour. The treatment T_1 (Fermentation for 8 days) had the highest observed TSS content of 3.48 ^{0}Brix which showed no significant difference with treatments T_2 (Fermentation for 10 days) and T_5 (control). The treatments T_3 (Acidification for 5 days) recorded a TSS of 1.35 ^{0}Brix and T_4 (Acidification for 8 days) as 1.78 ^{0}Brix with no significant difference statistically between the treatments.

Table 1. Effect of pre-treatments on TSS (^{0}Brix), titrable acidity (%) and starch (%) content of jackfruit seed flour

Treatments	TSS(^{0}Brix)	Titrable acidity (%)	Starch (%)
T_1 (Fermentation for 8 days)	3.48^a	2.20 ^{a}	66.28 ^{a}
T_2 (Fermentation for 10 days)	2.55^{ab}	1.88 ^{a}	62.50 ^{ab}
T_3 (Acidification for 5 days)	1.35^b	1.27 ^{ab}	52.43 ^{c}
T_4 (Acidification for 8 days)	1.78^b	1.39^{ab}	51.03 ^{c}
T_5 (Control)	2.25^{ab}	0.56 ^{b}	56.59^{bc}
SE (±m)	0.427	0.325	2.799
CD (0.05)	1.287	0.981	8.437

Table 2. Effect of pre-treatments on total sugar (%), reducing sugar (%) and protein (%) content of jackfruit seed flour

Treatments	Total sugar (%)	Reducing sugar (%)	Protein (%)
T_1 (Fermentation for 8 days)	10.00	8.00^{ab}	10.00^a
T_2 (Fermentation for 10 days)	8.83	6.65^{bc}	7.30 ^{b}
T_3 (Acidification for 5 days)	16.18	8.60^a	6.14^b
T_4 (Acidification for 8 days)	13.07	6.68^{bc}	3.14 ^{c}
T_5 (Control)	8.52	6.26^c	7.74^b
SE (±m)	2.015	0.52	0.551
CD (0.05)	NS	1.567	1.662

Table 3. Effect of pre-treatments on crude fibre (%), total ash (%) and crude fat (%) of jackfruit seed flour

Treatments	Crude fibre (%)	Total ash (%)	Crude fat (%)
T_1 (Fermentation for 8 days)	9.55^a	4.37 ^{a}	2.98
T_2 (Fermentation for 10 days)	9.18 ^{ab}	3.01 ^{c}	3.88
T_3 (Acidification for 5 days)	8.70 ^{ab}	3.31 ^{b}	2.80
T_4 (Acidification for 8 days)	8.48^b	2.17 ^{e}	3.18
T_5 (Control)	5.10^c	2.73^d	3.85
SE (±m)	0.353	0.089	0.287
CD (0.05)	1.063	0.269	NS

4.1.1.2. Titrable Acidity (%)

The treatment T_1(Fermentation for 8 days) had the highest observed titrable acidity of 2.20 % which had no significant difference with treatment T_2 (Fermentation for 10 days), T_3 (Acidification for 5 days) and T_4 (Acidification for 8 days). The treatment T_5 (Control) showed the lowest titrable acidity content of 0.56% for the jackfruit seed flour.

4.1.1.3. Starch (%)

The highest starch content of 66.28% was recorded for the treatment T_1 (Fermentation for 8 days) which recorded no significant difference with treatment T_2 (Fermentation for 10 days). The treatments T_3 (Acidification for 5 days) recorded a starch content of 52.43% which was on par with T_4 (Acidification for 8 days) whereas the treatment T_5(Control) recorded a starch content of 56.59%.

4.1.1.4. Total Sugar (%)

There was no significant difference between the treatments for total sugar, which varied from 8.52% to 16.18% (Table 2) depending on the jackfruit seed flour processing methods.

4.1.1.5. Reducing Sugar (%)

The processing methods for jackfruit seed flour influenced the reducing sugar content, which varied from 8.60% to 6.26% (Table 2). The treatments T_1 (Fermentation for 8 days) recorded a value of 8.00% whereas T_3 (Acidification for 5 days) recorded 8.60 % even though the difference was statistically non-significant. The treatment T_5(Control) showed the lowest reducing sugar content of 6.26%.

4.1.1.6. Protein (%)

The jackfruit seed flour obtained from the processing pre-treatment fermentation for 8 days (T_1) had the highest protein content of 10.00 % and treatment T_4 (Acidification for 8 days) recorded the lowest protein content of 3.14 % and the values are depicted in Table 2.

Table 4. Effect of pre-treatments on vitamin C (mg $100g^{-1}$), carotenoid (µg $100g^{-1}$) and antioxidant activity (%) of jackfruit seed flour

Treatments	Vitamin C (mg $100g^{-1}$)	Carotenoid (µg $100g^{-1}$)	Antioxidant activity (%)
T_1 (Fermentation for 8 days)	58.63^{a}	5.80^{a}	59.67^{c}
T_2 (Fermentation for 10 days)	29.53^{c}	5.69^{a}	69.96^{b}
T_3 (Acidification for 5 days)	26.87^{c}	4.69^{b}	58.39^{c}
T_4 (Acidification for 8 days)	49.81^{b}	4.42^{b}	79.98^{a}
T_5 (Control)	17.29^{d}	1.88^{c}	50.32^{d}
SE (±m)	2.747	0.262	1.367
CD (0.05)	8.281	0.791	4.121

Table 5. Effect of pre-treatments on functional properties of jackfruit seed flour

Treatments	Water absorption capacity (mL 100 g^{-1})	Oil absorption capacity (mL 100 g^{-1})	Swelling power (g g^{-1})
T_1 (Fermentation for 8 days)	103.16^{c}	76.00^{b}	1.17
T_2 (Fermentation for 10 days)	101.04^{c}	73.28^{b}	2.20
T_3 (Acidification for 5 days)	151.28^{b}	75.00^{b}	2.52
T_4 (Acidification for 8 days)	149.30^{b}	72.30^{b}	1.98
T_5 (Control)	169.18^{a}	84.28^{a}	2.37
SE (±m)	4.228	1.596	0.481
CD (0.05)	12.746	4.81	NS

4.1.1.7. Crude Fibre (%)

The crude fibre content of jackfruit seed flour ranged from 9.55% to 5.10% (Table 3). The highest crude fibre content of 9.55% was recorded for the treatment T_1 (Fermentation for 8 days), which showed no significant difference with T_2 (Fermentation for 10 days) and T_3(Acidification for 5 days). The jackfruit seed flour obtained from the control (T_5) treatment recorded the lowest crude fibre content of 5.10%.

4.1.1.8. Total Ash (%)

The total ash content of jackfruit seed flour was influenced by the processing methods (Table 3). The highest total ash (4.37%) was recorded for treatment T_1

(Fermentation for 8 days) and the lowest ash content (2.17 %) was recorded for acidification for 8 days (T_4).

4.1.1.9. Crude Fat (%)

There was no significant difference between the treatments for crude fat, which varied from 2.80% to 3.88% (Table 3) among the processing pre-treatments.

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

The different processing pre-treatments recorded difference in vitamin C content (Table 4) of jackfruit seed flour. The treatment T_1 (Fermentation process for 8 days) had the highest vitamin C content of 58.63%, while the treatment T_5 (Control) recorded the lowest vitamin C content of 17.29%.

4.1.1.11. Carotenoid (µg 100g^{-1})

The fermentation pre-treatments for 8 days (T_1) and 10 days (T_2) recorded no significant difference among the treatments which recorded the highest carotenoid content of 5.80 µg 100g^{-1} and 5.69 µg 100g^{-1} respectively. The treatment T_5 (Control) had the lowest carotenoid content of 1.88 µg 100g^{-1} and the values are depicted in Table 4.

4.1.1.12. Antioxidant Activity (%)

There was a significant difference in the antioxidant activity of jackfruit seed flour, obtained through various processing pre-treatments which varied between 50.32% and 79.98% (Table 4). The acidification process for 8 days (T_4) recorded the highest antioxidant activity of 79.98%, and treatment T_5 (Control) had the lowest antioxidant activity of 50.32%.

4.1.2. Functional Characteristics of Jackfruit Seed Flour

The functional characteristics 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. The effect of pre-treatments on the functional properties of jackfruit seed flour are depicted in Table 5.

Table 6. Effect of pre-treatments on yield (%), moisture content (%) and bulk density ($g\ cm^{-3}$) of jackfruit seed flour.

Treatments	Yield (%)	Moisture content (%)	Bulk density ($g\ cm^{-3}$)
T_1 (Fermentation for 8 days)	37.23	10.18 [b]	0.66[b]
T_2 (Fermentation for 10 days)	36.25	10.61 [ab]	0.64 [bc]
T_3 (Acidification for 5 days)	39.00	10.18 [b]	0.71[a]
T_4 (Acidification for 8 days)	38.13	8.50 [c]	0.72 [a]
T_5 (Control)	48.25	8.50 [c]	0.64 [c]
SE (±m)	3.368	0.316	0.006
CD (0.05)	NS	0.954	0.019

Table 7. Effect of pre-treatments on tapped density ($g\ cm^{-3}$), hausner factor and carr's index (%) of jackfruit seed flour

Treatments	Tapped density ($g\ cm^{-3}$)	Hausner factor	Carr's index (%)
T_1 (Fermentation for 8 days)	0.70	1.05	5.83[a]
T_2 (Fermentation for 10 days)	0.69	1.07	7.53[a]
T_3 (Acidification for 5 days)	0.73	1.02	2.55[b]
T_4 (Acidification for 8 days)	0.75	1.03	3.65[b]
T_5 (Control)	0.68	1.06	5.75[a]
SE (±m)	0.112	0.065	0.67
CD (0.05)	NS	NS	2.019

4.1.2.1. Water Absorption Capacity (mL 100g^{-1})

The water absorption capacity of jackfruit seed flour ranged from 101.04 mL $100g^{-1}$ to 169.18 mL $100g^{-1}$. The highest water absorption capacity of 169.18 mL $100g^{-1}$ was observed for the treatment T_5 (Control) and the lowest water absorption capacity of 101.04 mL $100g^{-1}$ was for the treatment T_2 (Fermentation for 10 days), which showed no significant difference with treatment T_1(Fermentation for 8 days).

4.1.2.2. Oil Absorption Capacity (mL 100 g^{-1})

The oil absorption capacity of jackfruit seed flour was influenced by processing methods, and the highest oil absorption capacity was recorded for treatment T_5 (Control) as 84.28 mL 100 g^{-1}. All other treatments T_1 (Fermentation for 8 days), T_2 (Fermentation for 10 days), T_3 (Acidification for 5 days), and T_4 (Acidification for 8 days) showed statistically no significant difference in oil absorption capacity even though it was 76.00 mL 100 g^{-1} for T_1 (Fermentation for 8 days) and the lowest as 72.30 mL 100 g^{-1} for T_4(Acidification for 8 days).

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

The highest swelling power of 2.52 g g^{-1} was recorded for treatment T_3 (Acidification for 5 days), and the lowest swelling power of 1.17 g g^{-1} was recorded for treatment T_1 (Fermentation for 8 days), although the results were found to be statistically non-significant.

4.1.3. Physical Properties of Jackfruit Seed Flour

The analysis results of physical properties of jackfruit seed flour obtained through various processing pre-treatments for yield (%), moisture content (%), bulk density (g cm^{-3}), tapped density (g cm^{-3}), Hausner factor, and Carr's index (%) are depicted in Table 6 and Table 7.

4.1.3.1. Yield (%)

The yield for jackfruit seed flour ranged from 36.25% to 48.25% (Table 6), with the highest yield (48.25%) in T_5 (Control) and the lowest (36.25%) in T_2 (Fermentation for 10 days) and the differences among the treatments were statistically non-significant.

4.1.3.2. Moisture Content (%)

The moisture content of jackfruit seed flour obtained through various processing pre- treatments ranged from 8.50% to 10.61% (Table 6). The treatment T_2 (Fermentation for 10 days) had the highest observed moisture content of 10.61%. The treatments T_4 (Acidification for 8 days) and T_5 (Control) both recorded the lowest moisture content of 8.50%

4.1.3.3. Bulk Density (g cm^{-3})

The jackfruit seed flour from the treatments T_3 (Acidification for 5 days) recorded a bulk density of 0.71 g cm^{-3} and T_4 (Acidification for 8 days) as 0.72 g cm^{-3} with no significant difference (Table 6). The lowest bulk density was recorded for the treatment T_5 (Control) and T_2 (Fermentation for 10 days) with a value of 0.64 g cm^{-3}.

Table 8. Compounds detected in aroma profiling of jackfruit seed flour using GC MS headspace analysis

Treatments	Compounds
T_1 (Fermentation for 8 days)	Dimethyl sulfide
	Acetic acid
	3-methylbutanal
	2-methyl-butyraldehyde
	2,2,4,6,6-pentamethylheptane
T_2 (Fermentation for 10 days)	Acetic acid
	3-methylbutanal
	2-methyl-butyraldehyde
	Capronaldehyde
	2,2,4,6,6-pentamethylheptane
T_3 (Acidification for 5 days)	Acetic acid
	3-methylbutanal
	2-methyl-butyraldehyde
	Hexanal
	2,2,4,6,6-pentamethylheptane
T_4 (Acidification for 8 days)	Acetic acid
	2-methyl-butyraldehyde
	2,2,4,6,6-pentamethylheptane
T_5 (Control)	Acetic acid
	3-methylbutanal
	2-methyl-butyraldehyde
	Methylbenzene
	2,2-dimethyl- decane

Table 9. Evaluation of sensory qualities of jackfruit seed flour

Treatments	Colour	Appearance	Flavour	Overall acceptability
T_1 (Fermentation for 8 days)	8.20	8.00	8.60	8.40
T_2 (Fermentation for 10 days)	8.00	7.60	7.60	8.00
T_3 (Acidification for 5 days)	7.60	7.20	7.00	7.00
T_4 (Acidification for 8 days)	7.00	6.80	6.60	6.60
T_5 (Control)	6.40	6.00	5.80	5.80
K	34.17	33.36	62.84	65.17
x^2 (0.05)	9.49			

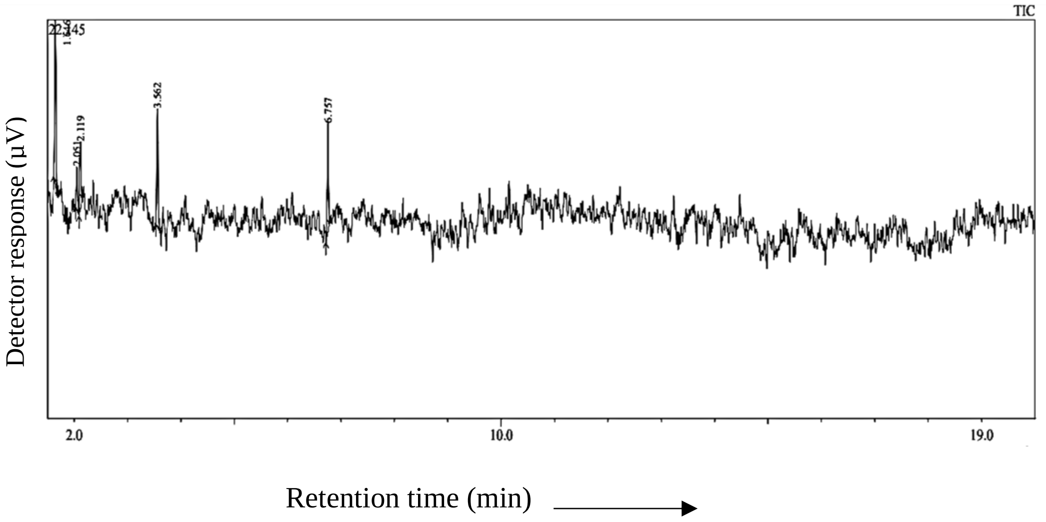


Fig 1. Chromatogram of aroma profiling of jackfruit seed flour with pre-treatment fermentation for 8 days

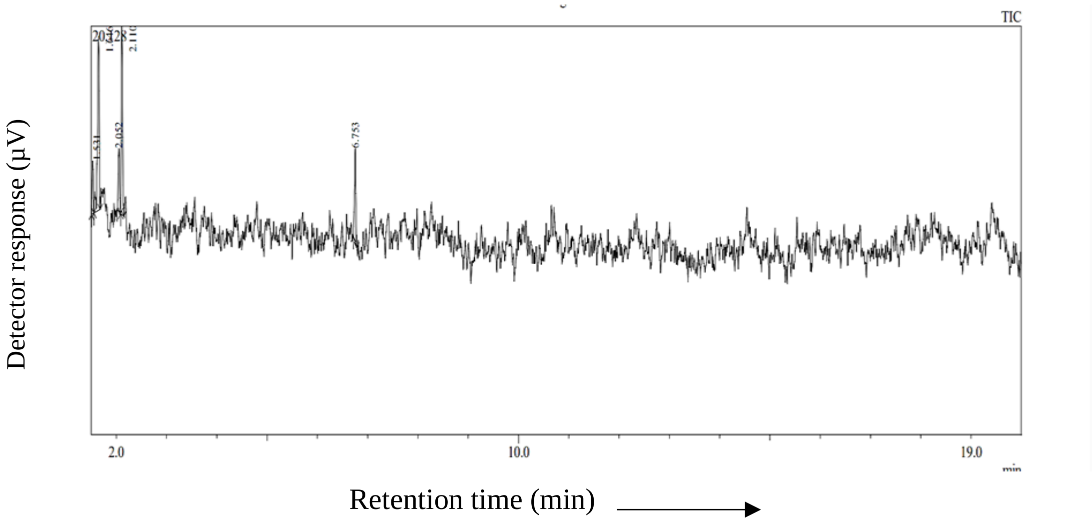


Fig 2. Chromatogram of aroma profiling of jackfruit seed flour with pre-treatment fermentation for 10 days

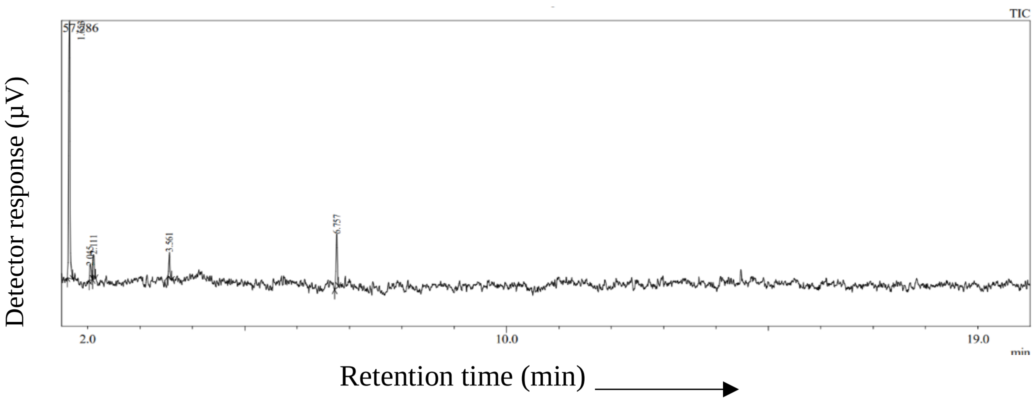


Fig 3. Chromatogram of aroma profiling of jackfruit seed flour with pre-treatment acidification for 5 days

4.1.3.4. Tapped Density (g cm^{-3})

Tapped density of jackfruit seed flour ranged from 0.68 g cm^{-3} to 0.75 g cm^{-3} (Table 7) with no significant difference among the treatments. The treatment T_4 (Acidification for 8 days) recorded the highest value of 0.75 g cm^{-3} and treatment T_5 (Control) recorded the lowest value of 0.68 g cm^{-3}, despite the values being statistically non-significant.

4.1.3.5. Hausner Factor

The processing pre- treatments of jackfruit seeds did not influence the Hausner factor of jackfruit seed flour and it varied from 1.02 to 1.07 (Table 7).

4.1.3.6. Carr's Index (%)

The Carr's index value of treatments T_1 (Fermentation for 8 days), T_2 (Fermentation for 10 days) and T_5 (Control) was recorded as 5.83%, 7.53% and 5.75% respectively even though the difference was found statistically non-significant (Table 7). The lowest value was recorded for T_3 (Acidification for 5 days) as 2.55% which was on par with T_4 (Acidification for 10 days) with a value of 3.65%

4.1.3.7. Aroma Profiling

The aromatic compounds detected in jackfruit seed flour obtained through various pre-treatments of jackfruit seeds using headspace analysis are depicted in Table 8. Aroma profiling of jackfruit seed flour through headspace analysis of GC /MS revealed that all the treatments of jackfruit seeds noticed the presence of 2,2,4,6,6-pentamethylheptane which was not present in jackfruit seed flour processed without any pre-treatments. The compound dimethyl sulfide was detected in the pre-treatment fermentation for 8 days (T_1) and capronaldehyde was detected in fermentation for 10 days (T_2) in addition to other compounds. The chromatograms of the aroma profiling of jackfruit seed flour is given as Fig. 1 to Fig. 5

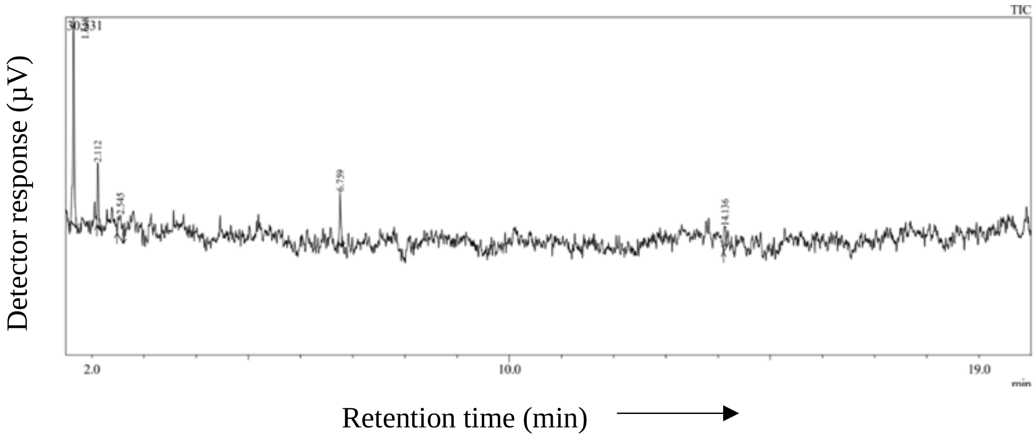


Fig 4. Chromatogram of aroma profiling of jackfruit seed flour with pre-treatment acidification for 8 days

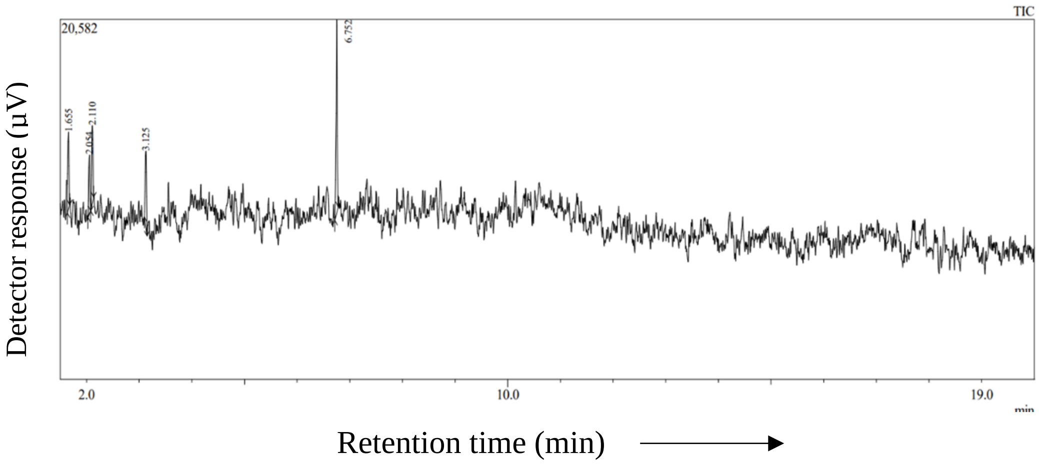


Fig 5. Chromatogram of aroma profiling of jackfruit seed flour without pre-treatment (Control)

4.1.4. Sensory Characteristics of Jackfruit Seed Flour

The 9-point hedonic scale was used to evaluate the sensory qualities of jackfruit seed flour and Table 9 summarises the mean scores for various sensory attributes *viz*., colour, appearance, flavour, and overall acceptability. The Kruskal- Wallis test revealed that the sensory scores varied significantly among the treatments.

The pre-treatment of jackfruit seeds, fermentation for 8 days (T_1) received the highest mean score of 8.20 for colour, and treatment T_5 (Control) recorded the lowest mean colour score of 6.40. The highest mean score value for appearance (8.00) was recorded for treatment T_1 (Fermentation for 8 days) and the lowest value of 6.00 for control (T_5). The range of the mean scores for flavour varied between 5.80 and 8.60 and the treatment T_1 (Fermentation for 8 days) recorded the highest score of 8.60 whereas the lowest score of 5.80 was for treatment T_5 (control). The overall acceptability mean scores for jackfruit seed flour processed through various pre-treatments ranged from 5.80 to 8.40 and the treatment T_1 (Fermentation for 8 days) recorded the highest score of 8.40 and control (T_5) recorded the lowest score of 5.80.

Based on the biochemical, functional, physical and sensory qualities, jackfruit seed flour processed after the pre-treatment, fermentation for 8 days was selected as the best aromatic jackfruit seed flour for the development of jackfruit seed flour cookies.

4.2. DEVELOPMENT OF JACKFRUIT SEED FLOUR COOKIES

The jackfruit seed flour with chocolate aroma processed from the selected best pre-treatment, fermentation for 8 days (T_1), was used for the development of jackfruit seed cookies at different proportions by replacing the refined wheat flour. The cookies prepared from the selected aromatic jackfruit seed flour (AJSF) were compared with jackfruit seed flour cookies (DJSF) and also refined wheat flour cookies (WF) with and without addition of cocoa powder. The biochemical, physical, anti-nutritional and sensory parameters were analysed for the developed cookies.

4.2.1. Biochemical Parameters of Jackfruit Seed Flour Cookies

Biochemical parameters *viz*., carbohydrate, crude protein, crude fibre, crude fat and total ash of jackfruit seed flour cookies were analysed and depicted in Table 10.

Table 10. Biochemical parameters of jackfruit seed flour cookies

Treatment formulations	Carbohydrate (%)	Crude protein (%)	Crude fibre (%)	Crude fat (%)	Total ash (%)
T_1 [AJSF(5%) + WF(95%)]	29.76^{abc}	10.25^{bc}	1.96^{bcde}	12.09	1.58^{de}
T_2 [AJSF(10%) + WF(90%)]	30.60^{abc}	10.53^{ab}	2.47^{abcd}	12.07	2.00^{cd}
T_3 [AJSF(15%) + WF(85%)]	32.92^{ab}	11.22^{ab}	2.72^{abc}	14.03	2.41^{bc}
T_4 [AJSF(20%) + WF(80%)]	33.33^{ab}	11.35^{a}	3.05^{ab}	14.08	2.79^{ab}
T_5 [AJSF(25%) + WF(75%)]	34.73^{a}	11.54^{a}	3.51^{a}	12.30	3.20^{a}
T_6 [DJSF (5%) + WF(95%)]	16.12^{f}	8.80^{def}	1.45^{de}	12.25	0.97^{ef}
T_7 [DJSF(10%) + WF(90%)]	16.92^{f}	8.61^{def}	1.53^{de}	11.97	1.18^{ef}
T_8 [DJSF(15%) + WF(85%)]	18.35^{f}	9.02^{de}	1.83^{cde}	12.13	1.23^{ef}
T_9 [DJSF(20%) + WF(80%)]	19.72^{ef}	9.15^{de}	2.04^{bcde}	13.58	1.42^{def}
T_{10} [DJSF(25%) +WF(75%)]	21.24^{def}	9.35^{ed}	2.35^{bcd}	12.31	1.55^{de}
T_{11}[WF(100%) with cocoa powder]	25.28^{cde}	8.29^{ef}	1.01^{e}	14.23	0.91^{f}
T_{12} [WF (100%) without cocoa powder]	27.22^{bcd}	7.90^{f}	1.19^{e}	14.99	0.89^{f}
SE(±m)	2.284	0.349	0.387	1.771	0.21
CD (0.05)	6.666	1.018	1.128	NS	0.613

AJSF-Aromatic jackfruit seed flour DJSF-Dried jackfruit seed flour WF- Refined wheat flour

4.2.1.1. Carbohydrate (%)

The carbohydrate content of jackfruit cookies varied from 16.12% to 34.73% (Table 10). Treatment T_5 [AJSF (25%) + WF (75%)] had the highest carbohydrate content of 34.73% which was at par with treatments T_1 [AJSF (5%) + WF (95%)], T_2 [AJSF (10%) + WF (90%)], T_3 [AJSF (15%) + WF (85%)], and T_4 [AJSF (20%) + WF (80%)]. The treatment T_6 [DJSF (5%) + WF (95%)] had the lowest carbohydrate content of 16.12%.

4.2.1.2. Crude Protein (%)

The highest protein content (11.54%) was noticed in treatment T_5 [AJSF (25%) + WF (75%)], which had no significant difference with treatments T_2 [AJSF (10%) + WF (90%)], T_3 [AJSF (15%) + WF (85%)], and T_4 [AJS (20%) + WF(80%)]. The lowest protein content (7.90%) was noticed in treatment T_{12} [WF (100%) without cocoa powder].

4.2.1.3. Crude Fibre (%)

The fibre content of jackfruit cookies ranged from 1.01% to 3.51% (Table 10). The treatment T_5 [AJSF (25%) + WF (75%) had the highest fibre content of 3.51% which showed statistically non-significant difference with treatments, T_2 [AJSF (10%) + WF (90%)], T_3 [AJSF (15%) + WF (85%)], and T_4 [AJS (20%) + WF(80%)]. The treatment T_{11} [WF(100%) with cocoa powder] recorded a crude fibre content of 1.01% and T_{12} [WF (100%) without cocoa powder] recorded 1.19% with no significant difference, which were the lowest crude fibre content .

4.2.1.4. Crude Fat (%)

There was no significant difference between the treatment combinations for crude fat, which varied from 11.97% to 14.99% (Table 10).

4.2.1.5. Total Ash (%)

Jackfruit cookies were evaluated for their total ash content, which varied from 0.89% to 3.20% (Table 10). The highest total ash content of 3.20% was observed for treatment T_5 [AJSF (25%) + WF (75%)], which showed no significant difference with treatment T_4 [AJS (20%) + WF (80%)]. There was no significant difference between treatments T_{11} [WF (100%) with cocoa powder] and T_{12} [WF (100%) without cocoa powder], which recorded the lowest (0.89%) total ash content.

4.2.2. Physical Parameters of Jackfruit Cookies

The physical parameters of jackfruit seed flour cookies *viz.,* yield, thickness, diameter and spread ratio were analysed and depicted in Table 11.

4.2.2.1. Yield (%)

The yield varied between 158.40 % (T_5 [AJSF (25%) + WF (75%)] and 141.57% (T_6 [DJSF (5%) + WF (95%)]) and the results were found statistically non-significant.

4.2.2.2. Thickness (cm)

The thickness of jackfruit cookies ranged from 0.95 cm to 1.12 cm with no significant difference among the treatments. The treatment T_1 [AJSF (5%) + WF (95%

recorded the highest value of 1.12 cm and treatment T_{10}[DJSF (25%) + WF(75%)] recorded the lowest value of 0.95 cm and the difference was statistically non-significant.

Table 11. Physical parameters of jackfruit seed flour cookies

Treatment formulations	Yield (%)	Thickness (cm)	Diameter (cm)	Spread ratio
T_1 [AJSF(5%) + WF(95%)]	142.30	1.12	4.71^{cdef}	4.19^{e}
T_2 [AJSF(10%) + WF(90%)]	145.13	1.05	4.39^{def}	4.17^{e}
T_3 [AJSF(15%) + WF(85%)]	150.37	1.01	4.21^{ef}	4.14^{e}
T_4 [AJSF(20%) + WF(80%)]	155.40	1.00	4.12^{f}	4.07^{e}
T_5 [AJSF(25%) + WF(75%)]	158.40	0.99	4.00^{f}	4.01^{e}
T_6 [DJSF (5%) + WF(95%)]	141.57	1.03	5.70^{abc}	5.68^{c}
T_7 [DJSF(10%) + WF(90%)]	144.76	1.01	5.45^{abcd}	5.42^{cd}
T_8 [DJSF(15%) + WF(85%)]	146.04	1.00	5.39^{abcde}	5.39^{cd}
T_9 [DJSF(20%) + WF(80%)]	149.88	0.98	5.10^{bcdef}	5.22^{d}
T_{10}[DJSF(25%) + WF(75%)]	151.00	0.95	4.89^{bcdef}	5.13^{d}
T_{11} [WF(100%) with cocoa powder]	146.88	0.99	6.10^{ab}	6.24^{b}
T_{12} [WF (100%) without cocoa powder]	150.23	0.96	6.47^{a}	6.76^{a}
SE(±m)	4.56	0.07	0.43	0.15
CD (0.05)	NS	NS	1.26	0.45

AJSF-Aromatic jackfruit seed flour DJSF-Dried jackfruit seed flour WF-Refined wheat flour

4.2.2.3. Diameter (cm)

The diameter of the jackfruit cookies varied from 6.47 cm to 4.00 cm (Table 11). The treatment T_{12} [WF (100%) without cocoa powder] recorded the highest value (6.47 cm) which showed statistically non-significant difference with treatment T11[WF(100%) with cocoa powder] and treatment T_4 [AJSF (20%) + WF(80%)] and T_5 [AJSF (25%) + WF (75%)] recorded the lowest value of 4.12 cm and 4.00 cm respectively.

4.2.2.4. Spread Ratio

The spread ratio of jackfruit cookies was influenced by both the diameter and thickness of the cookies. The treatment T_{12} [WF (100%) without cocoa powder] had the highest spread ratio of 6.76 and the treatment T_5 [AJSF (25%) + WF (75%)] recorded the lowest spread ratio of 4.01, which was on par with the treatments T_1 [AJSF(5%) + WF(95%)], T_2 [AJSF(10%) + WF(90%)], T_3 [AJSF(15%) + WF(85%)]and T_4 [AJSF(20%) + WF(80%)].

4.2.3. Antinutritional Factors of Jackfruit Cookies

The antinutritional factors, oxalate and phytate were analysed for all the formulations of jackfruit cookies could not be detected in all the combinations.

4.2.4. Sensory Qualities of Jackfruit Cookies

The 9-point hedonic scale was used to rate the sensory attributes of jackfruit cookies. The statistical analysis of sensory scores for a variety of attributes *viz.*, appearance, cracking, crumb colour, texture, mouthfeel, flavour, and overall acceptability is summarised in Table 12.

The range of the mean score for appearance varied between 5.20 and 8.80 and treatment T_1 [AJSF (5%) + WF (95%)] recorded the highest score of 8.80 whereas the lowest score of 5.20 was for treatment T_5 [AJSF (25%) + WF (75%)]. The treatment T_9 [DJSF (20%) + WF (80%)] had the highest mean cracking score (8.40), while T_{12} [WF (100%) without cocoa powder] had the lowest mean cracking score (6.00). The highest mean score value for crumb colour (8.40) was recorded with treatment T_5 [AJSF (25%) + WF (75%)] and the lowest value of 5.60 for treatment T_{12} [WF (100%) without cocoa powder]. For texture, treatment T_1 [AJSF(5%) + WF(95%)] and T_{12} [WF (100%) without cocoa powder] had the highest mean score (8.60), and treatments T_9 [DJSF(20%) + WF(80%)] and T_{10}[DJSF(25%) + WF(75%)] had the lowest mean score (7.00). For the mean score of mouthfeel, treatment T_2 [AJSF(10%) + WF(90%)] recorded the highest score of 8.60, while the mean scores for treatments T_7 [DJSF(10%) + WF(90%)] and T_9 [DJSF(20%) + WF(80%)] were the lowest (6.80). The range of the mean flavour scores for the treatments varied between 5.00 to 8.20. Treatments T_4 [AJSF (20%) + WF (80%)] and T_5 [AJSF (25%) + WF (75%)] recorded the highest

Table 12. Evaluation of sensory qualities of jackfruit seed flour cookies

Mean scores							
Treatment formulations	Appearance	Cracking	Crumb colour	Texture	Mouth feel	Flavour	Overall acceptability
T_1 [AJSF(5%) + WF(95%)]	8.80	6.20	6.00	8.60	8.00	7.40	7.40
T_2 [AJSF(10%) + WF(90%)]	8.40	6.40	6.20	8.20	8.60	7.60	8.60
T_3 [AJSF(15%) + WF(85%)]	7.20	6.80	6.60	7.80	7.20	8.00	7.20
T_4 [AJSF(20%) + WF(80%)]	6.20	7.00	7.80	7.40	7.40	8.20	6.60
T_5 [AJSF(25%) + WF(75%)]	5.20	7.20	8.40	7.20	7.00	8.20	6.60
T_6 [DJSF (5%) + WF (95%)]	7.00	7.60	6.00	7.80	7.00	6.00	6.40
T_7 [DJSF(10%) + WF(90%)]	6.60	7.80	6.40	7.60	6.80	6.20	6.40
T_8 [DJSF(15%) + WF(85%)]	6.40	8.20	7.00	7.40	7.00	6.60	5.80
T_9 [DJSF(20%) + WF(80%)]	5.80	8.40	7.60	7.00	6.80	7.00	5.80
T_{10}[DJSF(25%) + WF(75%)]	5.60	8.60	8.20	7.00	7.00	7.00	5.40
T_{11} [WF(100%) with cocoa powder]	6.80	6.20	6.80	8.40	7.60	7.20	6.40
T_{12} [WF (100%) without cocoa powder]	6.80	6.00	5.60	8.60	7.20	5.00	6.00
K	128.08	130.10	124.46	80.69	59.74	120.47	93.86
x^2 (0.05)	19.68						

AJSF-Aromatic jackfruit seed flour DJSF-Dried jackfruit seed flour WF- Refined wheat flour score of 8.20 and treatment T_{12} [WF (100%) without cocoa powder] recorded the lowest score of 5.00.

The mean score for overall acceptability for jackfruit cookies ranged from 5.40 to 8.60 and the treatment combination, T_2 [AJSF (10%) + WF (90%)] recorded the highest score of 8.60 and treatment T_{10} [DJSF (25%) + WF (75%)] recorded the lowest score of 5.40.

The biochemical, physical, and sensory analyses of jackfruit cookies developed with different combinations of jackfruit seed flour revealed that the formulation with 10 % aromatic jackfruit seed flour and 90 % refined wheat flour as the best formulation for the development of aromatic jackfruit seed flour cookies.

DISCUSSION

5. DISCUSSION

The findings from the research study “Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies” are discussed in this chapter as

1. Standardisation of processing methods for the development of chocolate aroma in jackfruit seed flour

2. Development of jackfruit seed flour cookies

5.1. STANDARDISATION OF PROCESSING METHODS FOR THE DEVELOPMENT OF CHOCOLATE AROMA IN JACKFRUIT SEED FLOUR

Jackfruit bulbs with seeds extracted from fully ripened jackfruit were subjected to different pre-treatments of fermentation and acidification and control as seeds without any pre-treatments. Jackfruit seeds after the pre-treatments were cleaned, dried (without spermoderm), roasted and milled to get jackfruit seed flour. The flour obtained were analysed for biochemical, physical, functional and sensory qualities. The processing pre-treatments influenced the quality of jackfruit seed flour.

5.1.1. Biochemical Parameters of Jackfruit Seed Flour

Total Soluble Solids (^{0}Brix), titrable acidity (%), starch (%), total sugar (%), reducing sugar (%), protein (%), crude fibre (%), total ash (%), crude fat (%), vitamin C (mg $100g^{-1}$), carotenoids (µg $100g^{-1}$) and antioxidant activity (%) of jackfruit seed flour processed after the pre-treatments were analysed.

The jackfruit seed flour exhibited total soluble solids (TSS) in the range of 1.35 ^{0}Brix to 3.48 ^{0}Brix among the treatments. The highest TSS content of 3.48 ^{0}Brix was recorded for the treatment fermentation for 8 days which showed no significant difference with treatments fermentation for 10 days and the seed flour processed without any pre-treatment (control). The acidification pre-treatment for 5 days and 8 days recorded the lowest TSS of 1.35 ^{0}Brix and 1.78 ^{0}Brix respectively with no significant difference. The TSS content of raw materials is an important criterion for the quality of processed food products. The jackfruit seed flour processing methods had an influence on its TSS content as reported by Kumar (2021) and recorded a higher TSS

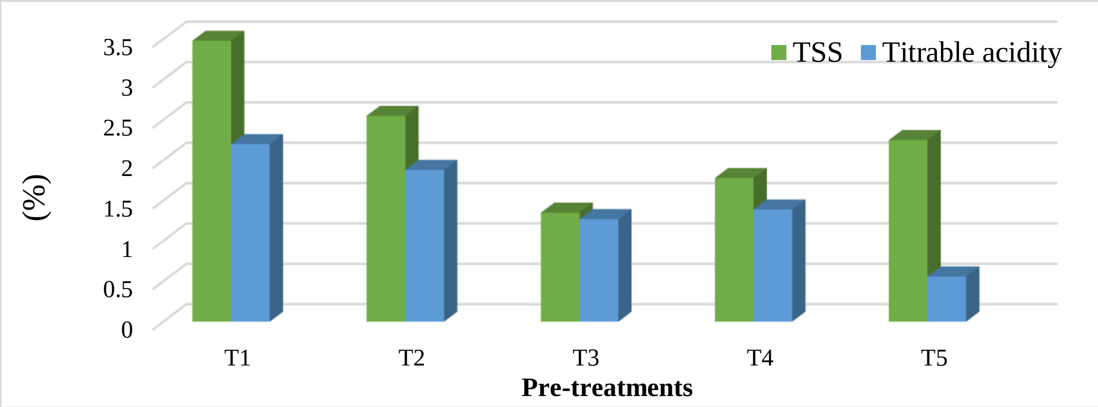


Fig 6. Effect of pre-treatments on TSS (0Brix) and titrable acidity (%) of jackfruit seed flour

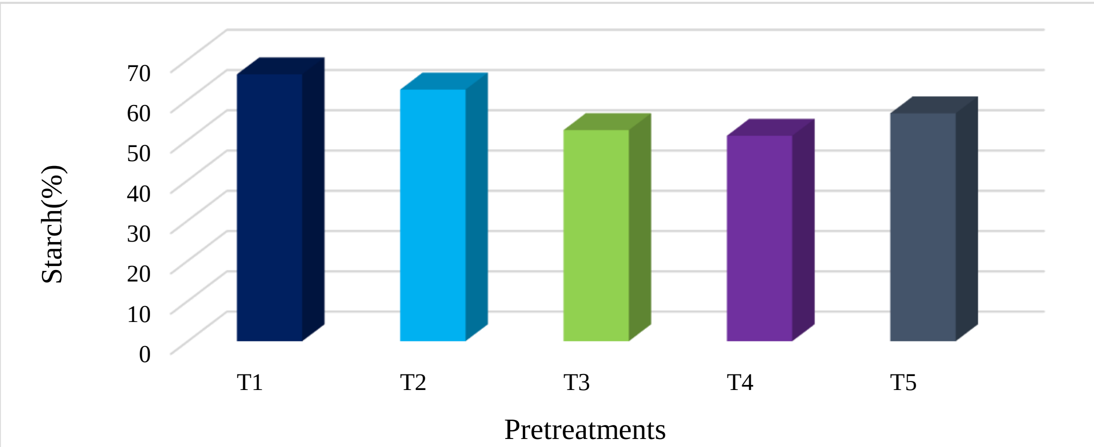


Fig 7. Effect of pre-treatments on starch content (%) of jackfruit seed flour

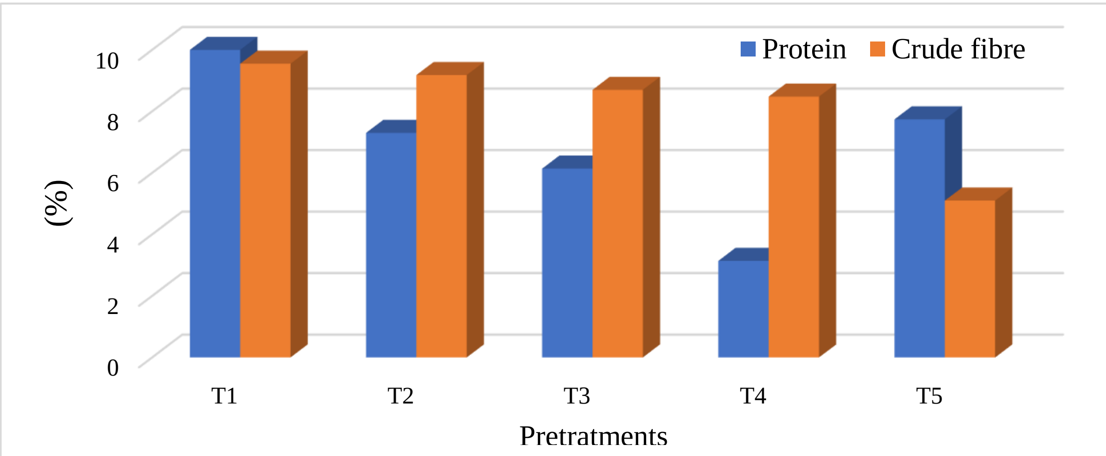


Fig 8. Effect of pre-treatments on Protein (%) and crude fibre (%) content of jackfruit seed flour

of 3.03 ^{0}Brix for seed flour obtained through oven drying as compared to pressure cooking and pan roasting methods.

The titratable acidity provides a measurement of the acid content and values are used to evaluate the flour quality of jackfruit seed flour. Ocloo *et al*. (2010) reported a titratable acidity of 1.18% in jackfruit seed flour. In the present study, the jackfruit seed flour obtained after fermentation of 8 days recorded the highest titrable acidity (2.20%) which had no significant difference with treatments fermentation for 10 days and acidification process of 5 and 8 days. The jackfruit seed flour without pre-treatment recorded an acidity of 0.56% which indicate that pre-treatments increased the acidity of jackfruit seed flour. An acidity of 0.08% in jackfruit seed flour was reported by Morshed *et al*. (2019) and Spada *et al*. (2017) recorded a wide range of titratable acidity in fermented jackfruit seed flour, with a general trend of an increase as pH decreased.

The fermentation process of jackfruit seeds increased the starch content of jackfruit seed flour. The highest starch content was recorded for the pre-treatment of fermentation for 8 days (66.28%) which recorded no significant difference with pre-treatment fermentation for 10 days (62.50%). The acidification treatments of 5 days recorded a starch content of 52.43% which was on par with pre-treatment acidification for 8 days and jackfruit seed flour processed without any pre-treatments recorded starch content of 51.03%. Ejiofor *et al.* (2014) and Kushwaha *et al*. (2020) reported that the starch content of jackfruit seed flour is influenced by the variety, maturity and jackfruit seed flour processing methods.

The total sugar content of jackfruit seed flour ranged from 8.52% to 16.18% and the pre-treatments did not influence the total sugar content whereas the reducing sugar content varied with the pre-treatments. The pre-treatment acidification for 5 days showed the highest reducing sugar content of 8.60% which recorded no significant difference with pre-treatment fermentation for 8 days and the control treatment recorded lowest reducing sugar content of 6.26%. Ejiofor *et al.* (2014) reported that the sugar contents of jackfruit seed flour ranged from 0.50% to 2.48%, with roasted jackfruit seed flour having the highest sugar content and autoclaved jackfruit seed flour having the lowest. According to Leite *et al.* (2020) reducing sugar content of jackfruit seed flour

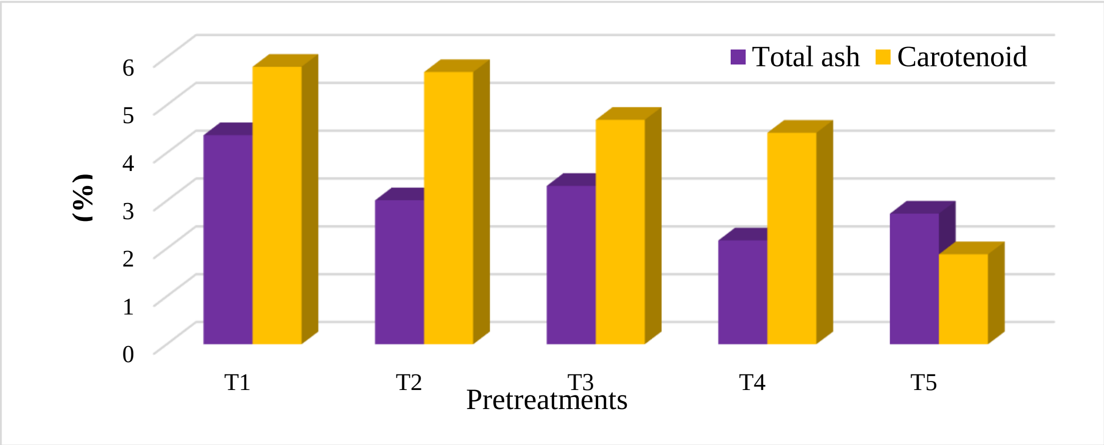


Fig 9. Effect of pre-treatments on total ash (%) and carotenoid (µg 100g-1) content of jackfruit seed flour

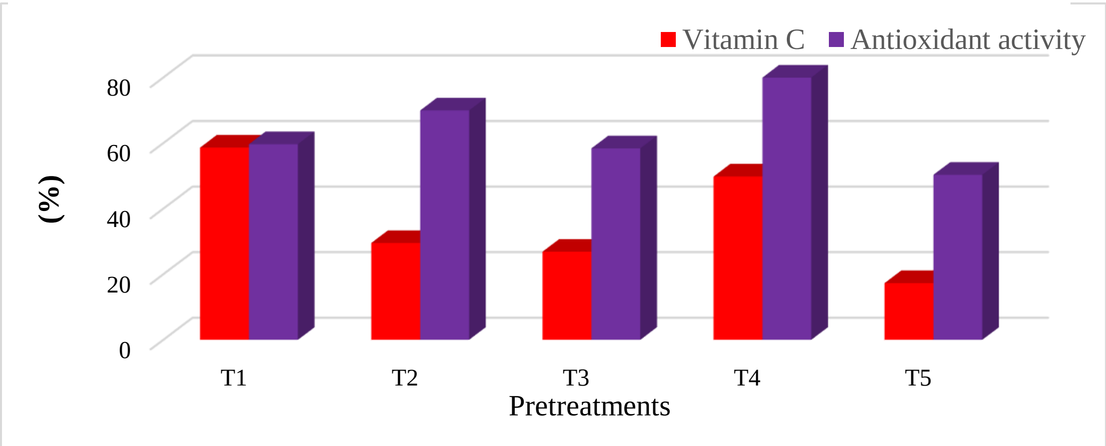


Fig 10. Effect of pre-treatments on vitamin C (mg 100g^{-1}) and antioxidant activity (%) of jackfruit seed flour

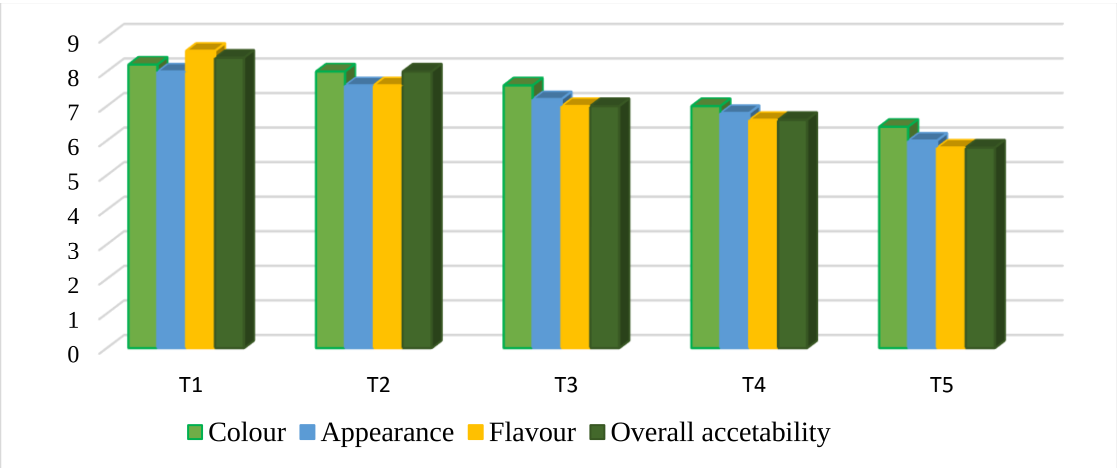


Fig 11. Evaluation of sensory qualities of jackfruit seed flour

varied from 1.66% (germinated) to 1.85% and the germination of jackfruit seed reduced the amount of reducing sugars.

The protein content of jackfruit seed flour increased with the fermentation process. The fermentation of jackfruit seeds for 8 days had the highest protein content of 10.00 % and the acidification pre-treatment for 8 days recorded the lowest protein content of 3.14 %. This was similar to the findings of Spada *et al.* (2017) who reported that the protein content of dried jackfruit seed flour, acidified jackfruit seed flour, and fermented jackfruit seed flour were 11.20%, 11.16%, and 14.82%, respectively. The processing methods of jackfruit seed flour influenced the protein content and the roasting of jackfruit seeds recorded higher protein content as reported by Ejiofor *et al.* (2014) and Kumar (2021).

The crude fibre content in jackfruit seed flour ranged from 5.10 to 9.55% among the various pre-treatments. The highest crude fibre content of 9.55% was recorded for the pre-treatment, fermentation for 8 days which showed no significant difference with pre-treatments fermentation for 10 days and acidification for 5 days. The lowest crude fibre content (5.10%) was recorded for the control treatment. The Pre-treatment fermentation for 8 days recorded the highest total ash content of 4.37% and pre-treatment acidification for 8 days recorded the lowest ash content (2.17%). The crude fat of jackfruit seed flour ranged from 2.80% to 3.88% and was without any influence of pre-treatments.

This was reliable with the results of Spada *et al.* (2017) who stated that dried jackfruit seed flour had crude fibre content of 10.34%, while acidified jackfruit seed flour had crude fibre content of 9.29%, and fermented jackfruit seed flour had a crude fibre content of 18.9%. They also reported that dried jackfruit seed flour had the lowest ash content (2.90%), followed by acidified jackfruit seed flour (2.44%), and fermented jackfruit seed flour (4.70%) and crude fat content of 0.40%, 0.30%, and 0.50% for dried jackfruit seed flour, acidified jackfruit seed flour, and fermented jackfruit seed flour respectively.

The vitamin C content of jackfruit seed flour varied with the processing pre-treatment and the highest vitamin C content of 58.63% was observed for the pre-treatment fermentation for 8 days and the seed flour without any pre-treatment (control) had the lowest vitamin C content of 17.29%. The carotenoid content of jackfruit seed flour ranged from 1.88 µg $100g^{-1}$ to 5.80 µg $100g^{-1}$. Carotenoid content varied between treatments, and fermentation treatment for 8 days recorded the highest value of 5.80 g $100g^{-1}$ which was on par with treatment fermentation for 10 days. The control treatment had the lowest carotenoid content of 1.88 g 100g-^{1}. The acidification pre-treatment for 8 days recorded the highest antioxidant activity of 79.98%, and the lowest antioxidant activity of 50.32% was recorded for the jackfruit seed flour processed without any pre-treatment.

Zuwariah *et al*. (2018) reported that vitamin C content affected nutritional value after processing and germinated jackfruit seed flour had the highest concentration of vitamin C (78.78 mg 100 g^{-1}), followed by raw jackfruit seed flour (31.98 mg 100 g^{-1}) and thermally processed jackfruit seed flour (21.71 mg 100 g^{-1}). According to Morshad *et al*. (2019), the vitamin C content of jackfruit flour was 55.82 mg 100 g^{-1} at the time of storage and 50.03 mg 100 g^{-1} at the end of storage and there was a decrease in vitamin C content during storage. Jackfruit seed flour obtained through oven drying recorded a carotenoid content of 5.64 µg $100g^{-1}$ and pressure-cooking method decreased the carotenoids in jackfruit seed flour (Kumar, 2021).

Roasting conditions increased the phenolic content and antioxidant activity due to the formation of Maillard products and enhanced polyphenol solubility (Srour *et al*., 2016) and according to Kushwaha *et al*. (2020), the antioxidant activity of jackfruit seed flour ranged from 7.00% to 53.78%.

5.1.2. Functional Properties of Jackfruit Seed Flour

In food processing, the functional properties are important for the development of new products (Akter and Haque, 2018). Functional characteristics *viz*., water absorption capacity (mL 100 g^{-1}), oil absorption capacity (mL 100 g^{-1}) and swelling power (g g-1) were analysed for the jackfruit seed flour.

The water absorption capacity of jackfruit seed flour varied from 101.04 mL $100g^{-1}$ to 169.18 mL $100g^{-1}$. The highest water capacity (169.18 mL $100g^{-1}$) was recorded for the control and the lowest water absorption capacity of 101.04 mL $100g^{-1}$ was recorded for the pre-treatment fermentation for 10 days and 8 days. In the present oil absorption capacity of jackfruit seed flour was influenced by processing methods and the highest oil absorption capacity (84.28 mL 100 g^{-1}) was recorded for jackfruit seed flour without any pre-treatment (control). The pre-treatment acidification for 8 days recorded lowest value of 72.30 mL 100 g^{-1} which showed no significant difference with treatments acidification for 5 days and fermentation pre-treatments of 8 and 10 days. The swelling power of jackfruit seed flour was not influenced by the processing pre-treatments and there was no significant difference between the treatments.

According to Chowdary *et al*. (2012) due to the high oil absorption capacity of jackfruit seed flour, it has the potential to develop bakery products like cakes and cookies. Ejiofor *et al*. (2014) reported that the oil absorption value of dried jackfruit seed flour is higher than that of roasted jackfruit seed flour. In chocolate products, one of the most important functional properties is swelling power or water uptake (Dogan *et al*., 2016). Heat processing affected the water absorption capacity of jackfruit seed flour. The water absorption capacity of the jackfruit seed flour ranged from 147.85% to 233.72% and oil absorption capacity was in the range of 67.91% to 102.42% as reported by Kushwaha *et al*. (2020). Spada *et al*. (2020) reported that even under various conditions of moisture, temperature, and exposure time, the water uptake values of dried jackfruit seed flour, acidified jackfruit seed flour and fermented jackfruit seed flour were close to the values for cocoa powder.

5.1.3. Physical Parameters of Jackfruit Seed Flour

Physical parameters *viz*., yield (%), moisture content (%), bulk density (g cm^{-3}), tapped density (g cm^{-3}), Hausner factor and Carr's index (%) of jackfruit seed flour processed after the pre-treatments were analysed.

The yield of jackfruit seed flour ranged from 36.25% to 48.25% and there was no significant difference between the treatments. The moisture content of jackfruit seed flour obtained through various processing pre-treatments ranged from 8.50% to 10.61%. The pre-treatment fermentation for 10 days had the highest observed moisture content of 10.61%. The flour processed without pre-treatment (control) and pre-treatment acidification for 8 days recorded the lowest moisture content of 8.50%. The bulk density of jackfruit seed flour varied from 0.64 g cm-3 to 0.72 g cm^{-3}. The highest bulk density was recorded for pre-treatment acidification for 5 days (0.71 g cm^{-3}) and acidification for 8 days (0.72 g cm^{-3}). The lowest bulk density of 0.64 g cm^{-3} was recorded for jackfruit seed flour processed without any pre-treatments and fermentation for 10 days.

Jackfruit seed flour had similar or lower moisture content and water activity as compared to cocoa powder, which is essential to limit microbial growth in the flour as reported by Spada *et al*. (2017). They also observed that flour yield from dried jackfruit seed flour, acidified jackfruit seed flour, and fermented jackfruit seed flour was 48, 45%, and 40% respectively. The bulk density of jackfruit seed flour prepared through different processing methods ranged from 0.70 g cm^{-3} to 0.82 g cm^{-3} with the highest value for seed flour through pressure cooking method (Kumar, 2021).

The tapped density and Hausner factor of jackfruit seed flour was not influenced by the pre-treatments and tapped density ranged from 0.68 g cm^{-3} to 0.75 g cm^{-3} and Hausner factor, varied from 1.02 to 1.07. The Carr's index indicate the compressibility of flour and it ranged from 2.55 % to 7.53% for the jackfruit seed flour processed after various pre-treatments. The treatment fermentation for 10 days recorded highest Carr's index value of 7.53% which was on par with treatment fermentation for 8 days and control. The lowest Carr's index value of 2.55% was recorded pre-treatment acidification for 5 days with no significant difference with acidification for 8 days.

With increasing drying temperature, the tapped density tends to decrease (Leite *et al*., 2020). Spada *et al*. (2020) reported that roasting temperature reduced viscosity, a property associated with amylose content by depolymerizing the starchy matrix and limiting the starch granules ability to expand during the gelatinization process. Due to its viscosity characteristics, roasted jackfruit seed flour could potentially replace cocoa powder and could be used in food products without the need for drying, acidification, or fermentation processes.

The ratio between the bulk and tapped densities was used to develop the Hausner Factor, which assesses the fluidity of materials. Quispe-Condori *et al*. (2011) reported that Hausner value between 1.25 and 1.5 require the addition of adjuvants to improve flow; values less than 1.25 indicate good flow, while values greater than 1.5 indicate poor flow and the Hausner factor for the jackfruit seed flour obtained through various processing pre-treatments were with in this range. Santhalakshmy *et al*. (2015) reported that increases in temperature or air velocity had no effect on the Carr's Index, which also indicated the fluidity of powder and flour and good fluidity is represented by Carr's index values between 15-20%, poor fluidity by 20-35%, bad fluidity by 35-45%, and very poor fluidity by Carr's index values greater than 45%.

Aroma profiling of jackfruit seed flour through headspace analysis of GC /MS revealed that all the treatments of jackfruit seeds noticed the presence of 2,2,4,6,6-pentamethylheptane which was not present in jackfruit seed flour obtained without any pre-treatments. According to Spada *et al.* (2017) roasting conditions, time and temperature were affected by the aroma compounds in the jackfruit seed flour. Spada *et al*. (2021) studied the aroma compounds found in roasted jackfruit seed flours and noticed different aroma profiles when the seeds were subjected to drying and acidification as compared to fermentation before drying and roasting.

5.1.4. Sensory Characteristics of Jackfruit Seed Flour

The processing pre-treatments of jackfruit seed flour affected the sensory quality attributes of jackfruit seed flour. The highest mean score value for colour (8.20), appearance (8.00), flavour (8.60), and overall acceptability (8.40) was recorded for the pre-treatment fermentation for 8 days and the lowest score was recorded for the control treatment.

The acidification or fermentation process prior to roasting of jackfruit seed yielded chocolate aroma in the jackfruit seed flour was reported by Spada *et al*. (2017) and the roasted jackfruit seed flour was used in cappuccinos as a substitute for cocoa powder (Spada, *et al*., 2018).

5.2. DEVELOPMENT OF JACKFRUIT SEED FLOUR COOKIES

Jackfruit seed flour with chocolate aroma (aromatic jackfruit seed flour (AJSF) obtained from pre-treatment of fermentation for 8 days was used for the preparation of jackfruit seed flour cookies with chocolate aroma. Aromatic jackfruit seed flour (AJSF) was combined with refined wheat flour (WF) in different proportions. The jackfruit seed flour obtained without any pre-treatments (Dried Jackfruit Seed Flour) of jackfruit seeds was also used for cookie preparation. The refined wheat flour (WF) was replaced with aromatic jackfruit seed flour (AJSF) as well as jackfruit seed flour (DJSF) at different proportions for the preparation of cookies and were compared with cookies from refined wheat flour with and without the addition of cocoa powder.

5.2.1. Biochemical Parameters of Jackfruit Cookies

Biochemical parameters *viz*., carbohydrate (%), crude protein (%), crude fibre (%), crude fat (%) and total ash (%) of jackfruit seed cookies were analysed.

The carbohydrate content of jackfruit cookies varied from 16.12% to 34.73%. The cookies developed with aromatic jackfruit seed flour (25%) and refined wheat flour (75%) recorded the highest carbohydrate content of 34.73% which was at par with cookies formulation of 5% AJSF and 95% RF, 10% AJSF and 90% RF, 15% AJSF and 85% RF, 20% AJSF with 80% RF. The lowest carbohydrate content (16.121%) was observed for the formulation of jackfruit seed flour from the drying process without any pre-treatment (5%) and refined wheat (95%) which showed no significant difference with dried jackfruit seed flour cookies with 10% and 15% formulations. The crude protein content of jackfruit seed flour cookies varied from 7.90% to 11.54% and the cookies with aromatic jackfruit seed flour (25%) recorded the highest values of 11.54% for protein and which showed no significant difference with treatment formulation of 5% AJSF, 10% AJSF,15%AJSF and 20% AJSF with refined wheat flour. The roasting / thermal processing might have increased the protein content of jackfruit seed flour which improved the protein content of cookies prepared with the addition of aromatic jackfruit seed flour as reported by Zuwariah *et al*. (2018) and Borgis *et al*. (2020). The treatment formulation with 25% AJSF and 75% WF had the highest crude fibre content of 3.51% which showed no significant difference with cookies prepared from 10%, 15% and 20% aromatic jackfruit flour with refined wheat flour while the treatment with 100% WF with cocoa powder and without cocoa powder recorded the lowest crude fibre content of 1.01 % and 1.19% respectively. The crude fat content of the cookies was not influenced by the treatment formulations and the total ash content of jackfruit cookies varied from 0.89% to 3.20%. The highest total ash content of 3.20% was observed for treatment formulation of 25% AJSF and 75% WF which showed no significant difference with formulation of 20% AJSF and 80% WF. The control treatments (refined

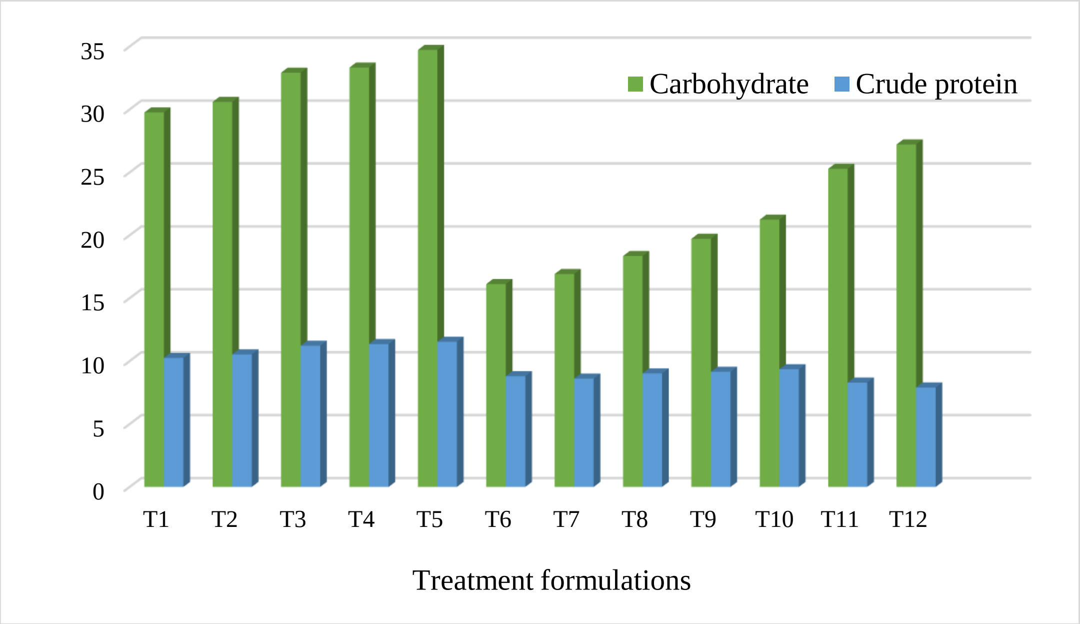


Fig 12. Carbohydrate (%) and crude protein (%) content of jackfruit seed flour cookies

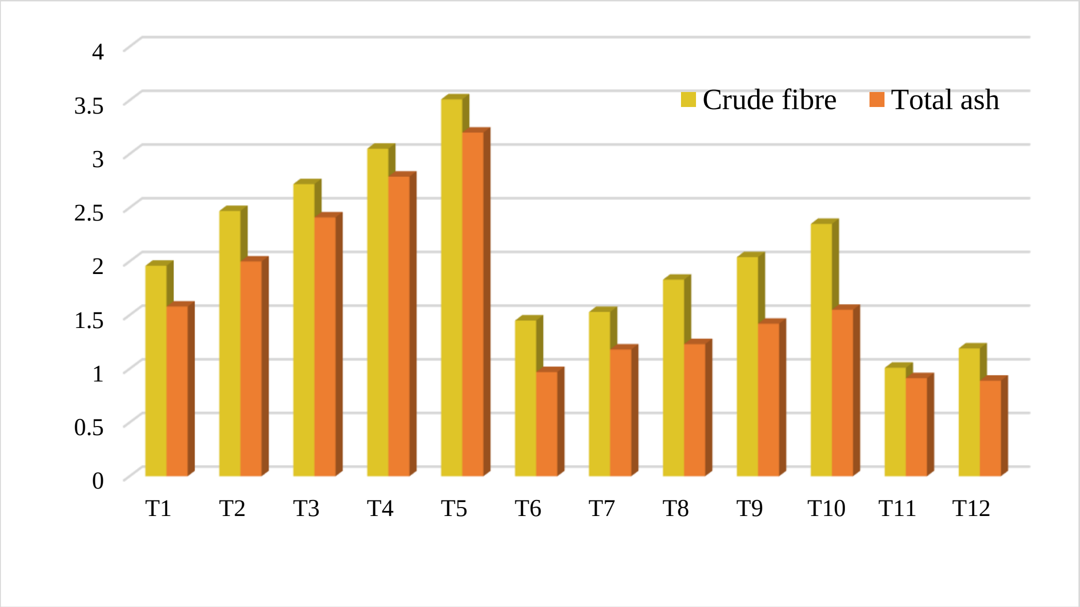


Fig 13. Crude fibre (%) and total ash (%) content of jackfruit seed flour cookies

wheat flour with cocoa powder and without cocoa powder) recorded the lowest ash content (0.91 % and 0.89% respectively).

These results are in line with the findings of Maskey *et al*. (2020) who reported 2.78% of crude fibre, 12.80% crude protein, 26.39% crude fat, and 1.43% total ash content in jackfruit cookies with 12.5% jackfruit seed flour. Ramya *et al*. (2020) reported that total carbohydrates in cookies were found to increase with the replacement of jackfruit rind flour and cookies with 15% jackfruit rind flour resulted in higher carbohydrate content of 64.56%.

5.2.2. Physical Parameters of Jackfruit Cookies

The increasing proportion of jackfruit seed flour in cookies had an effect on their physical parameters *viz*., yield (%), thickness (cm), diameter (cm), and spread ratio.

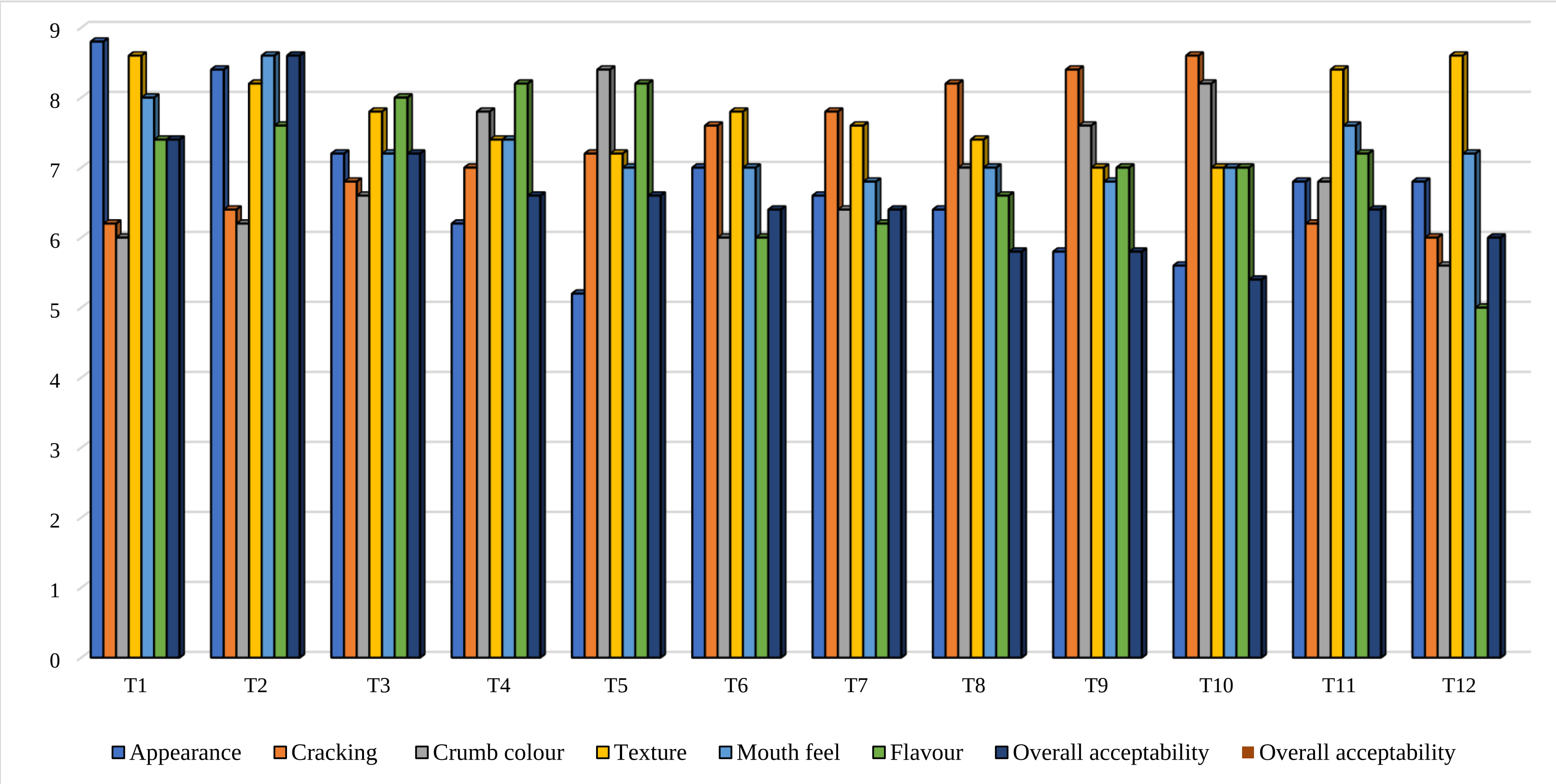
The yield of jackfruit seed flour cookies varied from 141.57% to 158.40% and there was no significant difference between the treatments. Quast *et al*. (2016) presented similar results for the yield of cookies which varied from 84.4% to 87.5% for taro flour cookies and the yield did not differ significantly between the different combinations of taro flour addition. The thickness of the jackfruit seed flour cookies was not significantly different between the treatments and varied from 0.95 cm to 1.12 cm. The diameter of jackfruit seed flour cookies was reduced with the addition of jackfruit seed flour however aromatic jackfruit seed flour (25%) cookies had lowest value (4.00 cm) for diameter which was on par with the formulation of 20% aromatic jackfruit seed flour and 80% refined wheat flour. The highest value of 6.47 cm for diameter was recorded for cookies with 100% refined wheat flour without cocoa powder which showed no significant difference with the treatment 100% refined wheat flour with cocoa powder. Maurya (2017) observed that the diameter of cookies decreased as the quantity of jackfruit seed flour increased. The diameter of jackfruit seed flour cookies varied from 0.89% to 0.95% (Maskey *et al*., 2020). The spread ratio of jackfruit seed flour cookies varied from 4.01 to 6.76 and decreased with an increasing amount of jackfruit seed flour and aromatic jackfruit seed flour cookies had a lower spread ratio than dried jackfruit seed flour cookies. The treatment formulation of 100% refined wheat flour without cocoa powder had the highest spread ratio (6.76) and the replacement of refined wheat flour with aromatic jackfruit seed flour decreased the spread ratio. The spread factor might have decreased as a result of the gluten being reduced with increased levels of replacement of wheat flour (Chowdhury *et al*., 2012). The biscuit prepared with jackfruit seed flour and coconut milk residue recorded a spread ratio in the range of 8 to 10 (Barge and Divekar, 2018).

5.2.3. Anti-nutritional Factors of Jackfruit Cookies

In the present study**,** anti-nutritional factors were not detected in jackfruit seed flour cookies. According to Abiola *et al.* (2018), the roasted samples had the highest percentage reduction in all the anti-nutrients when compared to the fermented sample (tannin, phytate, oxalate, and saponin). Attaugwu *et al.* (2018) reported that fermentation, roasting, and boiling treatments reduced anti-nutritional factors like oxalate, phytate, tannin, trypsin inhibitor, and haemagglutinin.

5.2.4. Sensory Qualities of Jackfruit Cookies

Sensory analysis plays an important role in quality control, estimating shelf life, and determining factors influencing consumer preferences. Sensory qualities *viz*., appearance, cracking, crumb colour, texture, mouthfeel, flavour and overall acceptability, were analysed for jackfruit seed flour cookies. The jackfruit seed flour cookies formulation with 5 % aromatic jackfruit seed flour and 95% refined wheat flour recorded the highest mean score of 8.80 for appearance and the lowest score (5.20) was recorded for cookies with 25% aromatic jackfruit seed flour. The appearance mean score decreased as the amount of jackfruit seed flour increased as the darker colour of jackfruit seed flour made cookies darker than other types of flour. In the present study, the cracking of jackfruit seed flour cookies varied from 6.00 to 8.60. The increase in cracking might be due to the replacement of refined wheat flour with jackfruit seed flour. The cookies with dried jackfruit seed flour cookies had cracking than aromatic jackfruit seed flour cookies and dried jackfruit seed flour (20%) with refined wheat flour (80%) cookie recorded the highest cracking mean score of 8.40 while cookies prepared from refined wheat flour without cocoa powder recorded the lowest cracking score of 6.00. The highest texture score (8.60) was obtained for refined wheat flour without cocoa powder and aromatic jackfruit seed flour formulation with 5% aromatic jackfruit seed flour and 95% refined flour cookies. There was a slight decrease in texture when



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Mouth feel
Flavour
Overall acceptability
Overall acceptability

the amount of jackfruit seed flour was increased; however, aromatic jackfruit seed flour cookies had higher mean score for texture as compared to dried jackfruit seed flour. The aromatic jackfruit cookies formulation with 10% aromatic jackfruit seed flour and 90% refined wheat flour had the highest value for mouthfeel (8.60) and with a good flavour (7.60). It was observed that when the amount of aromatic jackfruit seed flour increased, the flavour of the cookies also increased. The overall acceptability score (8.60) of 10% aromatic jackfruit seed flour cookies was higher as compared to all other formulations.

Similar results were obtained by Maskey *et al*. (2020) for appearance, crumb colour, and texture. Appearance score might have decreased as the amount of jackfruit seed flour increased because the darker colour of jackfruit seed flour made cookies darker than other formulations. The crumb colour of jackfruit seed cookies improved as the amount of jackfruit seed flour increased. Ramya *et al*. (2020) reported decreased mean sensory scores for texture with increase in the amount of jackfruit rind flour in preparation of cookies. The jackfruit seed flour could be used as a substitute for cocoa powder and 10 % substitution did not alter the characteristics of chocolate (Ravindran

Fig 14. Sensory evaluation of jackfruit seed flour cookies

SUMMARY

6. SUMMARY

The present study entitled "Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies" was carried out in the Department of Postharvest Management, College of Agriculture, Vellayani during the period 2020-2022, with the objective of standardisation of processing methods for the development of chocolate aroma in jackfruit seed flour and assessment of its suitability for jackfruit cookies with functional properties. The experiment was conducted in two parts, the standardisation of processing methods for the development of chocolate aroma in jackfruit seed flour and the standardisation of cookies with jackfruit seed flour are summarised below.

Jackfruit seeds with bulbs extracted from fully ripened jackfruit were subjected to different pre-treatments of fermentation and acidification. The jackfruit seeds after the pre-treatments were cleaned, dried (without spermoderm), roasted and milled to get jackfruit seed flour. The flour obtained were analysed for biochemical, physical, functional and sensory qualities. The processing pre-treatments were fermentation for 8 days, fermentation for 10 days, acidification for 5 days, acidification for 8 days and control (without pre-treatments). After the pre-treatment, the seeds were washed and dried after removing the spermoderm in a hot air oven at 60^{o}C for 2 hours. The seeds were then roasted (170^{o}C, 30 minutes) and milled to obtain the jackfruit seed flour. The jackfruit seeds without any treatment were dried in hot air oven at 60^{o}C for 2 hours after removing the spermoderm and then roasted at 170^{o}C for 30 minutes and milled.

Biochemical qualities *viz*., TSS (^{0}Brix), titrable acidity (%), starch (%), total sugar (%), reducing sugar (%), protein (%), crude fibre (%), total ash (%), crude fat (%), vitamin C (mg 100g^{-1}), carotenoids (mg 100 g^{-1}) and antioxidant activity (DPPH assay) were analysed for jackfruit seed flour obtained through various pre-treatments. The TSS content of jackfruit seed flour varied from 1.35 ^{0}Brix to 3.48 ^{0}Brix and the highest TSS content (3.48 ^{0}Brix) was recorded for the treatment fermentation for 8 days, fermentation for 10 days and control. The lowest TSS of 1.35 ^{0}Brix was recorded for the treatment acidification for 5 days and 8 days. The fermentation pre-treatments of 8 and 10 days and acidification pre-treatments of 5 and 8 days were recorded the highest titrable acidity. The lowest titrable acidity (0.56%) was noticed for the jackfruit seed flour processed without any pre-treatments. The starch content of jackfruit seed flour varied from 51.03% to 66.28% and the highest starch content of 66.28% and 62.50% was recorded for the treatment fermentation for 8 days and 10 days respectively and the lowest starch content (51.03% and 56.59%) was observed for the treatment acidification for 5 days and 8 days. The total sugar content of jackfruit seed flour ranged from 8.52% to 16.18% with no significant difference among the treatments. The highest reducing sugar content was recorded for the treatment fermentation of jackfruit seeds for 8 days (8.00%) and acidification of jackfruit seeds for 5 days (8.60%) and the lowest reducing content (6.26%) was recorded for the control. The highest protein content (10.00%) of jackfruit seed flour was recorded for the seeds with the pre-treatment, fermentation (for 8 days) and treatment acidification for 8 days recorded the lowest protein content of 3.14%. The crude fibre content of jackfruit seed flour was observed the highest for fermentation for days 8 days (9.55%), fermentation for 10 days (9.18%) and acidification for 5 days (8.70%). The lowest crude fibre content was observed for the control treatment (5.10%). The ash content of jackfruit seed flour was influenced by the pre-treatments and varied from 2.17% to 4.37%. The treatment fermentation for 8 days had the highest ash content (4.37%) and the treatment acidification for 8 days recorded the lowest ash content (2.17%). The crude fat content of jackfruit seed flour was not influenced by the pre-treatments and varied from 2.80% to 3.88% with no significant difference between the treatments. The vitamin C content and carotenoid content of jackfruit seed flour were influenced by the pre-treatments. The jackfruit seed flour obtained by the pre-treatment of fermentation for 8 days had the highest vitamin C (58.6 mg $100g^{-1}$) and the highest carotenoid was recorded for fermentation for 8 days (5.80 µg $100g^{-1}$) and 10 days (5.69 µg $100g^{-1}$). The jackfruit seed flour processed without any pre-treatment recorded the lowest vitamin C content of 17.29 mg $100g^{-1}$ and carotenoid content of 1.88 µg $100g^{-1}$. The antioxidant activity of jackfruit seed flour varied between 50.32% to 79.98% and the highest antioxidant activity of 79.98% was observed for the treatment acidification for 8 days and the control had the lowest (50.32%) antioxidant activity.

The functional characteristics of jackfruit seed flour *viz.*, water absorption capacity (mL 100 g^{-1}), oil absorption capacity (mL 100 g^{-1}) and swelling power (g g^{-1}) were analysed. The water absorption capacity of jackfruit seed flour ranged from 101.04 mL $100g^{-1}$ to 169.18 mL $100g^{-1}$ and the highest water absorption capacity of 169.18 mL $100g^{-1}$ was observed for the seed flour processed without pre-treatments (Control) and the lowest water absorption capacity of 101.04 mL $100g^{-1}$ and 103 mL $100g^{-1}$ was recorded for fermentation treatment 10 days and 8 days respectively. The oil absorption capacity of jackfruit seed flour was influenced by various pre-treatment methods. The highest oil absorption capacity (84.28 mL 100 g^{-1}) was observed for control and the lowest oil absorption was recorded for the pre-treatments fermentation for 8 days (76.00 mL 100 g^{-1}), fermentation for 10 days (73.28 mL 100 g^{-1}), acidification for 5 days (75.00 mL 100 g^{-1}) and 8 days (72.30 mL 100 g^{-1}). The different pre-treatments of jackfruit seeds had no influence on the swelling power of jackfruit seed flour and it varied from 1.17 g g^{-1} to 2.52 g g^{-1} among the treatments.

The yield (%), moisture content (%), bulk density (g cm^{-3}), tapped density (g cm^{-3}), Hausner factor, and Carr's index (%) of jackfruit seed flour obtained through various pre-treatments were analysed. The yield of jackfruit seed flour was not affected by the pre-treatment methods and there was no significant difference between the treatments. The moisture content of jackfruit seed flour varied from 8.50% to 10.61%. The treatment fermentation for 10 days had the highest moisture content of 10.61%, while the treatments acidification for 8 days and control recorded the lowest moisture content of 8.50%. The highest bulk density was recorded for pre-treatment acidification for 5 and 8 days and the lowest bulk density of 0.64 g cm^{-3} was observed for control and pre-treatment fermentation for 10 days. The pre-treatment methods did not affect the tapped density and Hausner factor of jackfruit seed flour. The highest Carr's index was noticed in treatment fermentation for 8 days (5.83 %), fermentation for 10 days (7.53%) and control treatment (5.75%). The lowest Carr's index of 2.55% was observed in treatment acidification for 5 days and 3.65% for acidification for 8 days.

Aroma profiling of jackfruit seed flour through headspace analysis of GC /MS revealed that all the treatments of jackfruit seeds noticed the presence of 2,2,4,6,6-pentamethylheptane which was not present in jackfruit seed flour obtained without any pre-treatments. The jackfruit seed flour processed after the pre-treatment of fermentation for 8 days recorded the aromatic compounds dimethyl sulfide, acetic acid, 3-methylbutanal, 2-methyl-butyraldehyde and 2,2,4,6,6-pentamethylheptane. Acetic acid, 3-methylbutanal, 2-methyl-butyraldehyde, capraldehyde and 2,2,4,6,6-pentamethylheptane were detected in seed flour with the pre-treatment fermentation for 10 days. Acidification of jackfruit seeds for 5 days yielded aromatic compounds, acetic acid, 3-methylbutanal, 2-methyl-butyraldehyde, hexanal and 2,2,4,6,6-pentamethylheptane. Whereas acidification for 8 days perceived the compounds acetic acid, 2-methyl-butyraldehyde, and 2,2,4,6,6-pentamethylheptane and control was detected with acetic acid, 3-methylbutanal, 2-methyl-butyraldehyde, methylbenzene and 2,2-dimethyldecane compounds.

The sensory qualities of jackfruit seed flour *viz.*, colour, appearance, flavour and overall acceptability were analysed. The pre-treatment of jackfruit seeds as fermentation (for 8 days) had the highest mean score for colour (8.20), and appearance (8.00). The lowest mean score for appearance (6.00) was recorded for the control. The range of the mean flavour scores for treatments varied between 5.80 and 8.60 and the highest score was recorded for treatment fermentation for 8 days (8.60,) while control treatment recorded the lowest score (5.80). Treatment fermentation for 8 days recorded the highest score of 8.40 for overall acceptability whereas the lowest score of 5.80 for the control treatment.

Based on the biochemical, functional, physical and sensory qualities, jackfruit seed flour processed after the processing pre-treatment, fermentation for 8 days was selected as the best aromatic jackfruit seed flour for the development of jackfruit seed flour cookies.

Aromatic jackfruit seed flour (AJSF) combined with refined wheat flour (WF) in different proportions was used for the preparation of jackfruit seed flour cookies. The cookies were also prepared with jackfruit seed flour processed from drying process (DJSF) alone without pre-treatments and refined wheat flour with and without addition of cocoa powder.

The treatment combinations were Aromatic jackfruit seed flour (AJSF 5%) + Refined wheat flour (WF 95%), Aromatic jackfruit seed flour (AJSF 10%) + Refined wheat flour (WF 90%), Aromatic jackfruit seed flour (AJSF 15%) + Refined wheat flour (WF 85%), Aromatic jackfruit seed flour (AJSF 20%) + Refined wheat flour (WF 80%), Aromatic jackfruit seed flour (AJSF 25%) + Refined wheat flour (WF 75%), Dried jackfruit seed flour (DJSF 5%) + Refined wheat flour (WF 95%), Dried jackfruit seed flour (DJSF 10%) + Refined wheat flour (WF 90%), Dried jackfruit seed flour (DJSF 15%) + Refined wheat flour (WF 85%), Dried jackfruit seed flour (DJSF 20%) + Refined wheat flour (WF 80%), Dried jackfruit seed flour (DJSF 25%) + Refined wheat flour (WF 75%), Refined wheat flour (100%) with cocoa powder and Refined wheat flour (100%) without cocoa powder.

Biochemical parameters *viz*., carbohydrate (%), crude protein (%), crude fibre (%), crude fat (%) and total ash (%) of jackfruit seed cookies were analysed. Aromatic jackfruit seed flour cookies had more carbohydrates, crude protein, crude fibre and total ash content than other cookies. Cookies with aromatic jackfruit seed flour (10%) and refined wheat flour (90%) combination had high carbohydrate (30.60%), crude protein (10.53%), crude fibre (2.47%) and total ash (2.00%) content compared with dried jackfruit seed flour cookies. The crude fat content of jackfruit seed flour cookies varied from 11.97% to 14.99% with no significant difference between the different treatment combinations.

The physical parameters of jackfruit seed flour cookies *viz*., yield (%), thickness (cm), diameter (cm), and spread ratio were analysed. The yield of jackfruit seed flour cookies varied from 141.57% to 158.40% and there was no significant difference between the treatments. The thickness of jackfruit seed flour cookies was not influenced by the formulation and type of jackfruit seed flour. The treatment combination of refined wheat flour (100%) without cocoa powder had the highest diameter of 6.47 cm, and aromatic jackfruit seed flour (10%) and refined wheat flour combination (90%) recorded a diameter of 4.39 cm. The spread ratio of jackfruit seed flour varied from 4.01 to 6.76 to the treatment combination of aromatic jackfruit seed flour (10%) and refined wheat flour (90%) had a spread ratio of 4.17.

The sensory qualities of the jackfruit cookies *viz*., appearance, cracking, crumb colour, texture, mouthfeel, flavour, and overall acceptability were analysed. The treatment combination of 10% aromatic jackfruit seed flour and refined wheat flour

(90%) recorded mean score of 8.40 for appearance with 6.40 mean score for cracking, 6.20 for crumb colour, 8.20 for texture, 8.60 for mouthfeel, 7.60 for flavour and 8.60 for overall acceptability.

The processing pretreatment, fermentation of jackfruit seeds for 8 days recorded jackfruit seed flour with the strongest aroma and acceptable biochemical, physical, functional and sensory qualities. The studies on different formulations of jackfruit seed flour cookies recorded that formulation with 10% aromatic jackfruit seed flour and 90% refined wheat flour was the best combination based on biochemical and sensory qualities.

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APPENDIX

APPENDIX- I

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Postharvest Management

Title: Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies

Score card for assessing the organoleptic qualities of jackfruit seed flour

Sample: Jackfruit seed flour

Instructions: You are given 5 jackfruit seed flours. Evaluate and give score for each criteria

Criteria	Scores				
	1	2	3	4	5
Colour					
Appearance					
Flavour					
Overall acceptability					

Scores

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike sightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

APPENDIX- II

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Postharvest Management

Title: Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies

Score card for assessing the organoleptic qualities of jackfruit seed cookies

Sample: Jackfruit seed cookies

Instructions: You are given 12 jackfruit seed cookies. Evaluate and give score for each criteria

Criteria	Score											
	1	2	3	4	5	6	7	8	9	10	11	12
Appearance												
Cracking												
Crumb colour												
Texture												
Mouthfeel												
Flavour												
Overall acceptability												

Scores

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike sightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Score for cracking attribute

Full cracking	9
Extreme cracking	8
Very high cracking	7
High cracking	6
Slight cracking	5
Moderate cracking	4
Less cracking	3
Very cracking	2
No cracking	1

PROCESS STANDARDISATION FOR JACKFRUIT SEED FLOUR WITH CHOCOLATE AROMA AND PREPARATION OF JACKFRUIT COOKIES

by

Hiba K

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Abstract of the thesis

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VELLAYANI, THIRUVANANTHAPURAM 695 522

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ABSTRACT

The present study entitled "Process standardisation for jackfruit seed flour with chocolate aroma and preparation of jackfruit cookies" was carried out in the Department of Postharvest Management, College of Agriculture, Vellayani during the period 2020-2022, with the objective of standardisation of processing methods for the development of chocolate aroma in jackfruit seed flour and assessment of its suitability for jackfruit cookies with functional properties.

Jackfruit seeds with bulbs extracted from fully ripened jackfruit were subjected to different pre-treatments of fermentation and acidification. The jackfruit seeds after the pre-treatments were cleaned, dried (without spermoderm), roasted and milled to get jackfruit seed flour. The flour obtained were analysed for biochemical, physical, functional and sensory qualities.

The jackfruit seed flour obtained from the fermentation treatment of 8 days recorded the highest TSS of 3.48 ^{0}Brix, 66.28% starch, 8.00% reducing sugar, 10% protein content, 9.55% crude fibre, 4.37% of total ash, 58.63 mg100g^{-1} vitamin C, 5.80 µg100g^{-1} carotenoid with water absorption capacity of 103.16 mL100g^{-1} and oil absorption capacity of 76.00 mL100g^{-1}.

The pre-treatments did not show any significant difference in yield, total sugar, crude fat, tapped density and Hausner factor. The bulk density of 0.66 g cm^{-3}, carr's index of 5.83% and 59.67% antioxidant activity with high sensory attributes were recorded for the jackfruit seeds fermented for 8 days.

Aroma profiling of jackfruit seed flour through headspace analysis of GC /MS revealed the presence of 2,2,4,6,6-pentamethylheptane in all jackfruit seed flour except jackfruit seed flour obtained without any pre-treatments.

Based on the biochemical, functional, physical and sensory qualities, jackfruit seed flour processed after the processing pre-treatment, fermentation for 8 days was selected as the best aromatic jackfruit seed flour for the development of jackfruit seed flour cookies.

The cookies prepared from the selected aromatic jackfruit seed flour were compared with jackfruit seed flour cookies as control with and without addition of cocoa powder. The biochemical, physical, anti-nutritional and sensory parameters were analysed for the developed cookies.

Cookies made using aromatic jackfruit seed flour (10%) and refined wheat flour (90%%) recorded the highest value for carbohydrate (30.60%), crude protein (10.53%), crude fibre (2.47%) and total ash (2.00%) with a thickness of 1.05 cm, diameter of 4.39 cm and spread ratio of 4.17 which was lower as compared to dried jackfruit seed flour cookies. Antinutritional factors *viz*., oxalate and phytate were not detected in the jackfruit seed flour cookies. There was no significant difference between the treatments for yield, thickness and crude fat.

Sensory evaluation of jackfruit cookies revealed that jackfruit seed flour cookies prepared with 10% aromatic jackfruit seed flour recorded the highest mean score of 8.40 for appearance with lower cracking score (6.40) with good colour (6.20), texture (8.20), mouth feel (8.60), flavour (7.60) with the highest overall acceptability score (8.60).

The processing pretreatment, fermentation of jackfruit seeds for 8 days recorded jackfruit seed flour with the strongest aroma and acceptable biochemical, physical, functional and sensory qualities. The studies on different formulations of jackfruit seed flour cookies recorded that formulation with 10% aromatic jackfruit seed flour and 90% refined wheat flour was the best combination based on biochemical and sensory qualities.

സംഗ്രഹം

ചക്കക്കുരുവിൽ നിന്ന് ചോക്ലേറ്റ് സുഗന്ധം വികസിപ്പിച്ച് എടുക്കുന്നതിനുള്ള സംസകരണരീതികൾ ക്രമീകരിക്കൽ അവ ഉപയോഗിച്ച് ഗുണനിലവാരം ഉള്ള കുക്കീസ് തയ്യാറാക്കൽ എന്ന വിഷയത്തെ ആസ്പദമാക്കി വെള്ളായണി കാർഷിക കോളേജിലെ വിളവെടുപ്പാനന്തര സാങ്കേതിക വിദ്യാവിഭാഗത്തിൽ 2020-2022 വർഷക്കാലയളവിൽ പഠനം നടത്തുകയുണ്ടായി.ചക്കക്കുരു പൊടിയിൽ നിന്നും ചോക്ലേറ്റ് സുഗന്ധം വികസിപ്പിക്കുന്നതിന് ഉള്ള രീതികളുടെ ക്രമികരണവും, അവ ഗുണങ്ങൾ അടങ്ങിയിട്ടുള്ള ചക്കക്കുരു കുക്കികൾ തയ്യാറാക്കുന്നതിന് അനുയോജ്യമാണോ എന്നും പഠനവിതേയമാക്കി.

പൂർണ്ണമായി പാകമായ ചക്കയിൽ നിന്ന് വേർതിരിച്ചെടുത്ത ചുളകൾ വിത്തുകളോടുകൂടി അഴുകൽ, അസിഡിഫിക്കേഷൻ എന്നീ വ്യത്യസ്ത രീതികൾക് വിധേയമാക്കി. ചക്കക്കുരു പൊടി തയ്യാറാക്കുന്നതിന് വേണ്ടി ചക്കയുടെ വിത്ത് പ്രീ-ട്രീറ്റ്മെന്റിന് ശേഷം വൃത്തിയാക്കി ഉണക്കി (തൊലി കൂടാതെ), വറുത്ത് പൊടിച്ചെടുത്തു. അപ്രകാരം തയ്യാറാക്കിയ ചക്കക്കുരു പൊടിയുടെ ജൈവ രാസ ഘടനയും ഭൗതികവും നിർവഹകണപരവുമായ പ്രത്യേകതകളും ഗുണനിലവാരവും വിശകലനം ചെയ്യുകയുണ്ടായി.

8 ദിവസത്തെ അഴുകൽ രീതിൽ നിന്ന് ലഭിച്ച ചക്കക്കുരു പൊടിയിൽ ഉയർന്ന തോതിൽ ഉള്ള 3.48 ഡിഗ്രി ബ്രിക്സ് ടി എസ് എസ് ഘടകവും,66.28% അന്നജവും, 8.00% റെഡ്യൂസിംഗ് ഷുഗറും,10% പ്രോട്ടീൻ, 9.55% നാരും,4.37% ക്ഷാരം,58.63 മില്ലിഗ്രാം/100ഗ്രാം വിറ്റാമിന്സി, 5.80 മൈക്രോ ഗ്രാം/100ഗ്രാം കരോട്ടിനോയിഡും,103.16 മില്ലി ലിറ്റർ/100ഗ്രാം ജല ആഗിരണ ശേഷിയും,76.00 മില്ലി ലിറ്റർ/100ഗ്രാം എണ്ണ ആഗിരണ ശേഷിയും ഉള്ളതായി കണ്ടത്തി.

വ്യത്യസ്തമായ നിർമ്മാണ രീതികൾ ചക്കക്കുരു പൊടിയുടെ മൊത്തം വിളവിനെയും ടോട്ടൽ ഷുഗറിനെയും കൊഴുപ്പിനെയും

ടാപ്പിംഗ് ഡെന്സിറ്റിയെയും ഹൌസ്നർ ഘടകത്തെയും സാരവത്തായി ബാധിച്ചിട്ടില്ല. 8 ദിവസത്തെ അഴുകൽ രീതിൽ തയ്യാറാക്കിയ ചക്കക്കുരു പൊടിയിൽ ഉയർന്ന തോതിൽ ഉള്ള 0.66 ഗ്രാം/സെൻറ്റിമീറ്റർ ബൾക്ക് ഡെന്സിറ്റി, 5.83% കാർഴ്സ് സൂചിക, 59.67% ആന്റി ഓക്സിഡന്റ് ആക്ടിവിറ്റി കൂടുതൽ സെൻസറി ആട്രിബ്യൂട്ടുകൾ ഉള്ളതായി കണ്ടത്തി.

ജി സി /എം സ് ഹെഡ്സ്പേസ് വിശകലനത്തിലൂടെ ചക്കക്കുരു പൊടിയുടെ അരോമ പ്രൊഫൈലിങ് ശേഷം നിർമ്മാണ രീതികൾ ഒന്നും അവലംബിക്കാത്ത ചക്കക്കുരു പൊടി ഒഴികെയുള്ള എല്ലാ ചക്കകുരു പൊടിയിലും 2,2,4,6,6-പെന്റമെഥൈൽഹെപ്റ്റേന്റെ സാന്നിധ്യം കണ്ടെത്തി.

ചക്കക്കുരു പൊടിയുടെ ജൈവ രാസ ഘടനയും ഭൗതികവും നിർവഹകണപരവുമായ പ്രത്യേകതകളും ഗുണനിലവാരവും വിശകലനം ചെയ്തതിന് ശേഷം 8 ദിവസത്തെ അഴുകൽ രീതിയിൽ സംസ്കരിച്ച ചക്കക്കുരു പൊടിയിൽ കൂടുതൽ ചോക്ലേറ്റ് സുഗന്ധം ഉള്ളതായി കണ്ടത്തുകയും ചക്കകുരു കുക്കീസ് തയ്യാറാക്കുന്നതിന് വേണ്ടി തിരഞ്ഞ് എടുക്കുകയും ചെയ്തു.

തിരഞ്ഞ് എടുത്ത ചോക്ലേറ്റ് സുഗന്ധം കൂടുതൽ ഉള്ള ചക്കക്കുരു പൊടിയിൽ നിന്നും തയ്യാറാക്കിയ കുക്കികൾ കൊക്കോ പൗഡർ ചേർത്തും അല്ലാതെയും തയ്യാറാക്കിയ കുക്കികളുമായി താരതമ്യം ചെയ്യുകയും തയ്യാറാക്കിയ കുക്കികളുടെ ജൈവ രാസ ഘടനയും ഭൗതികവും നിർവഹകണപരവുമായ പ്രത്യേകതകളും പോഷകാഹാര വിരുദ്ധ ഘടകവും ഗുണനിലവാരവും വിശകലനം ചെയ്യുകയുണ്ടായി.

ചോക്ലേറ്റ് സുഗന്ധം ഉള്ള ചക്കക്കുരു പൊടി (10%) ശുദ്ധീകരിച്ച ഗോതമ്പ് മാവ് (90%) എന്നിവ ഉപയോഗിച്ച് നിർമ്മിച്ച കുക്കികളിൽ

കാർബോഹൈഡ്രേറ്റ് (30.60%), പ്രോട്ടീൻ (10.53%), നാര് (2.47%), ക്ഷാരം(2.00%) എന്നിവ ഏറ്റവും ഉയർന്ന മൂല്യം രേഖപ്പെടുത്തി ഒപ്പം 1.05 സെന്റ്റിമീറ്റർ കനം, 4.39 സെന്റ്റിമീറ്റർ വ്യാസം, 4.17 സ്പ്രെഡ് അനുപാതം എന്നിവയവും രേഖപ്പെടുത്തി. ചക്കക്കുരു പൊടിയിൽ നിന്ന് തയ്യാറാക്കിയ കുക്കികളിൽ ഓക്സലേറ്റ്, ഫൈറ്റേറ്റ് എന്നീ പോഷക വിരുദ്ധ ഘടകങ്ങൾ കണ്ടെത്തിയില്ല. അവ തമ്മിൽ വിളവ്, കനം, കൊഴുപ്പ് എന്നിവ തമ്മിൽ കാര്യമായ വ്യത്യാസം കണ്ടെത്തിയില്ല.

ചക്ക കുക്കികളുടെ സെൻസറി മൂല്യനിർണ്ണയതിന് ശേഷം 10% ചോക്ലേറ്റ് സുഗന്ധം ഉള്ള ചക്കക്കുരു പൊടി ഉപയോഗിച്ച് തയ്യാറക്കിയ കുക്കികളിൽ ഉയർന്നതോതിൽ രൂപം (8.40), കുറഞ്ഞ ക്രാക്കിംഗ് സ്കോർ (6.40), നല്ല നിറം (6.20), ടെക്സ്ചർ (8.20), വായ ഫീൽ (8.60),ഫ്ലേവർ (7.60) മൊത്തത്തിലുള്ള ഏറ്റവും ഉയർന്ന സ്വീകാര്യത സ്കോർ (8.60). രേഖപ്പെടുത്തി.

8 ദിവസത്തെ അഴുകൽ രീതിൽ സംസ്കരിച്ച ചക്കക്കുരു പൊടിയിൽ ഏറ്റവും ശക്തമായ സുഗന്ധവും ഉയർന്ന ജൈവ രാസ ഘടനയും ഭൗതികവും നിർവഹകണപരവുമായ പ്രത്യേകതകളും സെൻസറി ഗുണങ്ങളും രേഖപ്പെടുത്തി. വ്യത്യസ്ത അനുപാതത്തിൽ തയ്യാറാക്കിയ ചക്കക്കുരു കുക്കികളിലെ വിശകലനത്തിന്ന് ശേഷം 10 % സുഗന്ധം ഉള്ള ചക്കക്കുരു പൊടിയും 90 % ശുദ്ധീകരിച്ച ഗോതമ്പ് മാവും ചേർന്നുള്ള അനുപാതത്തിൽ തയ്യാറാക്കിയ കുക്കികൾ ജൈവ രാസ ഘടനയും സെൻസറി ഗുണങ്ങളും അടിസ്ഥാനമാക്കി മികച്ച സംയോജനം അയി തിരഞ്ഞടുത്തു.