DEVELOPMENT AND EVALUATION OF JACKFRUIT BASED MEAT ANALOGUE BY EXTRUSION TECHNOLOGY

By

GOPIKA GOPI (2019-06-007)

MEERA KRISHNA P M (2019-06-012)

NANDANA M (2019-06-015)

FATHIMA SALEEKA (2019-06-022)

ANNA ROSE SABU (2019-06-024)

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR-679 573

KERALA, INDIA

2022

DEVELOPMENT AND EVALUATION OF JACKFRUIT BASED MEAT ANALOGUE BY EXTRUSION TECHNOLOGY

By

GOPIKA GOPI (2019-06-007)

MEERA KRISHNA P M (2019-06-012)

NANDANA M (2019-06-015)

FATHIMA SALEEKA (2019-06- 022)

ANNA ROSE SABU (2019-06-024)

PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology

IN

Food Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

KELAPPAJI COLLEGE OF AGRICUTURAL ENGINEERING AND TECHNOLOGY, TAVANUR-679573

KERALA, INDIA

2022

DECLARATION

We, hereby declare that this project report entitled **"Development and evaluation of jackfruit based meat analogue by extrusion technology"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Place: Tavanur

Date:

Gopika Gopi
(2019-06-007)

Meera Krishna P M
(2019-06-012)

Nandana M
(2019-06-015)

Fathima Saleeka
(2019-06-022)

Anna Rose Sabu
(2019-06-024)

CERTIFICATE

Certified that this project report entitled **“Development and evaluation of jackfruit based meat analogue by extrusion technology”** is a record of project work done jointly by Ms. Gopika Gopi, Ms. Meera Krishna P M, Ms. Nandana M, Ms. Fathima Saleeka and Ms. Anna Rose Sabu under our guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, associateship or other similar title of any other university or society.

Place: Tavanur

Date:

Project Guide:

Dr. Rajesh G. K.

Assistant Professor

Department of Processing & Food Engineering

KCAET, Tavanur

Project Co – Guide:

Er. Nighitha. M.T.

Assistant Professor(C)

Department of Processing & Food Engineering

KCAET, Tavanur

Acknowledgement

ACKNOWLEGEMENT

It is a matter of pleasure to recall the path of traverse during the days of hard work. This thesis becomes a reality with the support and help of many individuals. We would like to extend our sincere gratitude towards all those who have made it possible for us to complete this project work.

Foremost, we want to offer this endeavor to ***GOD Almighty*** *for the wisdom he bestowed upon us, the strength, peace of my mind and good health in order to finish this research.*

We would like to express our deep sense of gratitude to our guide, ***Dr. Rajesh G.K.,*** *Assistant Professor, Department of Processing and Food Engineering, K. C. A. E. T, Tavanur for his valuable encouragement, suggestions and support during entire stage of the project work. His supervision at each and every phase of the project work made us stronger and more inspired. We consider that it's our greatest opportunity to work with him.*

We sincerely thank ***Dr. Prince M. V.****, Professor and Head of the Department, Dept. of PFE, K. C.A.E.T, Tavanur for his encouragement and support to complete the project work successful.*

With extreme pleasure we express our whole hearted gratitude to ***Dr. Jayan P. R.,*** *Dean, Faculty of Agricultural Engineering and Technology for his support while carrying out the project work.*

We engrave our deep sense of gratitude to our co-guide ***Er. Nigitha M. T.,*** *Assistant Professor, Department of Processing and Food Engineering for her guidance and reassuring support to us. We extend our sincere thanks to* ***Dr. Riju M. C.,*** *Assistant Professor (Microbiology),* ***Er. Ann Annie Shaju****, Assistant Professor, Department of Processing and Food Engineering,* ***Er. Anjaly M. G.****, Assistant Professor, AICRP PHET for rendering timely advices and support during the entire period of our project work.*

It is our pleasure to offer whole hearted thanks to ***Mr. Radhakrishnan M. V., Er. Sneha M., Mrs. Raseena K. P., Mrs. Sandhya P., and Mrs. Pangajam T,*** *Lab Assistants, Department of Food and Agricultural Process Engineering for their immense help throughout the project work. We express our gratitude to* ***Mr. Vipin***

P., Mr. Lenin., *Technicians for their immense support and help during the project. We would also like to thank our seniors for their valuable help. We also express our thanks to all staff members of library, KCAET, Tavanur for their help and cooperation.*

We express our gratitude to Kerala Agricultural University for providing this opportunity to do the project work.

We are greatly indebted to our parents for their immense love, blessings and support at every moment and providing strength to complete our study. We also acknowledge our friends for their help and support throughout the project work. This project work would not have been possible without them. Once again, we express our sincere gratitude to all of those who helped us to accomplish this project with success.

Gopika Gopi

Meera Krishna P M

Nandana M

Fathima Saleeka

Anna Rose Sabu

Dedicated to our parents

and teachers

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS

-	Minus
%	Percent
&	And
/	Per
=	Equals
±	Plus, or minus
×	Multiplication
°C	Degree Celsius
µg	Microgram
3D	Three dimensional
a*	Greenness or redness
aw	Water activity
b*	Blueness or yellowness
CFTRI	Central Food Technological Research Institute
cfu	Colony-forming unit
Cfu/g	Colony-forming unit per gram
Cm	Centimeter
CMC	Carboxymethylcellulose
e.g.,	Exempli gratia
et al.	And others

etc	Etcetera
Fig.	Figure
FSSAI	Food Safety and Standards Authority of India
g	Gram
g/g	gram per gram
GHG	Greenhouse gases
HA	Hot air cabinet drier
HMMA	High moisture meat analogue
HP	Heat pump drier
Hrs	Hours
i.e.,	That is
IR	Infrared drier
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg	Kilogram
L*	Lightness or darkness
L/h	Liter per hour
Lbs	Pound
LDPE	Low density polyethylene
MC	Moisture content
Mg	Milligram
Min	Minute
Ml	Milligram

Mm	Millimeter
mm/sec	Millimeter per second
MS	Mild steel
NIAM	National Institute of Agricultural Marketing
OHC	Oil holding capacity
RDA	Recommended dietary allowances
RPM	Revolution per minute
RSM	Response surface methodology
SD	Standard Deviation
TNTC	Too numerous to count
TSP	Texturized soy protein
TVP	Texturized vegetable protein
viz.	Videlicet
w.b	Wet basis
WHC	Water holding capacity

Introduction

CHAPTER I
INTRODUCTION

Health awareness in the population has brought the idea for the innovation of plant protein-based meat in many countries. Nowadays, the semi-vegetarians or known as “flexitarians” who occasionally include meat in their diet, often prefer non vegetarian foods. In terms of sustainability, excessive meat production has driven environmental change and natural resource depletion. Livestock farming, particularly the production of red meat, requires significant resources cause various environmental consequences. Reducing meat consumption especially red meat can play a crucial role in addressing the sustainability challenges possessed by the livestock sector (Gerber *et al*., 2013).

The consumption of vegetable proteins in food products has been increasing over the years due to animal diseases, healthier foods, strong demand for wholesome and religious food and economic reasons. As mentioned earlier, the livestock meat based diet requires more environmental resources than plant protein-based diet. Currently, available marketed meat analogue products are plant-based meat in which the quality (i.e., texture and taste) are similarto the conventional meat.

The introduction of meat replacement in food products also known as meat analogue is not new, it was started in the early 1960s. Traditionally, soy protein was used as a popular ingredient in food analogues such as *tofu* and *tempeh* (fermented soybean cake). These products have been processed either by simple processing/fermentation techniques, and they have been consumed for centuries as traditional dishes in many southeast Asian products. Meat analogue is a food product which is made from non-animal protein and its appearance and smell are very much similar to meat (Kumar *et al*., 2017).

In addition to these traditional Asian meat analogues, the dry texturized vegetable protein (TVP) was obtained from the extruded defatted soymeal, soy protein concentrates or wheat gluten (Kinsella *et al*., 1978). The introduction of this TVP as meat alternatives emerged in the mid to late 20th century (Lawrence *et al*.,2019). TVP is made most commonly from soybeans. Texturized soy protein (TSP) for example is extremely versatile for food ingredients due to its meat like texture attributes and also provides similar protein quality to that of animal proteins (Asgar *et al*., 2010). Besides, the ingredients from vegetable proteins are an inexpensive source and they can be modified into meat substitutes such as canned meat (Featherstone, 2015), meat extender in patties (Penfield *et al*., 1990) and pet food (Stein *et al*.,2008).

Early 21st century, meat alternatives entered the mainstream due to demand towards healthy food. In last decade, the modern advances technology in food science, technology and manufacturing has been introduced in meat analogue products which can mimic the taste, texture, look and functionality of conventional meat based products. The current interest has focused more on the development of non-traditional protein sources in meat analogues such asplant-based meat and cultured meat.

The development of a meat analogue to provide alternatives for meat has become a trend. At present, vegetarian foods occupy a larger than ever shelf space in super markets due to the consumer's increasing health concerns and the related environmental issues. Analogues are those compounds that are similar in structure to another but differ slightly in composition. Meat analogue can be defined as the food which is structurally similar to meat but differs in composition. A typical meat analogue is composed of a combination of ingredients such as water (50-80%), non-textured proteins (4-20%), textured vegetable proteins (10-25%), fat (0-15%), flavorings (3-10%), binding agents (1-5%) and colouring agents (0-0.5%) (Hamid *et al.,* 2020). Meat analogue is also known as meat substitute, mock meat, faux meat, or imitation meat (Sadler *et al*.,2004). It may also refer to a meat based healthier and less expensive alternative to a particular meat product. Generally, meat analogue is understood to mean a food made from non-meats ingredients, sometimes without dairy products and are available in different forms such as burgers,sausages, nuggets, meat balls, pizza toppings etc.

Plate 1.1. Meat Analogue

Artocarpus heterophyllus Lam, which is commonly known as jackfruit is a tropical climacteric fruit, belonging to Moraceae family, is native to Western Ghats of India and common in Asia, Africa, and some regions in South America. It is known to be the largest edible fruit in the world.

Plate 1.2. Jackfruit

Jackfruit boasts a slightly sweet, fruity flavor. Its flesh has a texture that is reminiscent of shredded meat, which makes it a popular substitute for meat in vegetarian and vegan dishes.Jackfruit is rich in nutrients including carbohydrates, proteins, vitamins, minerals, and phytochemicals. Both the seeds and the flesh of jackfruit are consumed as curries and boiled forms, while the flesh in fully ripen stage can be eaten directly as a fruit. This fruit is a good source of carbohydrate as well as protein. The texture of unripe jackfruit pulp is smooth and tasteless which suitable to replace meat-based product. Jackfruit will absorb the flavor addedlike spice or herbs to irritate the meaty flavor. When immature, it is amazingly similar in grain to chicken, making jackfruit is an excellent vegetarian substitute for meat. This new formulation to produce healthier meat patties will provide better option to consumer to choosehealthier food and has high potential to be commercialized.

Meat analogue is generally manufactured by extrusion process. Extrusion permits texturization of plant proteins. Extrusion is used in food processing, forcing soft mixedingredients through an opening in a perforated plate or die designed to produce the required shape. The extruded food is then cut to a specific size by blades/knives. The machine which forces the mix through the die is an extruder, and the mix is known as the extrudate. Extrusionenables mass production of food via a continuous, efficient system that ensures uniformity of the final product. In extrusion cooking, process parameters determine the physicochemical and sensory characteristics of the extruded products by affecting the system parameters. Among the processparameters, feed moisture content is regarded as the most important parameter affecting the system and product parameters in extrusion cooking process. Moisture acts as a lubricant inside the extruder and the amount of force required to convey the material through the die exit decreases with the increase in moisture content of the feed.

However, design and development of an innovative food product that satisfies the consumersdemand are very challenging. Quality, nutrition, and sensory characters are the first parameters to be taken into consideration before developing the plant protein-based diet.

Considering above facts, a study has been undertaken at KCAET, Tavanur entitled “Development and Evaluation of Jackfruit Based Meat Analogue by Extrusion Technology” with the following objectives:

- Development of jackfruit-based meat analogue by extrusion technology.
- Optimization of process parameters of meat analogue.
- Storage studies of the optimized meat analogue.

Review of literature

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with a comprehensive review of literature done by various researchers related to general information of jackfruit, pre-treatment methods of jackfruit, development and evaluation of meat analogue, quality assessment of the final product and storage studies of the product.

2.1 JACKFRUIT

Jackfruit is the largest tropical plant and monoecious evergreen tree possibly indigenous to the rain forests of the Western Ghats in the Southwestern parts of India (Baliga *et al*.,2011). It is abundantly grown in India, Bangladesh, Thailand, Philippines and Sri Lanka (Baliga *et al*.,2011). Jackfruit is actually the largest edible fruit in the world, growing up to 8.6-35.4 inches (22-90 cm) in length, 5.1-19.7 inches (13- 50 cm) in diameter, and up to 22.7 pounds (50 kg) in weight (Reddy *et al*., 2004, Mitra *et al*., 2000, Selveraj *et al*., 1989). The Jackfruit types differ among themselves in the shape and density of spikes on the rind, bearing, size, shape, latex, flake colour, quality and period of maturity (Jagadeesh *et al*.,2006). Jackfruit has a relatively high productivity. It is a multiple aggregate fruit. The edible bulbs of ripe jackfruit are usually consumed fresh or processed into canned product. About 30% of the fruit weight is occupied by the flesh (Jagadeesh *et al*.,2006). Jackfruit is rich in nutrients including carbohydrates, protein, vitamins, minerals, and phytochemicals (Ranasinghe *et al*., 2019).

There are so many benefits from the fruit, tree, branches of jackfruit. The fruit is enriched with a diverse of nutrients and edible where the fruit can be consumed when its ripe and when its green part uses as a vegetable (Khan *et al*.,2021).

2.1.1 Global Scenario

The global jackfruit market is classified into five regions, viz. North America, Asia Pacific, Europe, Middle East and Africa, and Latin America. Asia Pacific is anticipated to be the dominant region in the global jackfruit market in the years ahead owing to increased product availability and demand in the south-eastern countries, contributing largely to the growth of the market. North America is anticipated to witness substantial growth in the jackfruit market due to favourable climatic conditions for the growth of jackfruit in countries such as US and Canada. The presence of prominent market players in these countries is expected to contribute to the jackfruit market growth in North America. Europe is expected to offer lucrative growth opportunities for the jackfruit market owing to the increased awareness about the health benefits of jackfruit in maintaining cardiovascular health and improving the body immunity. Other regions of the world such as Middle East and Africa and Latin America are expected to witness moderate growth in the jackfruit market, in the years ahead.

According to world leaders in Jackfruit Production, different varieties of jackfruit trees produce different yields per tree. NS 1 variety produces 10-20 fruits per tree every season while an average production of all varieties is 15 fruits per tree during every season. India is the largest jackfruit producer while Bangladesh which considers jackfruit a national fruit is the second highest producer. Other top producers of jackfruit include Thailand, Indonesia, and Nepal. According to the UN Food and Agricultural Organization, 75% of the fruit produced in India goes to waste since the fruit can easily go bad if not consumed or preserved within few days (Sawe, B.E., 2017).

2.1.2 National Scenario

Jackfruit is one of the well-known and largest tree fruits in the entire world. The scientific name of popular jackfruit is *Artocarpus heterophyllus*. Furthermore, it belongs to the Moraceae family. Tropical nations are the major jackfruit-producing countries. Primarily, the northern, as well as southern regions of India produce jackfruits. Some of the significant jackfruits producing states in India are Madhya Pradesh, Karnataka, Tamil Nadu, Kerala, Bihar, Uttar Pradesh, West Bengal, and Gujarat. Fruit is categorized under the most amazing economic products of jackfruits. Folks consume it during the phase of maturity as well as immaturity. Nevertheless, the sweet pulp of the fruit cannot be preserved for an extended time period due to its highly perishable quality.

Therefore, every year there a massive post-harvest loss takes place during the peak time. In the current scenario, various government research centres encompassing CFTRI are striving to standardize the production agreement of value-added products generated from jackfruits. All these products are as per the FSSAI standards. Thus, small-scale food business entrepreneurs can initiate a food processing unit or jackfruit business in India to accelerate the production of value-based products from jackfruits (Hagezy *et al*., 2016).

2.1.3 State Scenario

Jackfruit or Chakka as it is called in Kerala has just been officially declared the State fruit. Kerala produces around 30 to 60 Crore jackfruits in a year, but almost 30% of the produce gets wasted. The Kerala government is now focused on building a brand around it, if estimated right, the state can generate an annual income of INR 30,000 Cr through the sale of jackfruit and its value-added products.

When it comes to the State's official fruit, Idukki district leads the list with 5.7 crore jackfruits, followed by Thiruvananthapuram (2.6 crore) and Kannur (2.6 crore), according to the latest estimation of the Agricultural Department. The Malappuram and Kozhikode districts produce 2.4 crore and 2.1 crore jackfruit a year respectively, while Alappuzha fares comparatively poor at 60 lakhs. The jackfruit production in Kollam, Thrissur, Ernakulam, Kottayam, Kasaragod and Pathanamthitta districts range from 1.1 crore to 1.9 crore. The Malabar region alone churns out 12.2 crore jackfruits every year (Joseph, S. 2018).

2.1.4 Nutritional Benefits of Jackfruit

Khan *et al*., 2021 stated that jackfruit contains anti-bacterial, anti-diabetic, anti-oxidant, anti-inflammatory and anti-helminthic properties. The fruit is rich in carbohydrates, minerals, carboxylic acids, dietary fibre, vitamins and minerals. The seed is rich in manganese, magnesium, potassium, calcium iron and lectins and thus meets up nutritional requirements for the rural people.

Table.2.1. Nutritive value of jackfruit (100g)

Nutrients	Nutrient Value	RDA (%)
Cholesterol (mg)	0	0
Dietary fibre (g)	1.5	4.0
Vitamins		
Folate (µg)	24.0	6.0
Niacin (mg)	0.920	6.0
Pyridoxine (mg)	0.329	25.0
Riboflavin (mg)	0.055	4.0
Thiamine (mg)	0.105	9.0
Vitamin A (IU)	110.0	3.5
Vitamin C (mg)	13.7	23.0
Vitamin E (mg)	0.34	2.0
Electrolytes		
Sodium (mg)	3.0	0
Potassium (mg)	303.0	6.5
Minerals		
Calcium (mg)	34.0	3.4
Iron (mg)	0.60	7.5
Magnesium (mg)	37.0	9.0
Manganese (mg)	0.197	8.5
Phosphorous (mg)	36.0	5.0
Phosphorous (mg)	21.0	3.0
Selenium (mg)	0.6	1.0
Zinc (mg)	0.42	4.0

Phytonutrients		
Carotene-β (μg)	61.0	-
Crypto-xanthin-β (μg)	5.0	-
Lutein-zeaxanthin (μg)	157.0	-

2.1.5 Drying of Jackfruit

Khan *et.al.,* 2021 conducted a study on the effect of processing and drying on quality evaluation of ready-to-cook jackfruit. Results revealed that tender jackfruit treated with 1000 ppm is the best treatment to preserve its colour by reducing browning. Blanching and boiling highly affect the reconstitution characteristics of the dried product. This study shows that blanching time affects the KMS concentration and its residue was decreased with the increase of blanching time. Drying is one of the most important primary operations for increasing the storage life of the fruits by reducing their moisture. RTC jackfruit dried at 60°C temperature retained more nutritional value and was acceptable by the judgment of the sensory panels. Results indicated that RTC jackfruit treated with KMS and dried at high temperature could contribute to lower the residual level of KMS. Therefore, it is recommended that green tender jackfruit (angular size) can be treated with 1000 ppm, blanched at 8 min at 85°C temperature and dried at 60°C in terms of retaining colour, texture, nutritional and organoleptic test. The study revealed that the storage life of the RTC jackfruit could be extended to more than 6 months. This RTC jackfruit does not only reduces the cooking time but also reduces the hassle of primary processing operations.

Gan, P. L. and Poh, P, E. 2014 investigated on the effect of shapes on drying kinetics and sensory evaluation study of dried jackfruit. In this research, drying curves of three different shaped jackfruit slices were obtained using a convective oven at 40°C, 50°C, 60°C and 70°C. Drying was found to be most efficient at 50°C using the square shaped slices with an R square, RMSE and SSE value of 0.9984, 0.01127 and 0.002668 respectively. Sensory evaluation of untreated and additiveadded dried jackfruit slices was conducted by 40 untrained sensory panellists. Jackfruit with ascorbic acid and sugar coating had highest aesthetics value 16 due to better retention of colour by ascorbic acid. However, sugar coated jackfruit had the most favourable taste and smell. Further optimization must be done to satisfy consumers collectively to enable a highly marketable product.

2.1.6 Blanching of Jackfruit

Jackfruit samples which were subjected to blanching at different time duration showed negative result for H_2O_2 test. The time required to inactivate the peroxidase enzyme so that the pink colour disappears could be considered as the optimum time for blanching (Sudheer and Indira, 2007). All other enzymes would have been inactivated at this particular time and temperature combination (Srivastava and Sanjeev, 1994; Sudheer and Indira, 2007). Babu *et al.*,2012, observed the complete inactivation of the high heat resistant enzymes in the sample was within one minute of blanching and thus one minute blanching was considered as the optimum time for tender jackfruit blanching.

2.1.7 Different Value-Added Products of Jackfruit

2.1.7.1 Dried Jackfruit Flakes:

Dried Jackfruit flakes are prepared by slicing the jackfruit bulbs using jackfruit bulb slicer and subsequently dried in a combo drier. Mechanically sliced Jackfruits can be dried using an efficient blancher-cum- drier (Mittal *et al*.,2020).

2.1.7.2 Preserved Jackfruit Bulbs:

Fresh Jackfruit bulbs are a consumer-preferred commodity and relished well by all sections of population. Ready-to eat fresh Jackfruit bulbs along with seeds were preserved under vacuum (760 mm lbs pressure) by treating with 1.5% KMS and 0.5% sodium benzoate. Preserved bulbs depicted negligible changes in the chemical constituents and were organoleptically stable for period of 15 days under refrigeration (Mittal *et al*.,2020).

2.1.7.3 Dehydrated Jackfruit Bulbs:

The recommended approach to produce dehydrated bulbs involves steeping of Jackfruit bulbs in 0.1% potassium metabisulphite solution for 30 min to improve the quality of the dried products (Mittal *et al*.,2020).

2.1.7.4 Jackfruit Chips:

Jackfruit chips are prepared using raw bulbs. The oil used for frying influence the shelf-life of Jackfruit chips. Shelf stability of jackfruit chips could be increased by adding antioxidants like butylated hydroxytoluene and sorbic acid. Gokul brand of vacuum fried chips from Kundapur (India) are very popular (Mittal *et al*.,2020).

2.1.7.5 Jackfruit Jelly:

Jackfruit rind contains fair amount of sugar and pectin could be used for pectin extraction. Siddappa and Bhatia. 1956 standardized a method for preparing jelly and suggested an extract-sugar ratio of 1:1 with 0.6 and 0.8 acids preparing a good quality jelly (Mittal *et al*.,2020).

2.2 MEAT ANALOGUE

Analogues of meat are products that have certain properties (like taste and texture) identical to animal meat and are manufactured to mimic animal products. A meat analogue is a compound which, despite its structural similarity, differs in composition from its counterpart. Meat analogues share much of the same structure as meat but differs slightly in composition. They have also been called mock, imitation and faux meat techniques. In order for meat substitutes to fulfil the chemical attributes of meat (mainly flavor, texture and appearance), the substitutes to be made from meat-based compounds such as surimi which is a cheap and healthier alternative to meat (Singh *et al.,* 2022).

As the world's population increases, the need for reliable protein sources is growing. Meat is considered a good source of high biological value protein, but meat is not sustainable. In Western countries, the shift toward a diet with reduced meat consumption demands healthy and tasteful meat-free food products. Following this trend, the market turned toward vegetable proteins, such as pulses, wheat gluten and soy protein, which are processed into meat-like products, also known as meat analogues. These products approximate certain aesthetic qualities, such as texture, flavor, and colour, and nutritional characteristics of specific types of meat. The development of new, attractive food products is a challenge already, but this challenge becomes even greater considering that these products are meant as a substitute for meat (Kyriakopoulou *et al.*, 2019).

The aim of a meat analogue is to make the consumer think that they are consuming meat in all sense of the meaning including mimicking structure, composition and organoleptic properties. However, meat has a complex structure, which is difficult to reproduce. Redman. 2008 filed a patent for a meat analogue containing 5%–40% protein with a characteristic cross-sectional contraction resembling the skin of meat and imparting appearance of cooked meat. Similarly, Kumar et al. 2011 compared chicken nuggets with meat analogue nuggets prepared by incorporating texturized soy protein, mushroom, wheat gluten, etc., for their various physico-chemical and sensory attributes. The scores for the textural properties of real meat were significantly higher than the meat analogue in terms of hardness, chewiness and cohesiveness. (Kumar *et al.*, 2019).

Fig.2.1. Meat analogue

2.2.1 Nutrition of Meat Analogue

Meat is consumed primarily due to its high nutritional value. It is therefore vital to develop plant-based meat alternatives that meet the nutritional requirements as of traditional meats. Several plant- based meat alternatives currently found in the market appear to provide our diets with enough protein. The nutritional content of four varieties of conventional meat and plant-based meat substitutes (beef burgers, pork ham, beef meatballs, and chicken nuggets) available in the market were studied by Singh *et al.* 2022. They observed that a beef patty inside burger contains 23.33g of protein, in comparison to meat analogue patty that weighs approximately 19.46g. The plant-based meat alternative, however, is lower in cholesterol and higher in fibre, which makes them attractive to consumers. Also, the performance of different products (pork ham, beef meat-balls, and chicken nuggets) was same (Bohrer, 2019). Hence, plant-based meat analogues are likely to be better meat alternatives in terms of nutrition, especially protein content and are also healthy (Singh *et al.,* 2022).

2.2.2 Ingredients of Blood Substitute

2.2.2.1 Binders

Egg protein and methylcellulose are the main ingredients in commercial products, while wheat gluten can also play this role as it creates a network when hydrated and helps bind the TVP and other ingredients together. The texture and mouthfeel of the products are further improved, with the use of texturizers that present high water holding moisture and can make the burger softer and juicier. For the latter ingredient requirements, protein isolates, protein concentrates and polysaccharides can be used.

2.2.2.2 Fats

The mouthfeel of juiciness is also affected by the fat in the product, which can be liquid or solid plant-based fat, emulsified or free. In many cases, a combination of liquid (such as sunflower and canola oil) and solid fats (like coconut or palm oils) is used to achieve the right. Preferably the fats in the burger are solid at room temperature and turn liquid when the product is heated. This gives the product a pleasant mouthfeel, similar to corresponding meat products.

2.2.2.3 Others

Vegetarian burgers attempt to create the feeling of juiciness by using beetroot juice and at the same time giving the product a characteristic meat colour. Research and development on plant-based burgers are furthermore focused on achieving even better juiciness and improving the appearance and taste of these products by developing new colour changing compounds, flavorings and aroma precursors (Kyriakopoulou *et al.*, 2021).

2.2.3 Extrusion Technology

Extrusion is a widely accepted process for manufacturing protein-based foodstuffs that are used in a variety of textured convenience foods. Extrusion has been used for many years to produce texturized proteins, including spun soy protein isolates and extruded meat analogs, while other technologies, such as 3D printing of proteins, have only recently been introduced. Commercial feasibility has supported the development of three extrusion-based methods for the production of texturized proteins: dry extrusion, wet extrusion, and thermal extrusion. The development of each technology has been driven by consumer needs and demands for product texture, nutrition, and quality. Extrusion allows a wide range of protein sources to be continuously cooked using a combination of mechanical and thermal energy. The macromolecules in proteinaceous ingredients lose their native, organized structure and form a continuous, viscoelastic mass. As they pass through the extruder barrel and die, they are aligned in the direction of flow. This realignment exposes bonding sites that lead to cross-linking and a reformed, expandable structure that is responsible for the chewy, meat like texture in plant-based alternatives (Plattner *et al.*, 2020).

Protein is the most important ingredient in the production of HMMA using extrusion technology. During extrusion, protein is denatured, unfolded, realigned and cross-linked, due to the shear, heat, pressure and cooling achieved in the extruder and cooling die, respectively. The final texture of HMMA is influenced by different types of protein bonds. Several factors determine the protein interactions such as protein type, pre-treatment and extrusion parameters (Zahari *et al.*,2020).

2.2.4 Microbial analysis

The production processes of meat analogues contain a heating step, for example blanching, which make the product stable at that point of the process. However, plant-based meat analogues could be prone to microbial spoilage due to water activity. This microbial growth can be further facilitated by the pool of nutrients present in the product at neutral pH and moderate salt level. Therefore, post processing activities (packaging, storage, etc.) should aim at protecting the product from any microbial spoilage. After the meat-analogue production, contamination risks could be due to the exposure to the environment of the product's surface or from the use of non-sterilized flavor ingredients such as spices, herbs and marinades. Packaging and storage of the meat-analogue products to conditions and materials similar for meat products is suggested. Currently, meat analogues are mostly stored in chilled or frozen conditions in closed plastic containers or flexible bags. (Kyriakopoulou *et al.* 2019)

Microbiological analysis of grinded paste samples were carried out of finding microbial load with serial dilution. Nutrient agar and chloramphenicol yeast glucose agar media was used for the microbial analysis (bacteria, yeast and mold). For carrying out microbial analysis, agar media and glass wares were autoclaved at 121°C for 15 min to make them sterile. One gram of the sample was taken and added to 10 ml of sterile water blank. Emulsion was shaken well for 10 to 15 min to obtain uniform suspension of microorganisms and this gave a dilution of 10^{-1}. 1 ml from 10^{-1} dilution was transferred to 9 ml of sterile water blank with a sterile 1 ml micro pipette, to get a dilution of 10^{-2}. The process was repeated up to 10^{-5} dilutions with the sterile water blank. Pipette 1 ml of food homogenate from last three dilutions and triplicate each for more accuracy. About 15- 20 ml of growth media were poured to sterile petri plates at temperature (45-50°C). Mix the media along with dilution by swirling gently clockwise and anti-clockwise and kept undisturbed until the agar gets solidify. Incubate at room temperature in inverted position for 24 and 48 hours for bacteria, yeast and mold. The colonies were counted after the incubation period (FSSAI, 2015).

2.2.5 Storage studies

It is also necessary to develop effective techniques for extending shelf life and ensuring the health safety of meat analogs. One method of preserving the quality of meat analogues is the use of antioxidants, especially of natural origin, mentioned earlier. However, the microbiological stability of the product is an equally important aspect affecting the safety of meat analogues. Various food additives are used to ensure this, but they are undesirable as consumers are increasingly looking for “clean label” products. For this reason, modern methods of preserving food products, especially meat, may become an interesting alternative to preservatives used so far. The effect of high temperatures creates the risk of unfavorable byproducts forming in meat analogs. For this reason, special attention should be paid to thermal methods using low temperature and non-thermal methods.

Low-temperature methods that were applied in meat preservation are as follows: super-chilling, ultrarapid freezing, immersion vacuum cooling, hydro fluidization freezing, impingement freezing, electrostatic-assisted freezing and pressure-shift freezing. While non-thermal methods are acidic electrolyzed water coupled with high hydrostatic pressure and nonthermal plasma technique. However, there is a need to verify the applicability of these methods for preservation of meat analogues. Attention should also be paid to consumer attitudes towards such product preservation techniques and the possible need for consumer education in this regard. Innovative packaging, e.g., containing active clay, may also be a promising tool to ensure shelf life and safety of meat analogues (Kolodziejczak *et al.,* 2021).

After the extrusion process, the cooling process increases the viscosity of the mixture, thus inducing shear that generates a layered and fibrous structure. Extruded products were manually cut at the end of the cooling die and were allowed to cool at room temperature before the material was transferred to a sealed plastic bag where it was kept frozen at −18 °C prior to further analysis (Zahari *et al*., 2020).

2.2.6 Environmental Benefits of Meat Analogue

Food production is one of the most environmental damaging operations that account for 30% of global greenhouse gas (GHG) emissions and 70–85% of global water foot-print (Smetana *et al.,* 2015). Plant-based meat alternatives have been found to have a lesser environmental impact compared to animal meat. Several plant-based meat substitutes are reported as nutritious as animal meat, and have less environmental impact than animal meat in some cases (Sturtewagen *et al.,* 2016; Van-Mierlo *et al.,* 2017). Researchers have found that combining environmental constraints and nutrition considerations with modelling techniques (such as linear programming) caused meat products to be reduced or even eliminated, and thus decrease its environmental impact significantly (Singh *et al*., 2022).

2.2.7 Future of Meat Analogue

Meat analogues find raising interest of many consumers who are looking for indulgent, healthy, low environmental impact, ethical, cost-effective, and/or new food products. High moisture extrusion cooking enables the production of fresh, premium meat analogues that are texturally like muscle meat from plant or animal proteins. The appearance and eating sensation are similar to cooked meat while high protein content offers a similar nutritional value. This article focuses on plant-based meat analogues and covers process and product-related aspects including ingredients and structure formation, flavour, taste and nutritional value, post extrusion processing, packaging and shelf life, consumer benefits, and product-related environmental impacts (Wild *et al.*, 2016).

The definition of meat analogue refers to the replacement of the main ingredient with other than meat. It also called a meat substitute, meat alternatives, fake or mock meat, and imitation meat. The increased importance of meat analogue in the current trend is due to the health awareness among consumers in their diet and for a better future environment. The factors that lead to this shift is due to low fat and calorie foods intake, flexitarians, animal disease, natural resources depletion, and to reduce greenhouse gas emission. Currently, available marketed meat analogue products are plant-based meat in which the quality (i.e., texture and taste) are similar to the conventional meat. The ingredients used are mainly soy proteins with novel ingredients added viz. mycoprotein and soy leghaemoglobin. However, plant-based meat is sold primarily in Western countries. Asian countries also will become a potential market in the near future due to growing interest in this product (Ismail *et al.*, 2020).

Materials and methods

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials used and methodologies adopted for the development of jackfruit-based meat analogue. The process of evaluation and optimization of the process parameters towards the development of jackfruit-based meat analogue by extrusion technology, the experimental procedures for the microbial and organoleptic qualities and storage studies are also described in this section.

3.1 RAW MATERIALS

Fresh tender jackfruit (*Artocarpus heterophyllus* L.,*)* of variety *Koozha* harvested at 50 to 70 days after fruit formation, procured from the KCAET Instructional Farm, Tavanur were used in this study. Raw materials for the preparation of meat analogue were purchased from online shopping portal and local stores at Tavanur. Harvested jackfruits were stored at refrigerated temperature of 8°C till the conduct of further experiments.

3.2 PREPARATION OF JACKFRUIT POWDER

3.2.1 Cleaning of jackfruit

The collected jackfruits were washed, peeled and cut into small pieces of almost uniform thickness (5mm) and subjected to further operations.

Plate 3.1. Cleaning of jackfruit

3.2.2 Blanching of jackfruit

Hot water blanching method was used for blanching of jackfruits. Five hundred grams of sample were taken for blanching. In hot water blanching method, jackfruits were blanched at 100℃ temperatures for 1 min (Pritty and Sudheer, 2012). After blanching, the samples were instantly cooled in distilled water-bath mixed with salt (2%) at room temperature to avoid overcooking and discolouration (Dattatreya *et al*., 2006), followed by spreading samples over Whatman No.4 filter paper to remove excess water.

3.2.3 Drying of jackfruit

The blanched jackfruit slices were dried in a heat pump drier (Model, WRH-100B). The pretreated jackfruit slices were dried at a temperature of 60℃ for 7hrs. The moisture content of dried jackfruit were analyzed using oven dry method.

3.2.3.1 Heat pump

The principle of heat pump is based on the same thermodynamic cycle as that used in the refrigeration technique. Heat pump employs dehumidification drying at low temperatures does not harm to the material to be dried and its active ingredient will not lose. Strong air convection guarantees even drying. The basic components of the heat pump system comprises of an evaporator, compressor, condenser and expansion valve. It has a capacity of 3.5 L/h. Heat pump has a dimension of 1180×690×1800 (mm).

Plate 3.2. Heat Pump drier

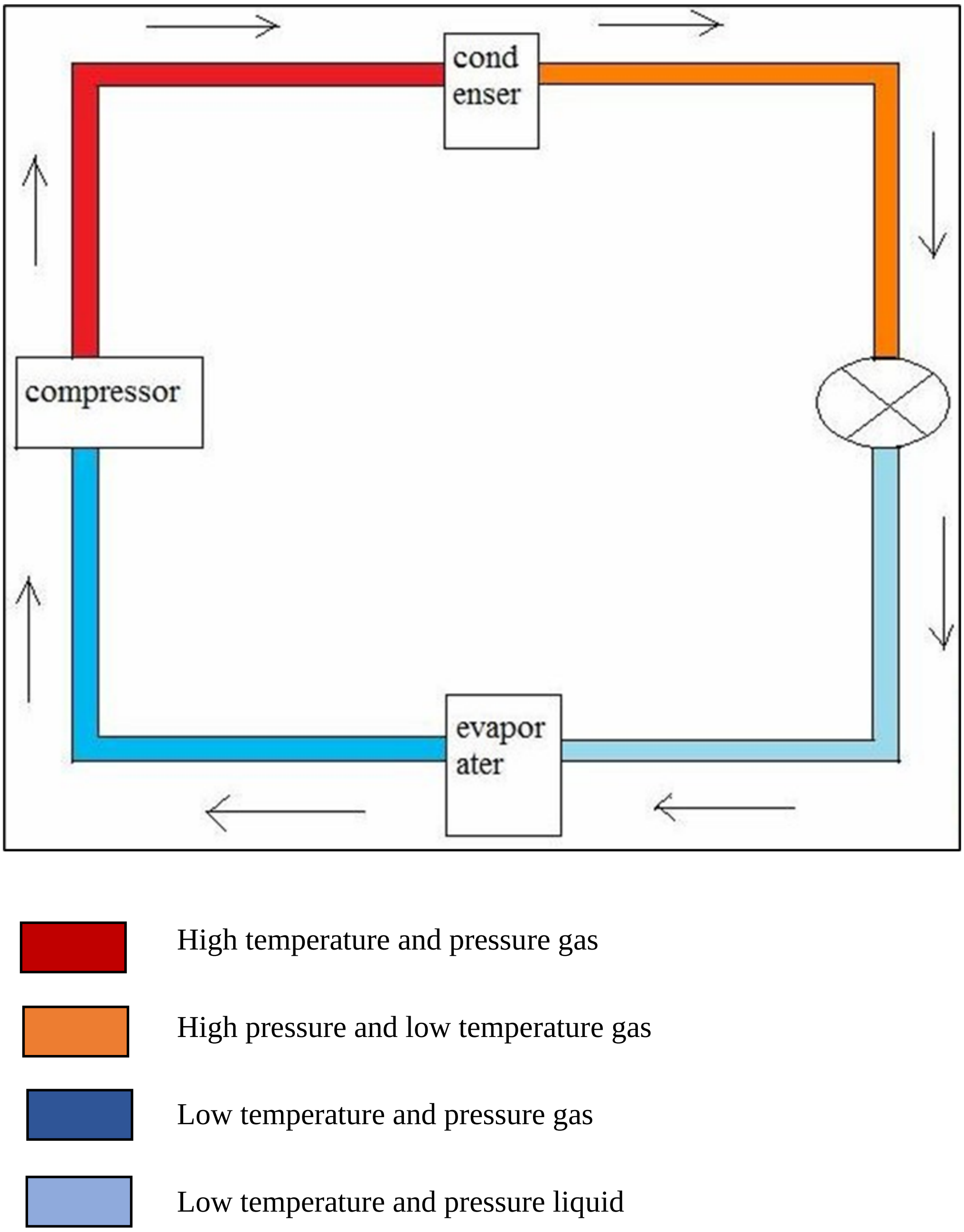


Fig. 3.1. Simple Vapor Compression refrigeration cycle

3.2.3.2 Determination of moisture Content

The moisture content present in the dried jackfruit was determined as per AOAC (2005) method. Sample of 5 g blanced jackfruit was taken into pre weighed petridish. The sample was then placed in the hot air oven at 105°C and dried to constant weight. The moisture content was expressed as percentage wet basis (%

w.b). The experiment was done by triplicates and the average value was noted. The percent of moisture content was determined by the following equation:

$$Moisture\ content\ (\%\ w.b) = \frac{(W_i - W_f)}{W_i} \times 100 \qquad \ldots(3.1)$$

Where

W_i – initial weight of developed meat analogue, g

W_f– dry weight of developed meat analogue, g

3.2.4 Disintegration

Dried samples were disintegrated using a hammer mill and sieved using a sieve size of 800 micron size. Moisture content of the jackfruit flour was found to be 10.5% (w.b). The process of size reduction is shown below.

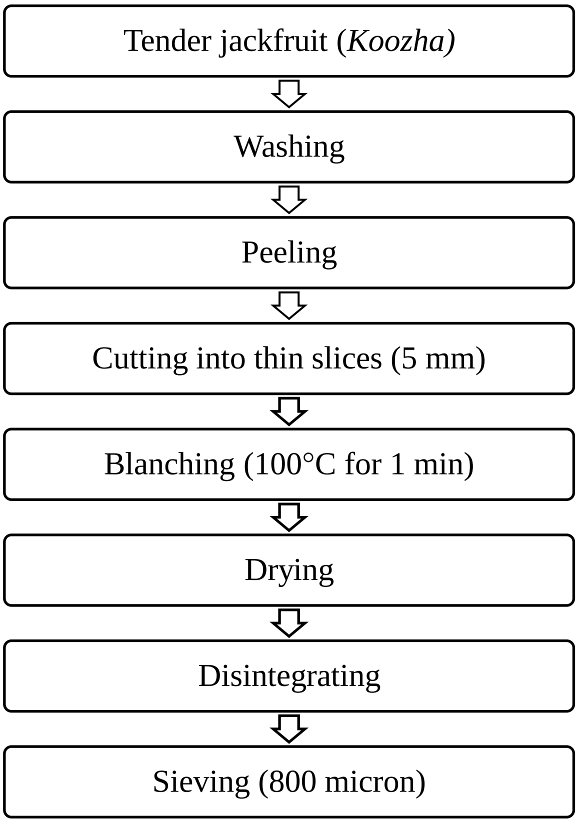


Fig. 3.2. Flow chart for size reduction of dehydrated jackfruit

Fig. 3.3. Grated jackfruit

3.2 DEVELOPMENT OF MEAT ANALOGUE

3.3.1 Preparation of Blood substitute

- Beet powder – 4g
- Cocoa powder – 2g
- Garlic powder – 1g
- Yeast extract – 4g
- Black strap molasses – 2g
- Mushroom extract – 4g
- Soy sauce – 15 ml
- Vinegar – 8 ml
- Water -250 ml

Dried ingredients were weighed and transferred them to a bowl. Wet ingredients were then added and were thoroughly mixed with the help of a whisk without lump formation.

Plate 3.3. Blood substitute

3.3.2 Preparation of Fat

2g CMC (Carboxy Methyl Cellulose) was added to 100ml of water and thoroughly blended. This would result in the formation of gel and turn into a gum, which is not as gummy as xanthan gum but more like slime. 300g of refined oil was then measured out and poured slowly to the mixture. This emulsifies the mixture and aids in the formation of a mayo type of consistency. 1g of Kappa carrageenan was added quickly while the mixture was blending.

Plate 3.4. Fat

3.3.3 Mixing

Jackfruit powder, refined wheat flour and Carboxy Methyl Cellulose (CMC) were taken and put in blood substitute. All these ingredients were mixed properly and kept this idle for 20-30 minutes for conditioning. The prepared mixture attained good consistency. In order to make the mix a little bit smoother, it was blended for a few seconds using a blender. Then 6g of Kappa carrageenan was added to the mixture.

Plate 3.5. Mixing

3.3.4 Extrusion

The prepared mixture was then extruded using a hand extruder. The process consists of forcing soft mixed ingredients through an opening in a perforated plate or die designed to produce the required shape.

Fig. 3.4. Hand extruder

3.3.5 Layering

Fat which was prepared earlier was put into a plastic piping bag. Then, it was layered with the extruded mixture.

Plate 3.6. Layering with fat

3.3.6 Preparation of steak

The mixture which was layered with fat was compressed in a foil and then made into a rectangular shape. It was packed in a retort pouch having thickness 100 micron size and sealed. Make sure that it was packed properly before the blanching process so that spoilage due to microbial growth could be prevented. It was then blanched by immersing in boiling water at 100°C for 30min and then immersed in chilled water immediately for 30 min. The packets were then taken out and uncovered. It appeared to have a structure as that of steak. It was then cut into pieces of about 1-2 inches.

Fig. 3.5. Retort pouch

Plate 3.7. Prepared Steak

3.3.7 Packaging

Prepared steak was vacuum packed in LDPE pouch of 100 micron thickness (M/s Sevana Electrical Appliances Pvt Ltd).

Plate 3.8. Vacuum packaged steak

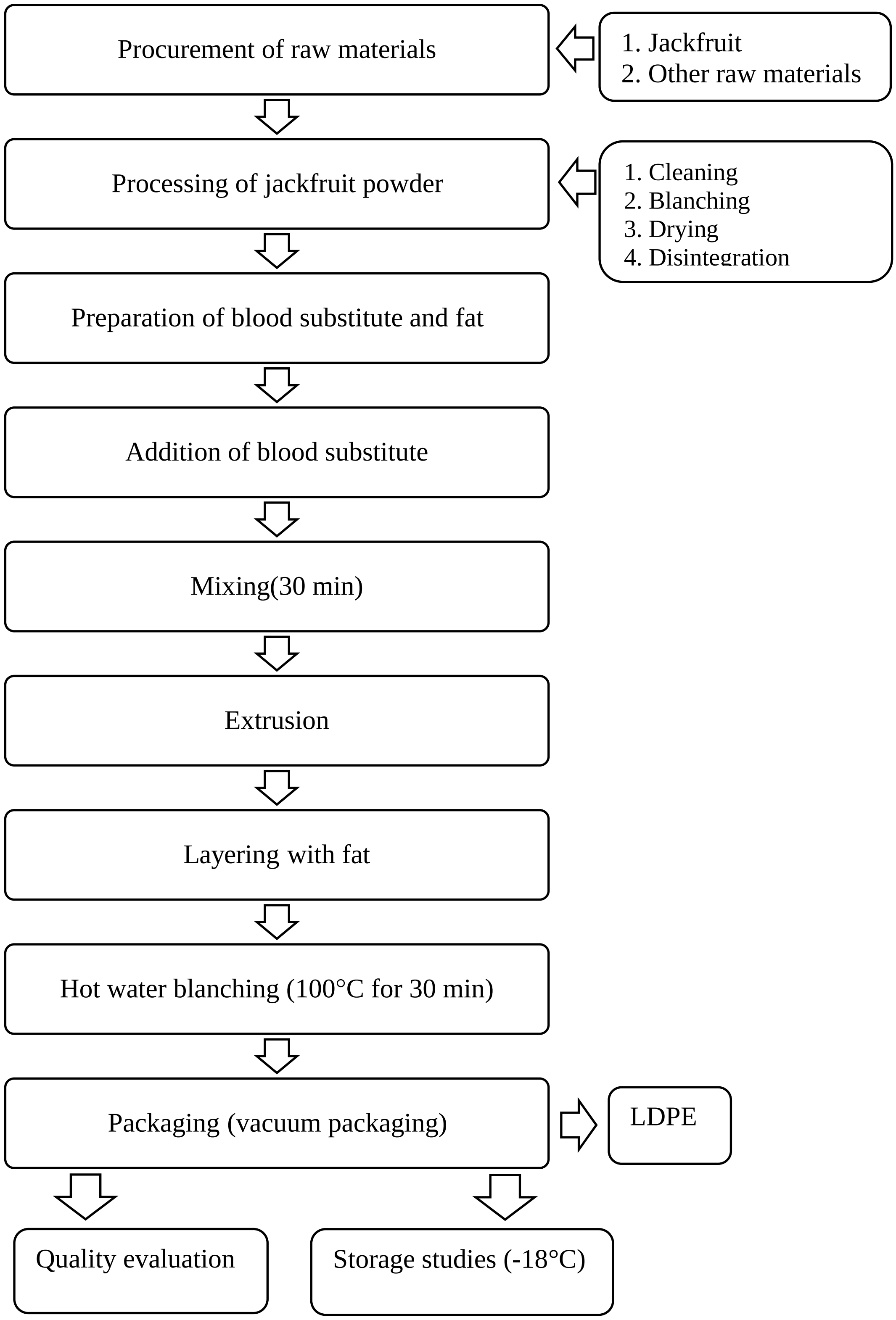


Fig. 3.6. Process flowchart for jackfruit-based meat analogue

3.4 DESIGN OF EXPERIMENTS

3.4.1 Optimization of process parameters of developed jackfruit-based meat analogue

3.4.1.1 Independent variables

- Texturizing agent (g)

  G1- 40g refined wheat flour

  G2- 50g refined wheat flour

  G3- 60g refined wheat flour

- Rotational speed (rpm)

  M1- Low speed

  M2- Moderate speed

  M3- High speed

- Binding composition (g)

  C1- 4g CMC

  C2- 6g CMC

  C3- 8g CMC

3.4.1.2 Dependent variables

- Moisture content (%)
- Water holding capacity (g/g)
- Oil holding capacity (g/g)
- Water activity
- Texture analysis
- Colour
- Sensory evaluation

3.4.2 Storage studies of developed jackfruit based meat analogue

3.4.2.1 Independent variables

- Period of storage

- Initial
- 1st week
- 2nd week
- 3rd week

3.4.2.2 Dependent variables

- Moisture content (%)
- Water holding capacity (g/g)
- Oil holding capacity (g/g)
- Water activity
- Microbial analysis (cfu/g)

EXPERIMENT I

3.5 OPTIMIZATION OF PROCESS PARAMETERS OF DEVELOPED JACKFRUIT-BASED MEAT ANALOGUE

The optimization of process parameters of developed jackfruit based meat analogue was done by three different combinations of texturizing agent, rotational speed and binding composition. The detailed description of the design has been explained under the section (3.5.1).

3.5.1 Experimental design

3.5.1.1 Introduction to experimental design (Response surface methodology)

Box-Behnken experimental design of Response Surface Methodology (RSM) was used (Bchir *et al*., 2020) in framing the experiment using Design-Expert software version 13. Response Surface Methodology (RSM) was applied to the experimental data to determine the optimal process parameters, to assess the interaction between them and to provide data for a predictive regression model. Box- Behnken designs are used to generate high order response surfaces using fewer required runs than a normal factorial technique. This design requires three levels for each factor. It set a mid-level of the factors, avoiding the extreme axial points. The Box-Behnken design with three numeric factors such as G, M and C provides twelve different responses.

3.5.1.2 Coded and actual values of experimental design

The coded and actual values of independent variables in Box- Behnken design for optimization of process variables for developed jackfruit based meat analogue are tabulated in Table. 3.1.

Table. 3.1. Coded & actual values of independent variables in Box- Behnken for optimization of process variables for the developed jackfruit based meat analogue

Independent variables	Coded variables	Levels in the coded form		
		-1	0	+1
Texturizing agent (g)	G	40	50	60
Rotational speed (rpm)	M	Low	Moderate	High
Binding composition (g)	C	4	6	8

3.5.1.3 Experimental design for optimization of process variables for the developed jackfruit based meat analogue

Jackfruit based meat analogue experiment was conducted with combinations of process parameters presented in Table. 3.2.

Table. 3.2. Box- Behnken experimental design for optimization of process variables for the developed jackfruit based meat analogue

	Coded values			**Decoded values**		
Run	Texturizing agent	Rotational speed	Binding composition	Texturizing agent	Rotational speed	Binding composition
1	-1	-1	0	40	Low	6
2	1	-1	0	60	Low	6

3	-1	1	0	40	High	6
4	1	1	0	60	High	6
5	-1	0	-1	40	Moderate	4
6	1	0	-1	60	Moderate	4
7	-1	0	1	40	Moderate	8
8	1	0	1	60	Moderate	8
9	0	-1	-1	50	Low	4
10	0	1	-1	50	High	4
11	0	-1	1	50	Low	8
12	0	1	1	50	High	8
13	0	0	0	50	Moderate	6
14	0	0	0	50	Moderate	6
15	0	0	0	50	Moderate	6
16	0	0	0	50	Moderate	6
17	0	0	0	50	Moderate	6

3.5.2 Preparation of jackfruit based meat analogue

The process flow chart for preparation of jackfruit based meat analogue with different combination treatment is shown in Fig. 3.7.

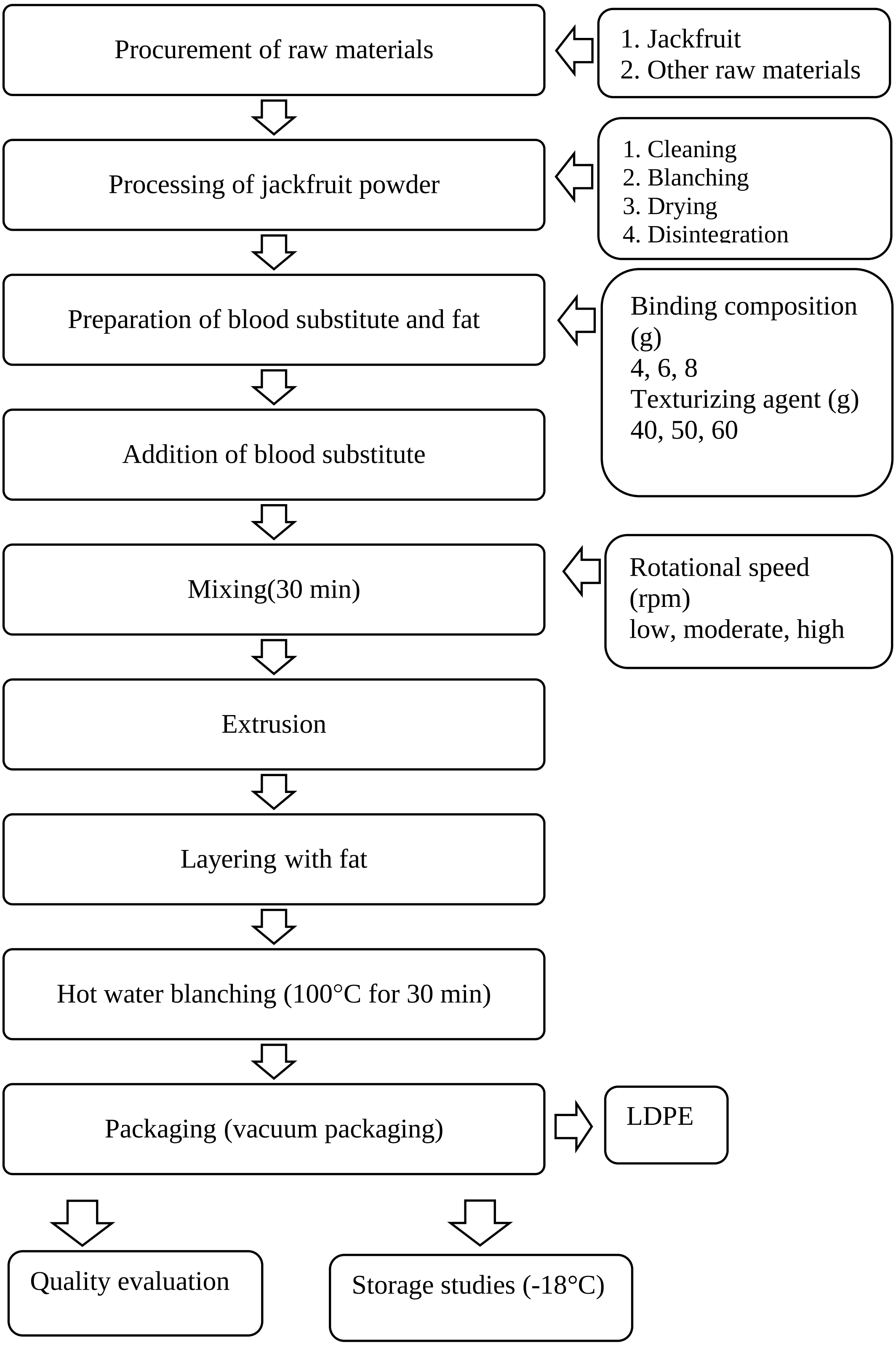


Fig. 3.7. The process flow chart for preparation of jackfruit based meat analogue with different combination treatment

3.5.3 Quality analysis of optimized jackfruit based meat analogue

The quality parameters such as moisture content, oil holding capacity, water holding capacity and water activity were determined as per the standard procedures explained below.

3.5.3.1 Determination of moisture content

Moisture content of optimized meat analogue was determined using AOAC (2005) method. The moisture content of developed jackfruit based meat analogue with different combinations was quantified using the method described in section *3.2.3.2.*

3.5.3.2 Determination of water holding capacity (WHC)

The WHC was measured using the technique of Traynham *et al.,* 2007. Extruded sample (5g) was placed in distilled water for WHC and kept a side for 30 min by gentle stirring at normal room temperature. After hydration, the samples were subjected to centrifuge at 3000rpm for 20 min; weight of the samplewas noted after removal of the supernatant. WHC was noted as g/g of sample. The WHC of developed jackfruit based meat analogue with different combinations was conducted.

3.5.3.3 Determination of oil holding capacity (OHC)

The OHC was measured using the technique of Traynham *et al.,* 2007. About 5g of extruded sample was placed in oil and kept a side for 30 min by gentle stirring at normal room temperature. After hydration, the samples were subjected to centrifuge at 3000rpm for 20 min. Weight of the sample was noted after removal of the supernatant. OHC was noted as g/g of sample. The OHC of developed jackfruit based meat analogue with different combinations was conducted.

3.5.3.4 Determination of water activity

It is one of the most important parameters while determining the shelf life offoods. Water activity (aw) is a measure for the amount of available water. Water activity of developed meat analogue was determined using water activity meter (Model- Aqua la, Decagon Devices Inc., Pullman (Wa), USA). The water activity of developed jackfruit based meat analogue with different combinations was conducted.

3.5.3.5 Texture analysis

Texture analysis of meat analogue was performed using texture analyzer (Shimadzu Universal Testing Machine, Shimadzu Vickers Hardness Tester (UTM EZSX 500N)). The cohesiveness, adhesiveness, hardness, gumminess and chewiness were determined as described by Breene *et al*., 1975. Sample was cut into size of 10mm. Cylinder probe of 10mm diameter is used for the experimental purpose. The texture analysis conditions were as follows: the cross-head speed of 0.5 mm/sec, maximum peak stress of 10 kg and the distance between two supports 10 mm.

3.5.3.6 Colour

The colour of developed meat analogue was measured using Hunter lab colour flex meter (Model: 45°/0°, USA). It works on the principle of light focusing on the sample and measures reflected energy from the sample across the entire visible spectrum. Colorimeter having standard observer curves such as red, green and blue colors. The Hunter lab colour scale indicating L^* as lightness with 0 for black and 100 for white, a^* as redness with "+" values for red and "-" values for green, and b^* as yellowness with "+" values for yellow and "-" values for blue (Diaante *et al.*, 2010). Before measuring the color of the sample, instrument should standardize by placing black and white standard tiles. The sample was placed in the glass jar and it should be filled upto the mark. The filled glass jar was placed on CIELAB scale.

3.5.3.7 Sensory analysis

Sensory evaluation has an essential role in new product development with regard to its acceptability. Nine-point hedonic scale was adopted for sensory evaluation of the optimized jackfruit-based meat analogue as per Archana *et al* (2016). A scoring point 9 indicates extremely like and point 1 indicates extremely dislike. A panel of 10 untrained judges were chosen for the evaluation. The organoleptic characters *viz*., colour, appearance, texture, flavor, taste and overall acceptability of developed meat analogue were evaluated. The data were then analyzed for determination of sensory acceptability. The sensory score card is shown in Appendix B.

EXPERIMENT – II

3.6 STORAGE STUDIES OF DEVELOPED JACKFRUIT BASED MEAT ANALOGUE

3.6.1 Experimental design

3.6.1.1 Independent variables

- Period of storage
  - Initial
  - 1st week
  - 2nd week
  - 3rd week

3.6.1.2 Dependent variables

- Moisture content
- Water holding capacity
- Oil holding capacity
- Water activity
- Microbial analysis

Shelf study of the food product refers to the period for which they can be used while maintaining the food quality. The developed meat analogue was packed in LDPE of gauge thickness 49 micron. The packaging was done using vacuum packing machine (M/s Sevana, Model:08500VMG) The packed samples were stored at freezing temperature (-18°C) for storage studies. The storage study was conducted to optimize shelf life for developed jackfruit-based meat analogue. During storage studies, the changes in the quality parameters of developed jackfruit based meat analogue were analyzed for every week at regular interval. Storage studies were conducted for 3 weeks.

3.7.2 Quality analysis of optimally developed jackfruit based meat analogue for storage studies

Various quality parameters of stored products *viz.*, moisture content, water holding capacity, oil holding capacity and water activity were determined by employing the standard measurement procedures as described in *3.5.3.1*, *3.5.3.2*, *3.5.3.3* and *3.5.3.4* respectively for every week of storage period.

3.7.2.1 Microbial analysis

The microbial analysis of optimized samples was carried out by standard pour plate method.

- *Enumeration of bacterial population*

The bacterial population in the developed meat analogue was analyzed by the standard pour plate method. This method was used to count the number of microorganisms in a mixed sample, which was added to a molten medium prior to its solidification. The selective media used for bacterial enumeration were nutrient agar. All instruments and solutions were sterilized before being used for plating procedures. The agar medium was dispensed into a test tube and pre-sterilized in an autoclave. First, the solid meat analogue was ground into a fine paste by a mortar and pestle. 1g of ground paste was transferred into a sterile test tube containing 10 ml of distilled water, which gave a 10^{-1} dilution. For proper dispersion, the test tubes were shaken well. 1 ml from the 10^{-1} dilution was pipetted to 9 ml of distilled water in another test tube to obtain a 10-^{2} dilution. This procedure was repeated until a 10^{-5} dilution was achieved. For enumeration, the lid of the empty petri dish was opened, and 1 ml of the 10^{-2} dilution was dispensed into the middle of the plate using a micro pipette, and the lid was closed. Pre-sterilized nutrient agar medium was poured into the petri dish containing the sample. The lid was closed, and the sample was mixed with the agar by gently swirling the plate. The agar was allowed to thoroughly solidify before inverting the plate for incubation. The procedure was repeated for 10^{-3} and 10^{-4} dilutions. The plates were incubated at room temperature for 24 hours. The colonies were counted after incubation.

- *Enumeration of yeast and mold population*

The selective media used for the enumeration of yeast and mold was chloramphenicol yeast glucose agar. The same procedures were followed as those for the enumeration of the bacterial population. The plates were incubated at room temperature for 48 hours. The colonies were counted after incubation.

Result and Discussion

CHAPTER IV

RESULT AND DISCUSSION

This chapter deals with the results of optimization of process parameters of developed jackfruit-based meat analogue. The quality evaluation and storage studies of the developed meat analogue are also detailed in this section.

4.1 Drying of jackfruit

The sliced jackfruit was dried using heat pump dehydration dryer at a temperature of 60°C for 7 hrs. The final weight of dried jackfruit was found to be 1.106g and had a moisture content of 10.5%(w.b)

EXPERIMENT - I

4.2 OPTIMIZATION OF PROCESS PARAMETERS OF DEVELOPED JACKFRUIT-BASED MEAT ANALOGUE

The Box- Behnken experimental design was selected to find out the best combination of process parameters in the developed jackfruit based meat analogue. Jackfruit based meat analogue was developed with different combinations of texturizing agent, rotational speed and binding composition as explained in section 3.5. The process parameters *viz*., texturizing agent, rotational speed and binding composition were optimized based on the quality of the final product. Seventeen experiments were conducted and the quality of jackfruit based meat analogue was studied.

4.2.1 Effect of process parameters on quality of developed jackfruit- based meat analogue

The effect of process parameters (texturizing agent, rotational speed and binding composition) on quality of developed jackfruit-based meat analogue were analyzed and discussed in the following section.

4.2.1.1 Moisture content

The effects of process parameters on moisture content of developed jackfruit based meat analogue are presented in Table. A1.2 (Appendix- A). Also, 3D graphs representing the response surface generated by the model (Equation. 4.1) are depicted in Fig. 4.1.

Analysis of variance (Table. A2.1) showed the process parameters *viz*., texturizing agent, rotational speed and binding composition had a significant effect ($p<0.05$) on moisture content of the product. From Fig. 4.1, it was found that the moisture content of the product varied between 39.56 to 48.93% (w.b). The maximum value of moisture content was obtained at 60g texturizing agent (refined wheat flour), moderate rotational speed and 4g binding agent (CMC) whereas minimum obtained at 50g texturizing agent, low rotational speed and 4g binding composition respectively.

The moisture content indicates the amount of water that exists in the sample and is very significant factor that defines its quality (Ghaffari *et al*., 2015). A second order quadratic equation was fitted between independent variables and moisture content using the experimental values. Following regression model are obtained to predict the moisture content of developed jackfruit based meat analogue.

$$MC = 44.46 + 1.73G - 0.2025M + 2.37C + 0.5250GM - 0.5925GC - 1.12MC + 1.50G^2 - 2.30M^2 + 0.6860C^2 \ldots \quad \ldots (4.1)$$

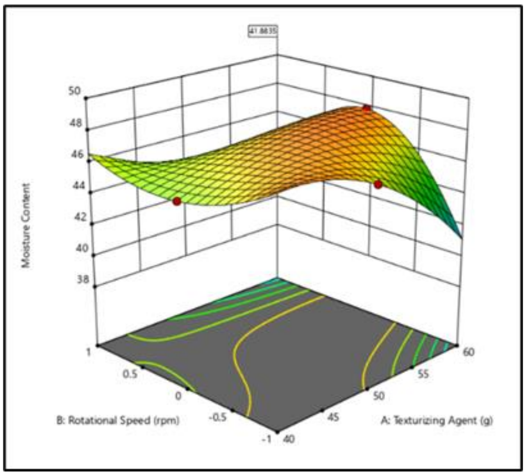
Where,

G= Texturizing agent, g

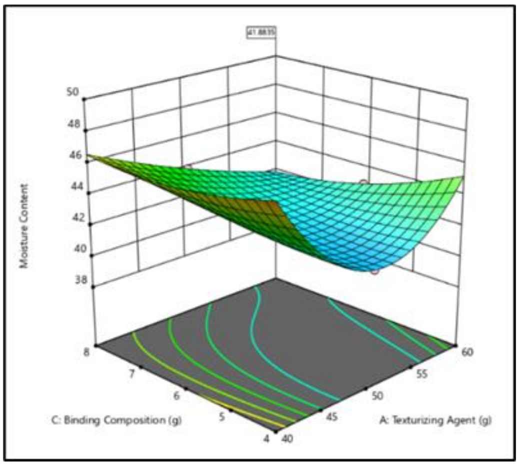
M= Rotational speed, rpm

C= Binding composition, g

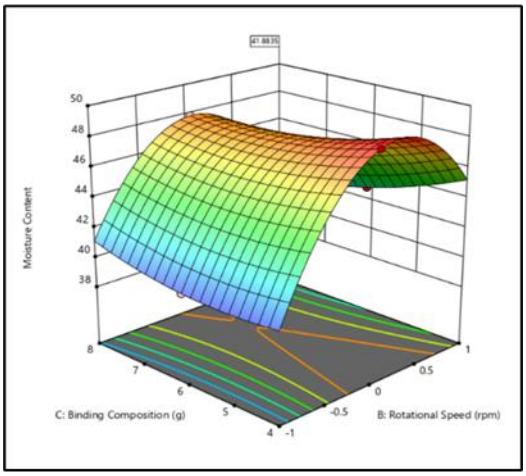
MC= Moisture content



(a)



(b)



(c)

Fig.4.1. Effect of process parameters on moisture content of developed jackfruit based meat analogue

4.2.1.2 Water holding capacity

WHC is an important factor as it affects the quality and yields of fresh meat or its products (Wang *et al.,* 2015). In meat analogue, WHC represents the ability of protein to hold water and to form the protein gel network. The higher the WHC in meat analogue, the more enhanced the juiciness.

The Fig. 4.2 displays the effect of change of water holding capacity of developed jackfruit based meat analogue. The water holding capacity of developed jackfruit based meat analogue at different operating conditions are tabulated in Table A1.2 (Appendix – A).

Analysis of variance (Table A2.2) showed that water holding capacity strongly dependent on texturizing agent, rotational speed and binding composition. The process parameters *viz*., texturizing agent, rotational speed and binding composition had a high significant effect ($p \leq 0.05$) on water holding capacity of developed jackfruit based meat analogue. The R- squared value of the model was 0.8596.

The WHC of developed jackfruit based meat analogue varied between 6.1 to 8.3g/g at different operating conditions. The water holding capacity at 50g texturizing agent, moderate rotational speed and 6g binding composition was found to be maximum whereas minimum obtained at 40g texturizing agent, moderate rotational speed and 8g binding composition respectively.

The relationship between the effect of process parameters and WHC of developed jackfruit based meat analogue are depicted by the equation 4.2:

$$WHC = 8.24 + 0.0638G + 0.1513M - 0.0875C + 0.1025GM + 0.2750GC - 0.6313G^2 - 0.1563M - 1.13C^2 \ldots \quad \ldots (4.2)$$

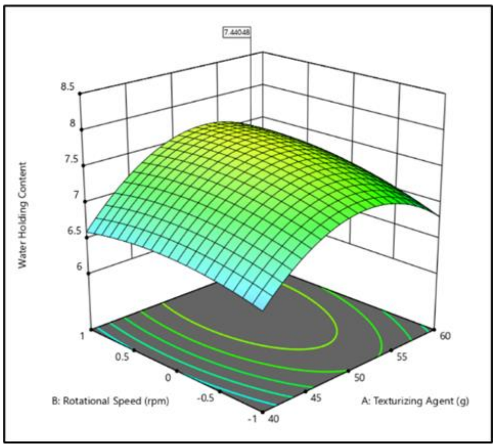
Where,

G= Texturizing agent, g

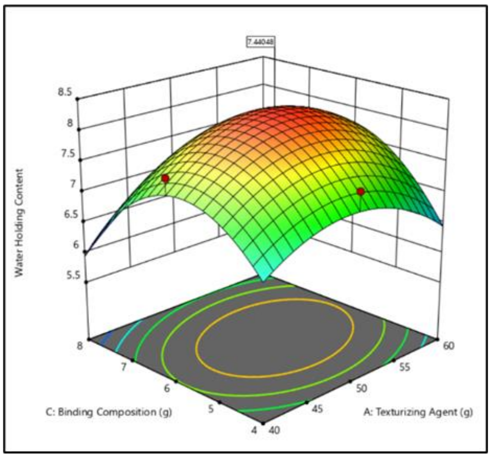
M= Rotational speed, rpm

C= Binding composition, g

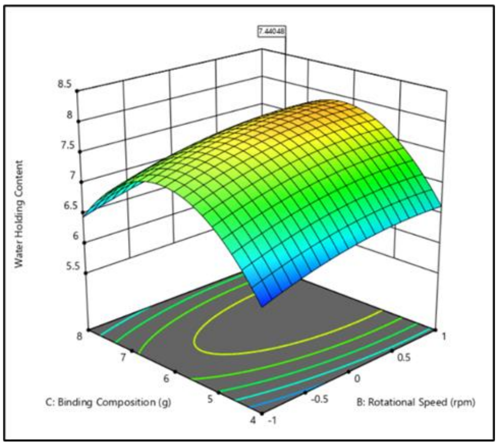
WHC= Water holding capacity



(a)



(b)



(c)

Fig.4.2. Effect of process parameters on Water holding capacity of developed jackfruit based meat analogue

4.2.1.3 Oil holding capacity

OHC is a functional property of the meat which depends on the pore size and the charges of molecule. High OHC indicates the hydrophobic character of proteins. OHC is important properties in meat products and effects on shelf life (Chen *et al.*, 2006).

The Fig. 4.3 displays the effect of change of water holding capacity of developed jackfruit based meat analogue. The oil holding capacity of developed jackfruit based meat analogue at different operating conditions are tabulated in Table A1.2 (Appendix – A).

Analysis of variance (Table A2.3) showed that oil holding capacity strongly dependent on texturizing agent, rotational speed and binding composition. The process parameters *viz*., texturizing agent, rotational speed and binding composition had a high significant effect ($p \leq 0.05$) on oil holding capacity of developed jackfruit based meat analogue. The R- squared value of the model was 0.8100.

The OHC of developed jackfruit based meat analogue varied between 5.8 to 6.4g/g at different operating conditions. The oil holding capacity at 540g texturizing agent, low rotational speed and 6g binding composition was found to be minimum whereas maximum obtained at 50g texturizing agent, moderate rotational speed and 6g binding composition respectively.

The relationship between the effect of process parameters and OHC of developed jackfruit based meat analogue are depicted by the equation 4.3:

$$OHC = 6.16 + 0.2125G + 0.0488M + 0.0138C \qquad \text{… (4.3)}$$

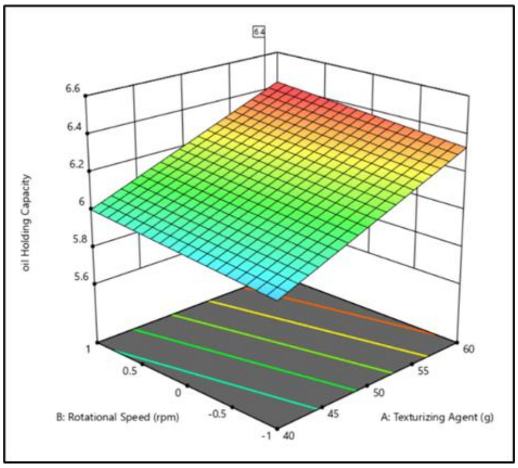
Where,

G= Texturizing agent, g

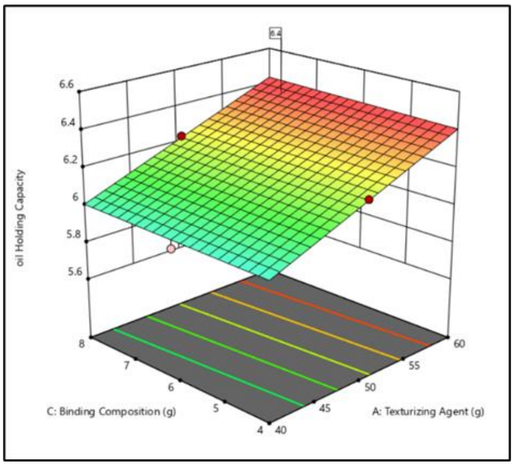
M= Rotational speed, rpm

C= Binding composition, g

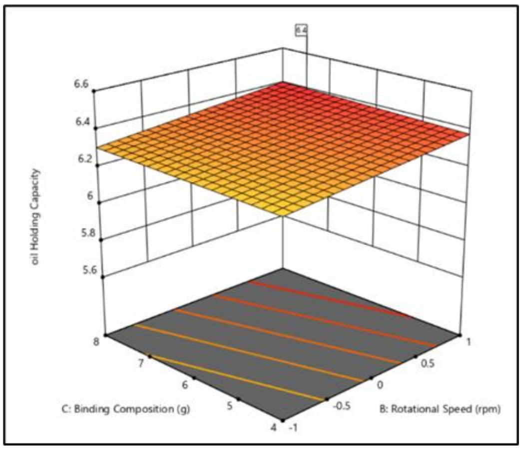
OHC= Oil holding capacity



(a)



(b)



(c)

Fig.4.3: Effect of process parameters on Oil holding capacity of developed jackfruit based meat analogue

4.2.1.4 Water activity

Water activity (aw) is a measure of the amount of water available. The effects of process parameters on water activity of developed jackfruit based meat analogue are presented in Table A1.2 (Appendix – A). Also, 3D surface plot displayed the response surface generated by the model (Equation. 4.4) are depicted in Fig.4.4.

The results were statistically analyzed and presented in Table A2.4. ANOVA table indicate that process parameters affected the water activity. Also, the second order interaction level between texturizing agent, rotational speed and binding composition also found to be significant ($p \leq 0.05$). The R- squared value of the model was 0.5457. The effects of process parameters on water activity of meat analogue samples are given in Table 4.2. It is observed from the table that the water activity values ranged from 0.966 to 0.976.

The second-order quadratic equation (4.4) explained the relationship between the process parameters and water activity of developed jackfruit based meat analogue:

$$aw = 0.9736 - 0.0013G - 0.0018M - 0.0008C - 0.0005GM - 0.0018GC - 0.0023MC - 0.0015G^2 - 0.0005M^2 - 0.0003C^2 \ldots \quad \ldots (4.4)$$

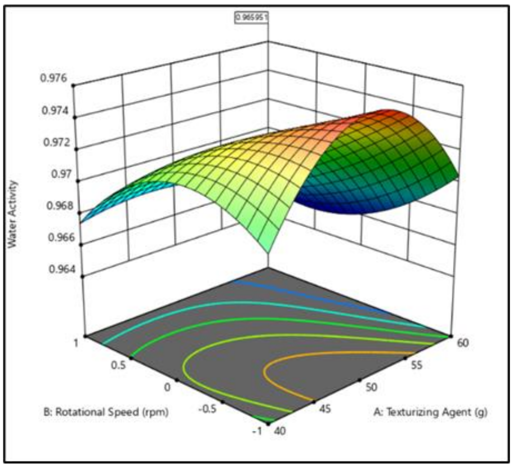
Where,

G= Texturizing agent, g

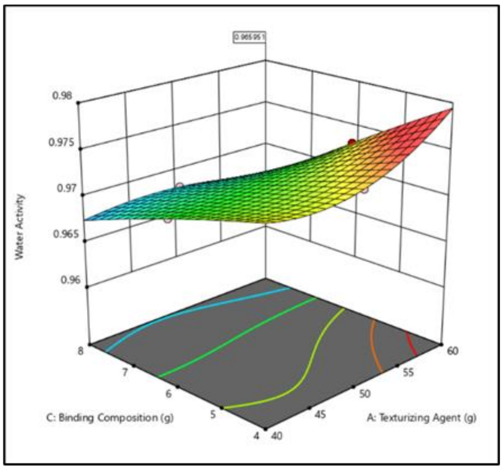
M= Rotational speed, rpm

C= Binding composition, g

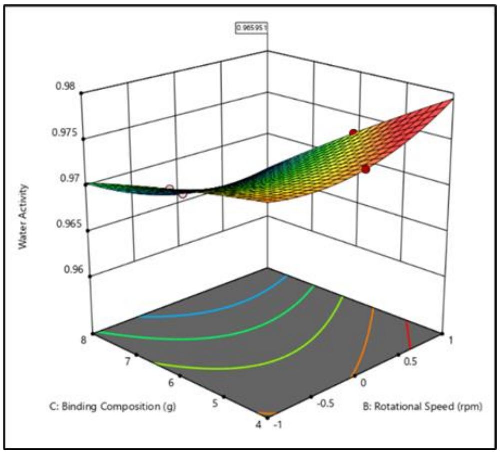
aw= water activity



(a)



(b)



(c)

Fig. 4.4. Effect of process parameters on Water activity of developed jackfruit based meat analogue

4.3 PROCESS OPTIMIZATION FOR THE DEVELOPED JACKFRUIT-BASED MEAT ANALOGUE

The jackfruit based meat analogue was developed using extrusion technology and the different process parameters which affect the quality characteristics of jackfruit based meat analogue were determined. Optimization of the process parameters was done by using the three independent variables *viz*., texturizing agent (40,50 and 60g), rotational speed (low. moderate and high) and binding composition (4,6 and 8g). The optimization was done using Box-Behnken design (randomized surface methodology) in Design expert software 13. In this experiment, the independent variables were kept within the range and dependent variables were selected as maximum, minimum, or in range depending upon the requirements. From the desirability analysis, the optimal level of various parameters were found and listed in Table 4.1. The optimum processing conditions for the development of jackfruit based meat analogue were found as texturizing agent of 58.536g, rotational speed of high rpm and binding composition of 7.434g.

Table 4.1. Multi response optimization constraints of developed jackfruit based meat analogue

SL. NO.	Parameters	Goal/ desirability	Lower limit	Upper limit
1	G: Texturizing agent	Is in range	40	60
2	M: Rotational speed	Is in range	Low	High
3	C: Binding composition	Is in range	4	8
4	Moisture content	Minimize	39.56	48.93
5	Water holding capacity	Maximize	6.1	8.3
6	Oil holding capacity	Maximize	5.8	6.4
7	Water activity	Minimize	0.966	0.976

4.4 QUALITY PARAMETERS OF OPTIMALLY PRODUCED JACKFRUIT BASED MEAT ANALOGUE

Based on the Box-Behnken Based design of RSM, the optimum processing conditions for the development of jackfruit based meat analogue were obtained as texturizing agent of 58.536g, rotational speed of high rpm and binding composition of 7.434g. The quality parameters of optimally produced jackfruit based meat analogue are tabulated in Table. 4.2. Jackfruit based meat analogue had an average moisture content of 42.071% (w.b) and water activity of 0.968. The water holding and oil holding capacity was found to be 7.440 g/g and 6.400 g/g, respectively.

Table. 4.2. Quality parameters of optimally produced jackfruit based meat analogue

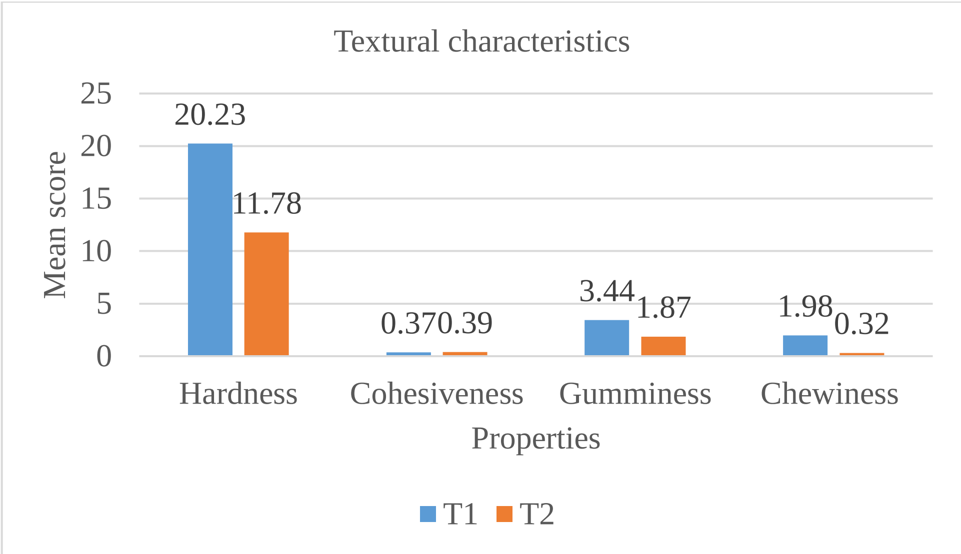
Quality parameters	Value
Moisture content (% w.b)	42.071
Water holding capacity (g/g)	7.440
Oil holding capacity (g/g)	6.400
Water activity	0.968

4.4.1 Textural properties

Different textural properties like hardness, cohesiveness, chewiness and gumminess were evaluated using texture analyzer. The instrumental textural properties of jackfruit-based meat analogue are shown in Table C1.1. Hardness is considered as the maximum force of the first compression. The hardness of control and developed meat analogue shows significant difference. The hardness of control is very much higher than the developed meat analogue. The control shows a hardness of 20.23±1.23, whereas the developed meat analogue shows11.78± 0.60. The control sample and developed meat analogue show cohesiveness of 0.37±0.04 and 0.39± 0.02 respectively.

The results implies that the cohesiveness of both the samples has no significant difference. The gumminess characterizes semi-solid foods and is calculated by hardness× cohesiveness. The gumminess of the control and developed meat analogue are 3.44±0.85 and 1.87± 0.43 respectively.

The gumminess of control is higher than that of developed meat analogue. Chewiness is an important parameter in textural analysis. Control shows the highest value for chewiness 1.98c0.48 and that of developed meat analogue is 0.32± 0.02. Chewiness is relatively low for developed meat analogue.

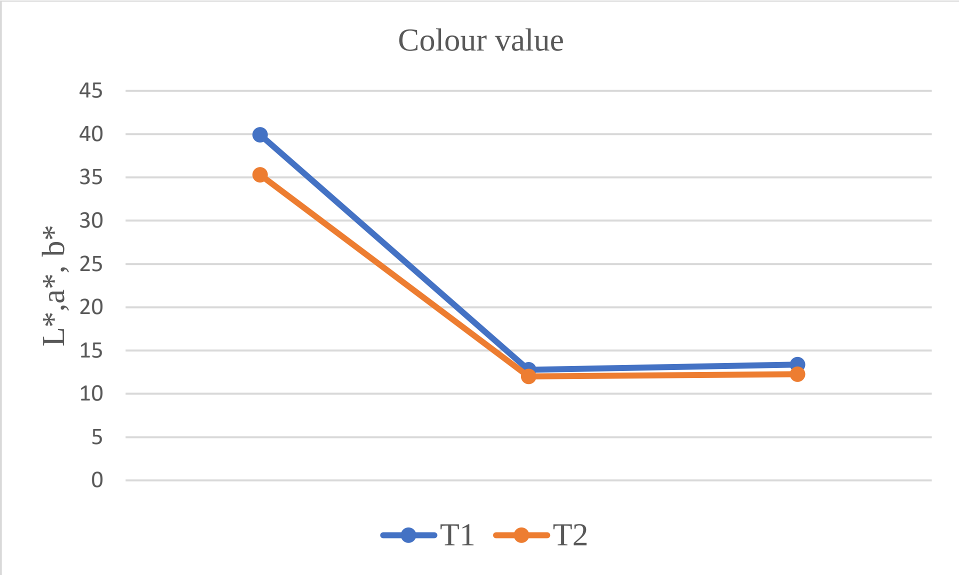


T1- Control, T2- Jackfruit-based meat analogue

Fig. 4.5. Effect of textural characteristics of jackfruit-based meat analogue and control

4.4.2 Colour

Colour was the main qualitative factor in processed meat, which affects consumer perception and product approval (Kamani *et al*., 2017). The colour of developed meat analogue was measured using Hunter lab colourimeter as explained in 3.5.3.6. The study shows that the developed jackfruit-based meat analogue had no significant difference in lightness than control. For the redness of the sample and control show no significant difference. This may due to the addition of colour giving ingredients such as beet powder to the blood substitute. Furthermore, yellowness of the product b* shows no significant difference. Colour values of jackfruit-based meat analogue is depicted in Table C1.2.



T1- Control, T2- Jackfruit-based meat analogue

Fig. 4.6. Effect of colour values of jackfruit-based meat analogue and control

4.4.3 Sensory evaluation

Optimally developed jackfruit-based meat analogue and control sample were subjected to sensory evaluation as explained in 3.5.3.7. The sensory analysis plays an important role in the selection of product and consumer acceptance. The mean sensory scores of different attributes like colour, appearance, texture, flavor, taste and overall acceptability as evaluated by the judges are shown in Table 4.3

Table 4.3 The mean sensory scores of developed meat analogue

Samples	Colour	Appearance	Texture	Flavour	Taste	Overall acceptance
T1	8.1	8.1	7.65	8	8.1	8.3
T2	8.1	8	7.9	7.9	7.7	8.3

T1- Control, T2- Developed meat analogue

Result shows that the developed meat analogue has no significant effect with control (commercial meat analogue) in terms of colour, appearance, flavor and overall acceptance. The sensory assessments indicated that the control had more taste as compared to the developed meat analogue. The preference score of control sample over the developed meat analogue may be due to jackfruit taste. The evaluation indicates that the developed meat analogue has good texture on par with control sample.

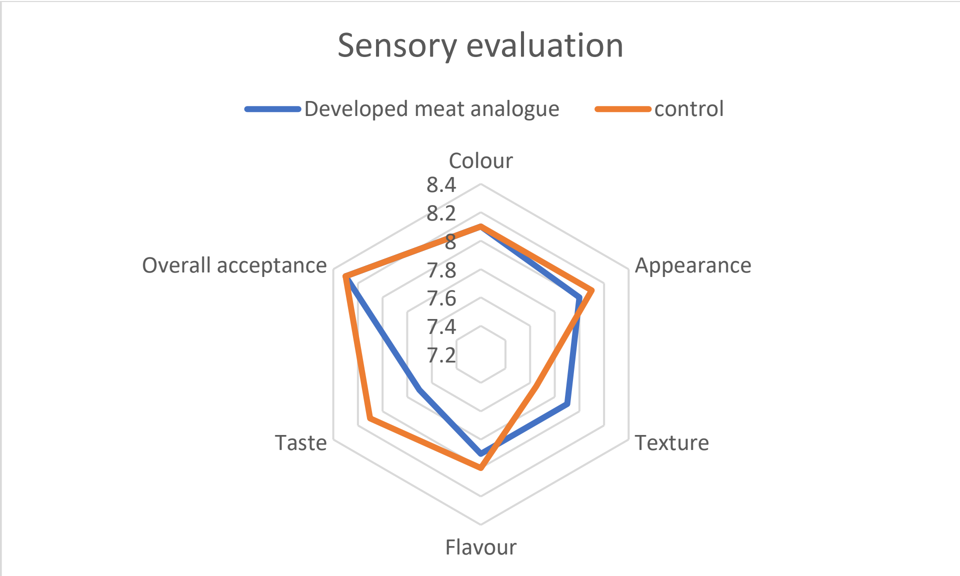


Fig. 4.7. The radar chart showing the variation of mean sensory evaluation score

EXPERIMENT II

4.5 STORAGE STUDIES

Storage studies were performed for the developed jackfruit based meat analogue. The jackfruit based meat analogue was packed in low-density polyethylene (LDPE) stand up pouches of 49 micron thickness. Packaging was done using vacuum packaging machine. The packed samples were stored at -18℃ for storage studies. The quality parameters like moisture content, water holding capacity, oil holding capacity and water activity were evaluated at every week for 3 weeks. The storage characteristics of jackfruit based meat analogue are shown in Fig. 4.8.

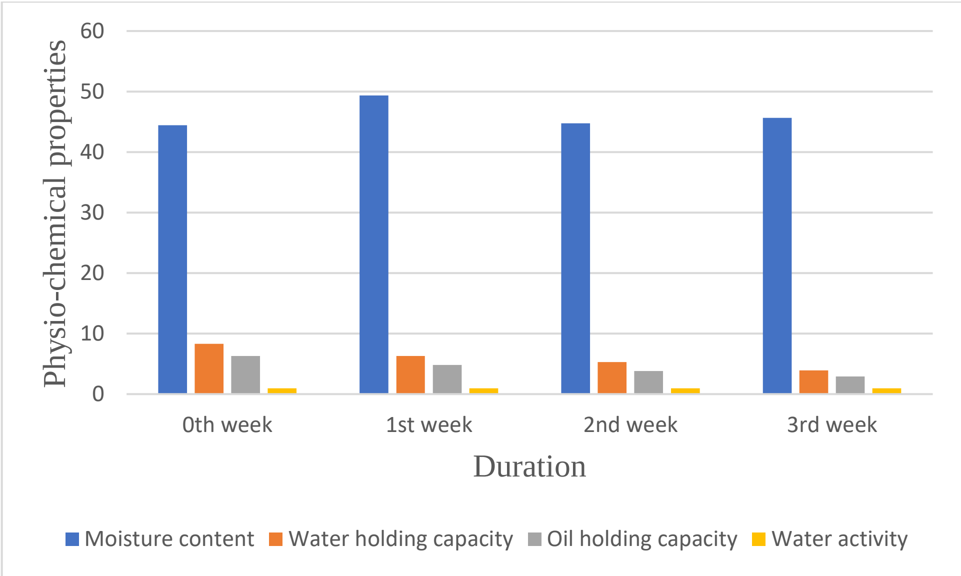


Fig. 4.8. Quality characteristics of jackfruit-based meat analogue during storage

4.5.1 Effect of packaging on quality parameters of developed jackfruit-based meat analogue during storage

4.5.1.1 Effect of packaging on moisture content during storage of developed jackfruit-based meat analogue

The effect of packaging on moisture content of jackfruit-based meat analogue during storage is depicted in Fig 4.9. The moisture content of stored meat analogue packed in low density polythene (LDPE) decreased from 49.35% to 44.46% at 0^{th} to 3^{rd} week of storage respectively. The lower the moisture content of meat analogue, the better its shelf stability and hence the quality.

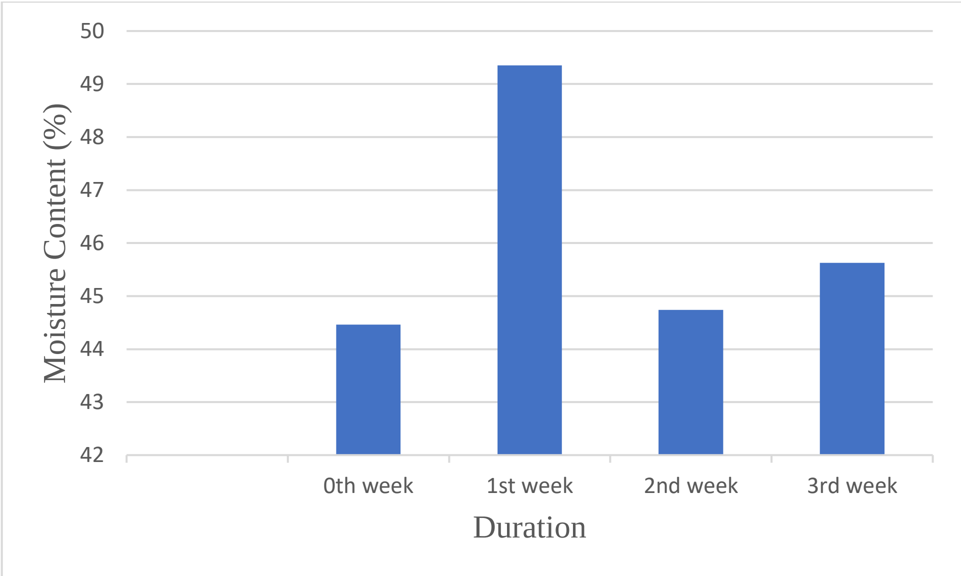


Fig. 4. 9. Effect of storage period on moisture content of developed jackfruit-based meat analogue

4.5.1.2 Effect of storage period on water holding capacity of developed jackfruit-based meat analogue

WHC is an important factor as it affects the quality and yield of fresh meat or its products (Wang *et al*., 2015). In meat analogues, WHC represents the ability of protein to hold water. The higher the WHC in meat analogues, the more enhanced the juiciness. Fig 4.10 shows the effect of WHC on optimized jackfruit-based meat analogue. It was observed that the WHC gradually decreases from initial week to final week. This shows that the juiciness of meat analogue has been decreased as the time goes. The WHC of stored meat analogue packed in low density polythene (LDPE) decreases from 8.3 to 6.3, 8.3 to 5.3 and 8.3 to 3.9 at 0^{th} to 3^{rd} week of storage respectively. Significant reduction in WHC was observed.

Decrease in WHC may be due to the responses related to protein water interactions, therefore the protein content within the flour blends may influence the WHC (Sadhana *et al*., 2019). Similar results were quoted by Traynham *et al*., 2007 in the evaluation of water holding capacity for wheat-soy flour bends. WHC is an important character of fresh meat since it affects the quality of the end product.

Polysaccharides are extensively used as ingredients in a number of meat products to obtain desirable binding characteristics, texture and appearance (Perez-Mateos and Montero, 2000).

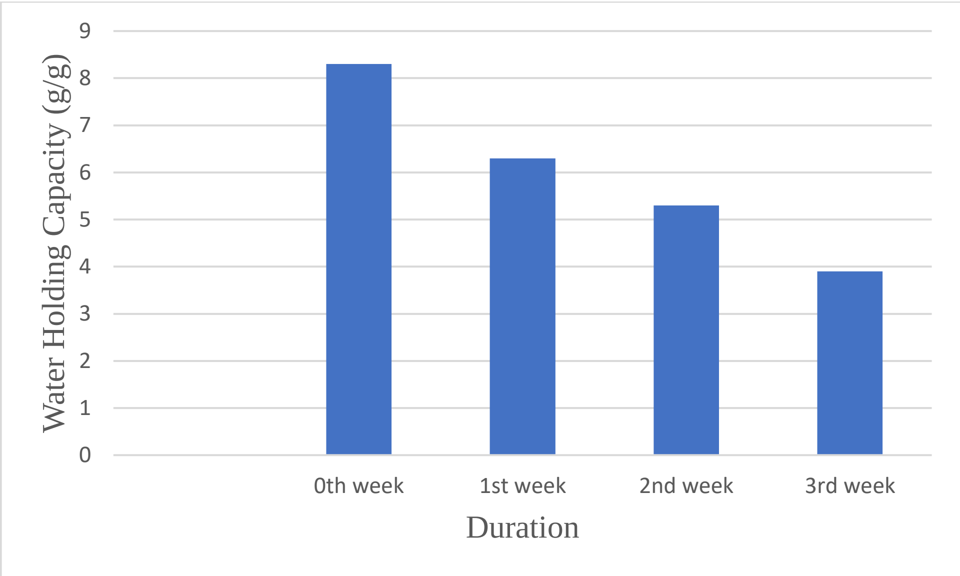


Fig. 4. 10. Effect of storage period on WHC of optimized jackfruit-based meat analogue

4.5.1.3 Effect of storage period on oil holding capacity of developed jackfruit-based meat analogue

OHC corresponds to the amount of oil that a sample can absorb per unit of weight. It can also be used to improve the juiciness of meat analogue. Fig 4.11 shows the effect of OHC on optimized jackfruit-based meat analogue. It represents significant reduction in OHC from initial week to final week. This shows that the juiciness of meat analogue has been decreased as the time goes. The OHC of stored meat analogue packed in low density polythene (LDPE) decreases from 6.3 to 4.8, 6.3 to 3.8 and 6.3 to 2.9 at 0^{th} to 3^{rd} week of storage respectively.

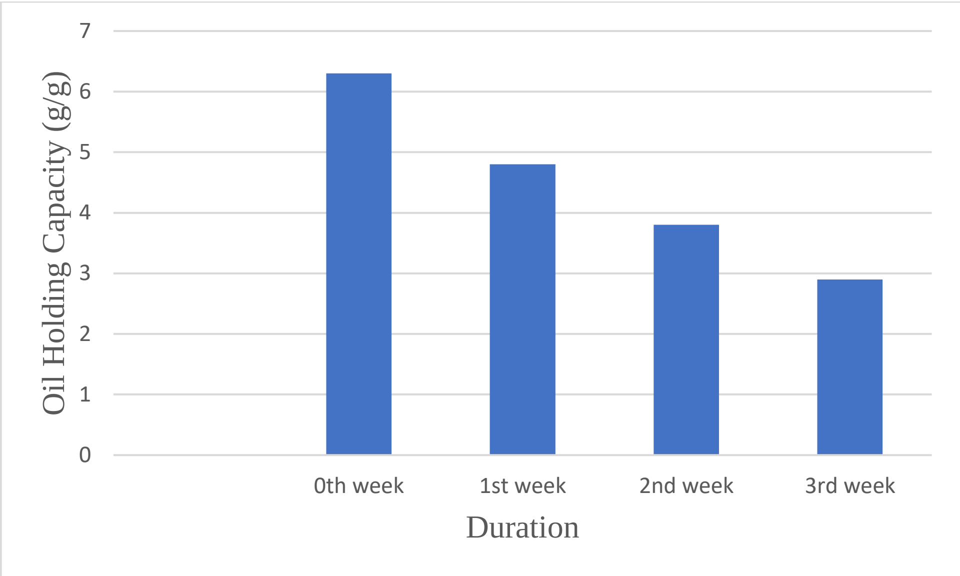


Fig. 4. 11. Effect of storage period on OHC of optimized jackfruit-based meat analogue

4.5.1.4 Effect of storage period on water activity of developed jackfruit-based meat analogue

The effect of optimized jackfruit-based meat analogue on water activity during storage is represented in Fig 4.12. The water activity of the developed meat analogue stored at 0^{th} week of packaging was 0.974. During storage period, the water activity in low density polyethylene (LDPE) decreased from 0.974 to 0.971, 0.974 to 0.963 and 0.974 to 0.959 at 0^{th} to 3^{rd} week of storage respectively. Microbial spoilage is faster in vegan food. The high-water content and water activity of protein raw material promote bacterial proliferation (Samard *et al*., 2019).

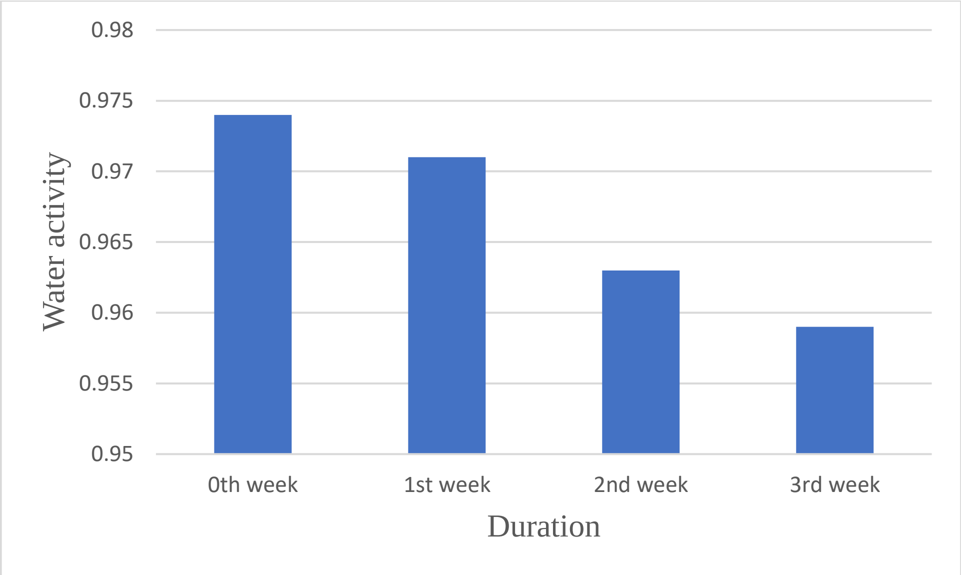


Fig 4. 12. Effect of storage period on water activity of optimized jackfruit-based meat analogue

4.5.1.5 Microbial Analysis

Post-process contamination is the more significant factor regarding food quality. The presence of bacteria, yeasts and molds in food is usually caused by raw materials or post-process contamination, therefore bacterial and fungal counts can be used as a hygiene process indicator primarily in the case of plant-based products. Table D1.2 represents the microbial analysis of jackfruit-based meat analogue. Microbial analysis is carried out for 0^{th}, 1^{st} and 9^{th} week and the serial dilutions of 10^{-2},10^{-3} and 10^{-4} are considered. The initial (0^{th} week) and final (9^{th} week) bacterial count after 24hrs is found to be 11×10^4 cfu/g and 10×10^4 cfu/g respectively in 10^{-4} dilutions. The significant range of bacteria is 30-300 cfu on a plate. This depicts that, there is no significant difference in the number of bacteria even after 9 weeks. i.e., even though the viability exists, there is no multiplication of bacteria found. During the storage period the bacterial count is found to be uniform and only the initial bacteria are found. The analysis of yeast and molds are carried up to 9^{th} week. There is no growth found in the 10^{-2}, 10^{-3} and 10^{-4} serial dilutions for 9 weeks. The fungal growth is slightly initiated after 9^{th} week.

The bacterial, yeast and mold growth is controlled in the sample during a storage period of 9 weeks. This depicts that the microbiological quality of the developed jackfruit-based meat analogue is maintained.

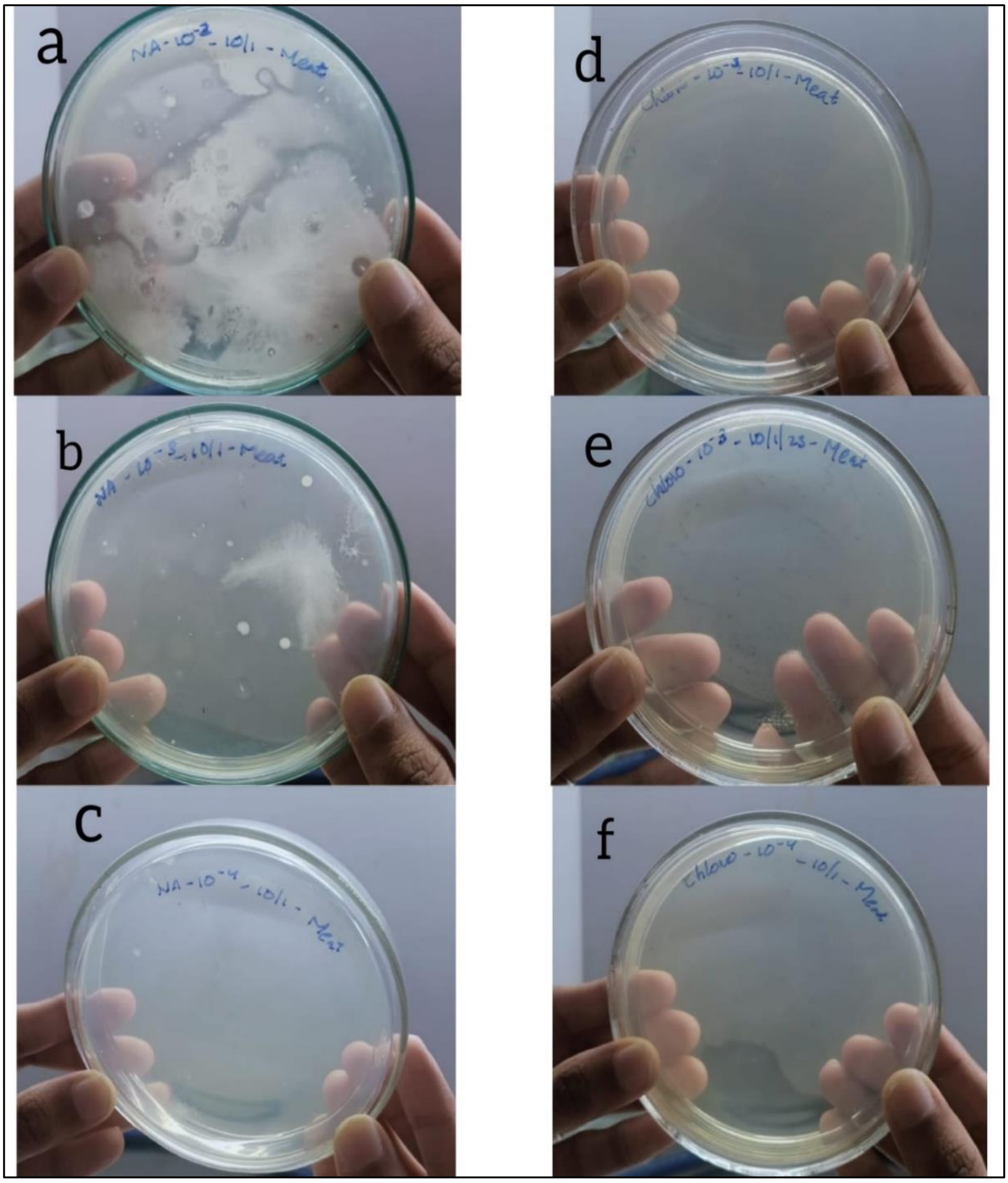


Plate 4.1. Microbial analysis (bacteria, yeast and mould): plate a, b, c nutrient agar 10^{-2}, 10^{-3}, 10^{-4} respectively. Plate d, e, f chloramphenicol yeast glucose agar 10^{-2}, 10^{-3},$10^{-4.}$ respectively.

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

Meat analogue, also known as plant-based meat or meat substitute, refers to a category of food products designed to mimic the taste, texture, and appearance of traditional animal-based meat. These innovative creations are crafted using a combination of plant-based ingredients such as soy, jackfruit, peas, mushrooms and grains, among others. Meat analogues have gained immense popularity due to various reasons, including ethical concerns, environmental sustainability, and health considerations. With advancements in food technology, manufacturers have been able to create meat analogues that closely resemble real meat in taste and texture, providing consumers with a viable alternative that satisfies their cravings while reducing the need for animal products.

Jackfruit contains vitamins, minerals, and antioxidants, making it a great addition to any diet. Since it's so versatile, jackfruit can be part of various recipes, from sweet to savory. It has elevated levels of fibre and vitamin C. The fruit packs more protein than other varieties and offers 4 grams per cup – higher than guava and twice as high as a banana. According to studies, unripe jackfruit has more protein and fibre and fewer carbohydrates than ripe jackfruit and can be employed for the production of meat analogue.

Meat extenders and meat analogues are produced by extrusion of vegetable proteins, resulting in products that have an appearance and texture similar to the fibrillar structure of meat. Meat analogues find raising interest of many consumers who are looking for indulgent, healthy, low environmental impact, ethical, cost-effective, and/or new food products. High moisture extrusion cooking enables the production of fresh, premium meat analogues that are texturally like muscle meat from plant or animal proteins. The appearance and eating sensation are similar to cooked meat while high protein content offers a similar nutritional value. Meat analogues present a clear advantage to meat when it comes to shelf life and food safety.

The investigation on “Development and Evaluation of Jackfruit Based Meat Analogue by Extrusion Technology” was under taken with objectives: i) Development of jackfruit-based meat analogue by extrusion technology ii) Optimization of process parameters of meat analogue iii) Storage studies of the optimized meat analogue.

Jackfruit (*Koozha)* was peeled, cored and cut into pieces of 5mm thick slices. Five hundred grams of sample were taken for blanching. In hot water blanching method, jackfruits were blanched at 100℃ temperatures for 1 minute followed by instant cooling. These slices were dried using heat pump drier at 60°C for 7 hrs. Dried samples were disintegrated using blender and sieved to 800 micron meter.

Preparation of blood substitute was done by thorough mixing of dry and wet ingredients. The prepared mixture was then extruded using a hand extruder. It was then layered with fat and packed in a retort pouch and sealed followed by blanching and cooling. It appeared to have a structure as that of a steak. It was then cut into pieces of about 1-2 inches. Prepared steak was packed in LDPE packaging material using vacuum packaging machine.

The standardization of process parameters of vacuum fried product was done by three different combinations of texturizing agent **(**refined what flour) (40, 50 and 60g), rotational speed (low, moderate and high rpm) and Binding composition binding material (CMC) (4, 6 and 8g). The optimization was done using the Box-Behnken design (response surface methodology) in Design Expert Software 13. The process parameters *viz*. texturizing agent, rotational speed and binding composition were optimized based on the quality of the final product-textural analysis, color and sensory evaluation. Storage studies of the optimized product were conducted for 3 weeks. The jackfruit based meat analogue was packed with LDPE pouch then subjected to vacuum packing using vacuum packaging machine and were stored under at -18℃ and the quality analysis was periodically done at 7 days interval for 3 weeks. The quality of the jackfruit based meat analogue tested after the conduct of every batch and the quality parameters viz. moisture content, water holding capacity, oil holding capacity and water activity were determined.

The results of the above experiments are summarized as following:

The weight of the dried jackfruit samples was 1.106 g and the moisture content as 10.5% (wb). Box-Behnken design was used for the selection of best combination of process parameters in development of jackfruit based meat analogue. Jackfruit based meat analogue were prepared with different combination of texturizing agent, rotational speed and binding composition. The optimum operating condition for the development of jackfruit based meat analogue was obtained at texturizing agent (refined wheat flour) of 58.536g, rotational speed of high rpm and binding agent (CMC) composition of 7.434g. Quality parameters of the optimized jackfruit based meat analogue were estimated using standard procedures. The moisture content, water activity, water holding and oil holding capacity of the meat analogue were found to be 42.071% (w.b), 0.968, 7.440 g/g and 6.400 g/g, respectively.

Different textural properties like hardness, cohesiveness, chewiness and gumminess were evaluated using texture analyzer. The results imply that the cohesiveness of both the samples has no significant difference. The gumminess of control is higher than that of developed meat analogue. Chewiness is relatively low for developed meat analogue. The study shows that the developed jackfruit-based meat analogue and control had no significant difference in lightness and redness in terms of colour values. Sensory analysis (nine-point hedonic scale) was done with a panelist of 10 judges. The results showed that the developed meat analogue and control (commercial meat analogue) had no significant difference in terms of colour, appearance, flavor and overall acceptance. The sensory assessments indicated that the control had more taste compared with developed meat analogue.

The storage study of optimized jackfruit-based meat analogue was done based on the quality parameters like moisture content, water holding capacity, oil holding capacity and water activity. Storage studies were evaluated at every 7th day for 3 weeks which was packed in LDPE of 49 micron thickness. The study depicts that the developed jackfruit-based meat analogue showed a significant decrease in moisture content, water holding capacity, oil holding capacity and water activity. Microbial analysis is carried out for 0th, 1st and 9th week and serial dilutions of 10^{-2}, 10^{-3} and 10^{-4} using standard pour plate method. From the microbial test, it was observed that there was no significant difference in microbial growth during the storage period and hence it is concluded that the sample was kept safe up to 9 weeks.

References

CHAPTER VI

REFERENCES

Abdullah, I. and Shah, P.S. H. A. 2017. Effect of Using Unripe Jackfruit as a Meat Substitute on Nutrition Composition and Organoleptic Characteristic of Meat Patty. *J. Eng. Technol.* 1: 128.

Akinyede, A.I. and Amoo I.A. 2009. Chemical and Functional Properties of Full Fat and Defatted Cassia Fistula Seed Flours. *Pakistan J. Nutrition*. 8(6): 765 - 769.

Ambily, K. M. and Anitha, D. 2016. Effect of Dehydration Techniques for the Development of Ready to Cook Tender Jackfruit. *IOSR J. Agric. Veterinary Sci.* 9(2): 2319-2372.

Anila, H. L. and Divakar, S. 2018. Development of Textured Vegetable Protein (TVP). *Food Sci. Research J.* 9(2): 289-293.

Arkroyd, C. G. and Balasubramanuyam, S. C. 1966. The Nutritive Value of Indian Food and the Planning Of Satisfaction Diet. *Indian Council Medical Research*. 42:1-255.

Azad, A. K. 2000. Genetic Diversity of Jackfruit in Bangladesh and Development of Propagation Methods. Ph. D Tesis. University of Southampton. 200p.

Babu, S. P. and Sudheer, K. P. 2012. Optimization of Blanching Process for Tender Jackfruit (Artocarpus Heterophyllus L.). *Indian J. Dairy Biosci.* 23.

Bakhsh, A., Lee, S., Lee, E., Hwang, Y. and Joo, S. 2021. Evaluation of Rheological and Sensory Characteristics of Plant-Based Meat Analog with Comparison to Beef and Pork. *Food Sci. Anim. Resour.* 41(6): 983-996.

Chikkanna, G. S. 2021. Technical Facts on the Current Scenario and Future Potential of Jackfruit Processing. *Res. Biotica*. 3(2): 94-106.

Cornet, S. H. V., Snel, S. J. E., Lesschen, J. and Sman, R. G. M. 2021. Enhancing the Water Holding Capacity of Model Meat Analogues through Marinade Composition. *J. Food Eng*. 290 (110283).

Diamante, L., Durand, M., Savage, G. and Vanhanen, L. 2010.Effect of temperature on the drying characteristics, colour and ascorbic acid content of green and gold kiwifruit. International Food Research Journal. 17(441-451).

Egbert, R. and Borders, C. 2006. Achieving success with meat analogs. *Food Technol.* 60: 28–34.

Fayose, F. and Huan, Z. 2016. Heat Pump Drying of Fruits and Vegetables: Principles and Potentials for Sub-Saharan Africa. *Int. J. Food Sci*. 2016:1-8.

Fellows, P. J. 2017. Extrusion Cooking. *Food Processing Technol.*: 753- 780.

Filho, G.C.S., Penna, T. C. P. And Schaffner, D. W. 2005. Microbiological Quality of Vegetable Proteins during the Preparation of a Meat Analog. *Ital. J. Food Sci*. 17(3):269-283.

Gan, P. L. and Poh, P.E. 2014. Investigation on the Effect of Shapes on the Drying Kinetics andSensory Evaluation Study of Dried Jackfruit. *Intl. J. Sci. and Eng.* 7(2): 193-198.

Gerber, P. J., Steinfield, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. and Tempio, G. 2013. Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities. *J. Environ. Protection.* 7(7).

Ghangale, D., Veerapandian, C., Rawson, A. and Rangarajan, J. 2022. Development of Plant-Based Meat Analogue Using Jackfruit a Healthy Substitute for Meat. *Pharma Innovation J.* 11(8): 85-89.

Gunaratne, A., *et al*., 2011. Effect of Fertiliser on Functional Properties of Flour from Four Rice Varieties Grown in Sri Lanka. *J. Sci. Food Agric.* 91(7): 1271-1276.

Hamid, M. A., Tsia, F. L. C., Okit, A. A. B., Xin, C. W., *et al.* 2020. The Application of JackfruitBy-Product on the Development of Healthy Meat Analogue. *IOP Conf. Series: Earth Enviro. Sci.* 575: 12001.

Haq, N. 2006. Jackfruit (Artocarpus heterophyllus). *Tropical Fruit Trees.*

Ismail, I., Hwang, Y. H. and Joo, S. T. 2020. Meat Analog as Future Food: A Review. *J. Anim.*

Joseph, S. 2018. Jackfruit declared as Kerala's official fruit. *The times of india.* 21 march 2018.

Joshi, V. K. and Kumar, S. 2015. Meat analogues: Plant based alternatives to meat products- A review. *Intl. J. Food Ferment. Technol.* 5(2): 107-119.

Kamani, M. H., Meera, M. S., Bhaskar, N. and Mod, V. K. 2019. Partial and Total Replacement of Meat by Plant-Based Proteins in Chicken Sausage: Evaluation of Mechanical, Physio-Chemical and Sensory Characteristics. *J. Food Sci. Technol*. 56(5): 1-10.

Khan, A. U., Ema, I. J., Faruk, M. R. and Tarapder, A. Z. 2021. A Review on Importance of Artocarpus heterophyllus L. (Jackfruit). *J. Multidisciplinary Applied Natural Sci*. 1(2): 106-116.

Khan, M. H. H. *et al,*. 2021. Effect of Processing and Drying on Quality Evaluation of Ready-To-Cook Jackfruit. *J. Agrl. Sci. Food Technol.* 7(2): 2465-7522.

Kolodziejczak, K., Onopiuk, A., Szpicer, A. and Poltorak, A. 2022. Meat Analogues in the Perspective of Recent Scientific Research: A Review. *Foods*. 11(105).

Kyriakopoulou, K., Keppler, J. K., and Goot, A. J. 2021. Functionality of Ingredients and Additives in Plant-Based Meat Analogues. *Foods*. 10(3): 600.

Kyriakopoulou. K., Dekkers. B. and van der Goot. A. J . 2019. Plant- based meat analogue. Sustainable meat production and processing. 103-126.

Lindriati, T., Herlina, H., Arbiantara, H. and Asrofi, M. 2020. Optimization of meat analog production from concentrated soy protein and yam ((Xanthosoma sagittifolium) powder using pasta machine. *Food res*. 4(3):887-895.

McClements, D. J., Weiss, J., Kinchla, A. J., Nolden, A. A. and Grossmann, L. 2021. Methods for Testing the Quality Attributes of Plant-Based Foods: Meat- and Processed-Meat Analogs. *Foods*. 10 (260).

Mittal, R., Sankaran. K. and Achar. A. P. 2020. Market Feasibility Study for Jackfruit Value Added Products. National Institute of Agricultural Marketing, Jaipur. 89p.

Mottet, A., Haan, C. D., Falcucci, A., Tempio, G., Opio, C. and Gerber, P. 2017. Livestock: On Our Plates Or Eating At Our Table? A New Analysis of the Feed/Food Debate. *Global Food Sec.*14: 1–8.

Nansereko, S., Muyonga, J. and Byaruhanga, Y. B. Influence of Drying Methods on Jackfruit Drying Behavior and Dried Products Physical Characteristics. *Int. J. Food Sci*. 2022: 1-16.

Narasimham, P., Nagy, P. S., Shaw, P. E., and Wardowski, W. F. 1990. Breadfruit and jackfruit. *Florida Sci. Source*. 193–259.

Nivetha, B. R, Sudha, K., Narayanan, R. and Vimalarani, M. 2019. Development and Sensory Evaluation of Meat Analog. *Int. J. Curr. Microbiol. App. Sci* 8(8): 1283-1288.

Nychas, G. J. E. and Panagou, E. 2011. Microbiological Spoilage of Foods and Beverages. In Food and Beverage Stability and Shelf Life. *Elsevier*. 3–28.

Ocloo, F. C. K., Bansa, D., Boatin, R. and Adom, T. 2010. Physico-Chemical, Functional nd Pasting Characteristics ff Flour Produced from Jackfruits (Artocarpus Heterophyllus) Seeds. *Agric. Biology J. North America*. 1(5): 903-908.

Perez-Mateos, M. and Montero, P. 2000. Contribution of Hydrocolloids to Gelling Properties of Blue Whiting Muscle. *European Food Res.Technol*. 210: 383-390.

Plattner, B. 2020. Extrusion Techniques for Meat Analogues. *Cereal foods world*. 65(4).

Ranasinghe, S., Maduwanthi, T. and Marapana, R. A. U. J. 2019. Nutritional and Health Benefits of Jackfruit (*Artocarpus Heterophyllus* Lam): A Review. *Intl. J. Food Sci.* 6: 1-12.

Ryu, G. H. 2020. Extrusion Cooking of High-moisture Meat Analogues. *Extrusion cooking*: 205-224.

Sadhana, T., Pare, A., Bhuvana, S. and Mohan, R. J. 2019. Effect of Soy-Jackfruit Flour Blend on the Preparation of Developed Meat Analogues Using Response Surface Methodology. *Intl. J. Pure App. Biosci.* 7(2): 600-610.

Sala, L. G. G. and Scholten, E. 2022. Meat Analogues: Relating Structure to Texture and Sensory Perception. *Foods*.11 (2227).

Samard, S. and Ryu, G. 2019. A comparison of physicochemical characteristics, texture, and structure of meat analogue and meats. *J. Sci. Food Agric*. 99: 2708–2715.

Sawe, B.E., 2017. World leaders in jackfruit production. *Economics: world Atlas*.

Schreuders, F. K. G., Schlangen, M., Kyriakopoulou, K., Boom, R. M.and Goot, A. Texture Methods for Evaluating Meat and Meat Analogue Structures: A Review. *J. Food Control*. 127: 108103.

Singh, A. and Sit, N. 2022. Meat Analogues: Types, Methods of Production and Their Effect on Attributes of Developed Meat Analogues. *Food Bioprocess Technol.* 15(5):1-19.

Soepadmo, E., Verheij, E. W. M. and Coronel, R. E. 1992. Artocarpus Heterophyllus Lam. *Sci. Technol.* 62(2): 111-120.

Soyer, A., *et al*. 2010. Effect of Freezing Temperature and Duration of Frozen Storage on Lipid and Protein Oxidation in Chicken Meat. *Food Chem.* 120(4): 1025-1030.

Springmann, M., Clark, M., Mason-D’Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., *etal.* 2018. Options for Keeping the Food System within Environmental Limits. *Nature.* 562:519–25.

Srivastava, R. and Singh, A. 2020. Jackfruit (Artocarpus heterophyllus Lam) Biggest Fruit with High Nutritional and Pharmacological Values: A Review. *Int. J. Curr. Microbiol. App. Sci.* 9(8):764-774.

Sudheer, K. P., Saranya, S. and Sankalpa, K. B. 2019. Process Protocol Stsndardisation and Shelf-Life Study of Minimally Processed Fresh Cut Tender Jackfruit. *The Pharma Innovation J.* 8(12): 164-169.

Suna, C., Gea, J., He, J., Gan, R. and Fanga, Y. 2021. Processing, Quality, Safety, and Acceptance of Meat Analogue Products. *Eng*. 7(5): 674-678.

Talukder, S., Sharma, B. D., Mendiratta, S. K. and Kumar, R. R. 2012. Effect of Young Jackfruit (Artocarpus Heterophyllus) Pulp on the Quality Characteristics of Restructured Chicken Meat Block. *Indian J. Poultry Sci*. 47(3): 368-371.

Thakur, A. K. and Ansari, M. I. A. 2017. Drying Kinetics of Unripe Jackfruit under Convection. *Trends in biosciences*. 10(18): 3327: 3331.

Toth, A.J., Anna Dunay, A., Battay, M., Illes, C. B. and Suth. M. 2021. Microbial Spoilage of Plant-Based Meat Analogues, *Appl. Sci.* 11(18): 8309.

Traynham, T. L., Myers, D. J., Carriquiry, A. L. and Johnson, L. A. 2007. Evaluation of water-holding capacity for wheat–soy flour blends. *J. American Oil Chemists' Society*. 84 (2): 151.

Wi, G., Bae, J., Kim, H., Cho, Y. and Choi, M. 2020. Evaluation of the Physicochemical and Structural Properties and the Sensory Characteristics of Meat Analogues Prepared with Various Non-Animal Based Liquid Additives. *Foods*. 9 (461).

Yadav, P., Ahlawat, S. S., Jairath, G., Rani, M. and Bishnoi, S. 2015. Studies on Physico- Chemical Properties and Shelf Life of Developed Chicken Meat Anlaogue Rolls. *Haryana Vet*. 54 (1):25-28.

Yahya,M., Fudholi, A., Hafizh, H. and Sopian, K. 2016.Comparison of solar dryer and solar assisted heat pump drier for cassava. Solar Energy. 136(606-613).

Zahari, I., Ferawati, F., Helstad, A., Ahlstrom, C., Ostbring, K., Rayner, M. and Purhagen, J. K. 2020. Development of High-Moisture Meat Analogues with Hemp and Soy Protein Using Extrusion Cooking. *Foods*. 9 (772).

Zahari, I., Ferawati, F., Helstad, A., Ahlström, C., Östbring, K., Rayner, M. and Purhagen, J. K. 2020. Development of High-Moisture Meat Analogues with Hemp and Soy Protein Using Extrusion Cooking. *Foods*. 9(6): 772-781.

Appendix

Appendix- A

Table A1.1. Treatments details of optimization of process parameters

	Coded values			**Decoded values**		
Run	Texturizing agent	Rotational speed	Binding composition	Texturizing agent	Rotational speed	Binding composition
1	-1	-1	0	40	Low	6
2	1	-1	0	60	Low	6
3	-1	1	0	40	High	6
4	1	1	0	60	High	6
5	-1	0	-1	40	Moderate	4
6	1	0	-1	60	Moderate	4
7	-1	0	1	40	Moderate	8
8	1	0	1	60	Moderate	8
9	0	-1	-1	50	Low	4
10	0	1	-1	50	High	4
11	0	-1	1	50	Low	8
12	0	1	1	50	High	8
13	0	0	0	50	Moderate	6
14	0	0	0	50	Moderate	6
15	0	0	0	50	Moderate	6
16	0	0	0	50	Moderate	6
17	0	0	0	50	Moderate	6

Table A1.2. Quality attributes of the developed jackfruit based meat analogue

Run	Texturizing agent	Rotational speed	Binding composition	MC	WHC	OHC	A
1	40	Low	6	45.49	7.6	5.8	0.969
2	60	Low	6	39.88	7	6.3	0.973
3	40	High	6	46.38	7.7	5.95	0.971
4	60	High	6	42.87	7.51	6.36	0.973
5	40	Moderate	4	44.28	6.2	5.9	0.974
6	60	Moderate	4	48.93	6.3	6.3	0.975
7	40	Moderate	8	45.54	6.1	5.92	0.972
8	60	Moderate	8	47.82	7.3	6.31	0.966
9	50	Low	4	39.56	7.2	6.1	0.973
10	50	High	4	41.39	7.5	6.2	0.974
11	50	Low	8	46.53	6.4	6.15	0.976
12	50	High	8	43.89	6.7	6.23	0.968
13	50	Moderate	6	44.46	8.3	6.3	0.974
14	50	Moderate	6	44.41	8.2	6.4	0.975
15	50	Moderate	6	44.50	8.1	6.4	0.972
16	50	Moderate	6	44.33	8.3	6.1	0.973
17	50	Moderate	6	44.59	8.3	6.0	0.974

Table. A2.1. Analysis of variance (ANOVA) for moisture content of developed meat analogue

Source	Sum of squares	df	Mean square	F- value	p-value	Coeff. Est.	df	SE	95% C I Low	95 % CI High
Model	98.71	12	8.23	868.62	<0.0001	44.46	1	0.0435	44.34	44.58
A-Texturizing agent	12.01	1	12.01	1267.82	<0.0001	1.73	1	0.0487	1.60	1.87
B- Rotational speed	0.1640	1	0.1640	17.32	0.014	-0.2025	1	0.0487	-0.3376	-0.0674
C- Binding	22.42	1	22.42	2367.50	<0.0001	2.37	1	0.0487	2.23	2.50
AB	1.10	1	1.10	116.42	0.0004	0.5250	1	0.0487	0.3899	0.0661
AC	1.40	1	1.40	148.28	0.0003	-0.5925	1	0.0487	-0.7276	-0.4574
BC	5.00	1	5	527.48	<0.0001	-1.12	1	0.0487	-1.25	-0.9824
A^2	9.45	1	9.45	998.39	<0.0001	1.50	1	0.0474	1.37	1.63
B^2	92.30	1	22.30	2355.09	<0.0001	-2.30	1	0.0474	-2.43	-2.17
C^2	1.98	1	1.98	209.24	0.0001	0.6860	1	0.0474	0.5543	0.8177
A^2B	2.75	1	2.75	290.34	<0.0001	1.17	1	0.0688	0.9814	1.36
A^2C	10.86	1	10.86	1146.55	<0.0001	-2.33	1	0.0688	-2.52	-2.14
AB^2	32.20	1	32.20	3400.24	<0.0001	-4.01	1	0.0688	-4.20	-3.82
Pure error	0.0379	4	0.0095							
Cor total	98.75	16								
Std. Deviation	0.0973	R- Squared			0.9996	df = degrees of freedom; SE = Standard Error				
Mean	44.40	Adj R- Squared			0.9985	Coeff. Est. = Coefficient of Estimate				
C. V. %	0.2192	Pred R- Squared			NA	CI = Confidence of Interval				
		Adeq precision			110.1076	ns = non significance				

Table. A2.2. Analysis of variance (ANOVA) for water holding capacity of developed meat analogue

Source	Sum of squares	df	Mean square	F- value	p-value	Coeff. Est.	df	SE	95% CI Low	95 % CI High
Model	8.32	9	0.9248	4.76	0.0259	8.24	1	0.1971	7.77	8.71
A-	0.0325	1	0.0325	0.1674	0.6946	0.0638	1	0.1558	-0.3047	0.4322
B- Rotational	0.1830	1	0.1830	0.9425	0.3640	0.1513	1	0.1558	-0.2172	0.5197
C- Binding	0.0612	1	0.0612	0.3154	0.5919	-0.0875	1	0.1558	-0.4559	0.2809
AB	0.0420	1	0.0420.	0.2164	0.5559	0.1025	1	0.2203	-0.4185	0.6235
AC	0.3025	1	0.3025	1.56	0.2521	0.2750	1	0.2203	-0.2460	0.7960
BC	0.0000	1	0.0000	0.0000	1.0000	0.0000	1	0.2203	-0.5210	0.5210
A^2	1.68	1	1.68	8.64	0.0217	-0.6313	1	0.2148	-1.14	-0.1234
B^2	0.1028	1	0.1028	0.5294	0.4905	-0.1563	1	0.2148	-0.6641	0.3516
C^2	5.41	1	5.41	27.87	0.0011	-1.13	1	0.2148	-1.64	-0.6259
Residual	1.36	7	0.1942							
Lack of fit	1.33	3	0.4424	55.30	0.0010					
Pure error	0.0320	4	0.0080							
Cor total	9.68	16								
Std.	0.4407	R- Squared			0.8596	df = degrees of freedom; SE = Standard Error				
Mean	7.34	Adj R- Squared			0.6791	Coeff. Est. = Coefficient of Estimate				
C. V. %	6.01	Pred R- Squared			-1.1985	CI = Confidence of Interval				
		Adeq precision			6.4835	ns = non significance				

Table. A2.3. Analysis of variance (ANOVA) for oil holding capacity of developed meat analogue

Source	Sum of squares	df	Mean square	F- value	p-value	Coeff. Est.	df	SE	95%CI Low	95 % CI High
Model	0.3818	3	0.1273	8.57	0.0021	6.16	1	0.0296	6.10	6.22
A-Texturizing agent	0.3613	1	0.3613	24.33	0.0003	0.2125	1	0.0431	0.1194	0.3056
B- Rotational speed	0.0190	1	0.0190	1.28	0.2783	0.0488	1	0.0431	-0.0443	0.1418
C- Binding composition	0.0015	1	0.0015	0.1019	0.7547	0.0138	1	0.0431	-0.0793	0.1068
Residual	0.1930	13	0.0148							
Lack of fit	0.0610	9	0.0068	0.2055	0.9771					
Pure error	0.1320	4	0.0330							
Cor total	0.5748	16								
Std. Deviation	0.1219	R- Squared			0.6642	df = degrees of freedom; SE = Standard Error				
Mean	6.16	Adj R- Squared			0.5867	Coeff. Est. = Coefficient of Estimate				
C. V. %	1.98	Pred R- Squared			0.5722	CI = Confidence of Interval				
		Adeq precision			8.8399	ns = non significance				

Table. A2.4. Analysis of variance (ANOVA) for water activity of developed meat analogue

Source	Sum of squares	df	Mean square	F-value	p-value	Coeff. Est.	df	SE	95%CI Low	95 % CI High
Model	0.0001	12	8.920E-06	6.86	0.0386	0.9736	1	0.0005	0.9722	0.9750
A-Texturizing agent	6.250E-06	1	6.250E-06	4.81	0.0934	-0.0013	1	0.0006	-0.0028	0.0003
B- Rotational speed	0.0000	1	0.0000	9.42	0.0373	-0.0018	1	0.0006	-0.0033	-0.0002
C- Binding	2.250E-06	1	2.250E-06	1.73	0.0257	-0.0008	1	0.0006	-0.0023	0.0008
AB	1.000E-06	1	1.000E-06	0.7692	0.04300	-0.0005	1	0.0006	-0.0021	0.0011
AC	0.0000	1	0.0000	9.42	0.0373	-0.0018	1	0.0006	-0.0033	-0.0002
BC	0.0000	1	0.0000	15.58	0.0169	-0.0023	1	0.0006	-0.0038	-0.0007
A^2	0.0000	1	0.0000	7.78	0.0493	-0.0015	1	0.0006	-0.0031	-7.261E-
B^2	1.274E-06	1	1.274E-06	0.9798	0.383	-0.0005	1	0.0006	-0.0021	0.0010
C^2	3.789E-07	1	3.789E-07	0.2915	0.6179	-0.0003	1	0.0006	-0.0018	0.0012
A^2B	0.0000	1	0.0000	7.79	0.0493	0.0022	1	0.0008	0.0000	0.0045
A^2C	8.000E-06	1	8.000E-06	6.15	0.0682	-0.0020	1	0.0008	-0.0042	0.0002
AB^2	0.0000	1	0.0000	11.63	0.0270	0.0027	1	0.0008	0.0005	0.0050
Pure error	5.200E-06	4	1.300E-06							
Cor total	0.0001	16								
Std. Deviation	0.0011	R- Squared			0.9537	df = degrees of freedom; SE = Standard Error				
Mean	0.9725	Adj R- Squared			0.8147	Coeff. Est. = Coefficient of Estimate				
C. V. %	0.1172	Pred R- Squared			NA	CI = Confidence of Interval				
		Adeq precision			10.0295	ns = non significance				

Appendix- B

Sensory score card for organoleptic evaluation

SENSORY SCORE CARD

Department of Processing and Food Engineering

KCAET, Tavanur

Name of the judges:

Date:

You are requested to assess the product in terms of general acceptability on a 9-point hedonic scale.

Score system:

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

Characteristics	**Sample code**	
	A	**B**
Colour		
Appearance		
Texture		
Flavor		
Taste		
Overall acceptability		

Comments if any:

Appendix- C

Quality parameters of developed jackfruit-based meat analogue

Table. C1.1 Instrumental textural properties

Sample	Score (Mean± SD*)			
	Hardness	Cohesiveness	Gumminess	Chewiness
T1	20.23±1.23	0.37±0.04	3.44±0.85	1.98±0.48
T2	11.78± 0.60	0.39± 0.02	1.87± 0.43	0.32±0.02

Table. C1.2 Colour values

Sample	Score (Mean± SD*)		
	L*	a*	b*
T1	39.94±0.44	12.77±0.35	13.37±0.12
T2	35.32±0.19	12.01±0.13	12.28± 0.24

T1- Control, T2- Developed meat analogue, SD*- Standard deviation

Appendix- D

Table.D1.1 Storage study of optimized jackfruit-based meat analogue

Time period	MC	WHC	OHC	Aw
0th week	44.46	8.3	6.3	0.974
1st week	49.35	6.3	4.8	0.971
2nd week	44.74	5.3	3.8	0.963
3rd week	45.63	3.9	2.9	0.959

Table.D1.2 Microbial analysis of developed jackfruit-based meat analogue.

Time period	Dilution	Bacteria (cfu/g)		Yeast & Mold (cfu/g)	
		24hrs	48hrs	24hrs	48hrs
0th week	10^{-2}	TNTC	TNTC	No growth	No growth
	10^{-3}	39×10^{3}	TNTC	No growth	No growth
	10^{-4}	11×10^{4}	TNTC	No growth	No growth
1st week	10^{-2}	TNTC	TNTC	No growth	No growth
	10^{-3}	TNTC	TNTC	No growth	No growth
	10^{-4}	10×10^{4}	TNTC	No growth	No growth
9th week	10^{-2}	TNTC	TNTC	No growth	1×10^{2}
	10^{-3}	TNTC	TNTC	No growth	No growth
	10^{-4}	10×10^{4}	TNTC	No growth	No growth

TNTC- Too numerous to count

DEVELOPMENT AND EVALUATION OF JACKFRUIT BASED MEAT ANALOGUE BY EXTRUSION TECHNOLOGY

By

GOPIKA GOPI (2019-06-007)

MEERA KRISHNA P M (2019-06-012)

NANDANA M (2019-06-015)

FATHIMA SALEEKA (2019-06-022)

ANNA ROSE SABU (2019-06-024)

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology

IN

Food Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

KELAPPAJI COLLEGE OF AGRICUTURAL ENGINEERING

AND TECHNOLOGY, TAVANUR-679573,

KERALA, INDIA

2022

ABSTRACT

The research paper depicts the development and storage evaluation of jackfruit-based meat analogue. Meat analogue is a product produced from vegetarian ingredients but it resembles the meat in both nutritional and sensory characteristics. In this study, we used jackfruit as significant ingredients for developing a meat analogue. Refined wheat flour was used as a texturizing agent and flavoring agents such as mushroom extract, garlic powder, cocoa powder etc are used. While developing a meat analogue, cold extrusion was carried out. The optimization of process parameters such as texturizing material, rotational speed and binding composition was done using Design Expert Software. 17 treatments were tried with three independent variables. An optimized product of 58.536g of texturizing agent (refined wheat flour), high rotational speed (RPM) and 7.434g of binding composition (CMC) was developed which resembles meat in structure. The quality analysis, Sensory parameters and shelf-life study of the developed meat analogue were studied in detail. A good customer acceptance has been obtained in the sensorial analysis. The samples demonstrated desired appearance, taste, flavor, and overall acceptability in sensory evaluation. It emphasized that a jackfruit would make a suitable meat analogue.