DEVELOPMENT AND EVALUATION OF VACUUM FRIED JACKFRUIT CHIPS (*Artocarpus heterophyllus*)

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DECLARATION

We hereby declare that this thesis entitled **"Development And Evaluation Of Vacuum Fried Jackfruit Chips (*Artocarpus heterophyllus*)"** is a bonafide record of research work done by us during the course of research and the thesis has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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Dedicated to our beloved parents, teachers and to our profession

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SYMBOLSAND ABBREVIATIONS

%	Percent
&	And
/	Per
@	At the rate of
+	Plus
<	Less than
µg/kg	Micro gram per kilo gram
Ml	Micro litre
a*	Greenness or redness
AACC	American Association of Cereal Chemists
AOAC	Association of Official Analytical Chemists
aw	Water activity
b*	Blueness or Yellowness
cm	Centimeter
cm-1	Per centimeter
et al.	And others
etc	Etcetera

Fig	Figure
FFA	Free fatty acids
H	Hour
HMI	Human Machine Interface
Hp	Horse power
i.e.,	That is
JF	Jackfruit
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg/cm	Kilogram per centimeter
kg/cm^2	Kilogram per centimeter square
Kg/m^3	Kilogram per meter cube
kg/kg db	Kilogram per kilogram in dry basis
kg/h	Kilo gram per hour
kPa	Kilo Pascal
kw	Kilo watt
L	Litre
L*	Lightness or Darkness
l/min	liter per minute
LDPE	Low Density Poly Ethylene

mc	Moisture content
meq O2/kg	Milli equivalent oxygen per kilo gram
min	Minute
Mha	Million hectare
ml	Milliliter
mm	Milli metre
MT	Metric Tons
N	Newton
N_2	Nitrogen
NHB	National Horticultural Board
ºC	Degree Celsius
rpm	Revaluation per minutes
SS	Stainless steel
TA	Texture Analyser
TPC	Total Polar Compounds
VF	Vacuum Frying
W	Watts
w.b	Wet basis
ΔE	Colour difference

INTRODUCTION

CHAPTER I

INTRODUCTION

India is the second largest producer of food next to China with an estimated food processing industry size of 70 billion US dollars (National Horticultural Board (NHB), 2017). The annual production of fruits and vegetables in India during 2017 was 90.2 MT and 169.1 MT from an area of 6.3 Mha and 10.1Mha, respectively (Ministry Of Commerce& Industry, Government of India, 2017). But out of the total production, only 2.2 per cent were processed into value added products. In contrast to countries like USA (65%) and China (23%), India is far below to reduce the postharvest loss and enhance value addition and shelf life of farm products. The actual estimated loss in postharvest sector is 20 to 25 % in fruits and vegetables, but these values are not accepted as it negatively affects the Indian economy (Charlie *et al.,*). Hence, development of ready-to-eat products from locally available fruits and vegetables has to be promoted to improve consumption and nutritive value, to reduce the postharvest loss and to ensure food security (Ravindranath, 2005).

Jackfruit (*Artocarpus heterophyllus*), is an exotic fruit also known as jack tree, fenne, jakfruit, or sometimes simply jack or jak. It is a species of tree in mulberry and breadfruit family (Moraceae) and is native to southwest India. India is considered to be the native of jack fruit. The area and production of jackfruit in India during the year 2015 – 2016 was 1.51Lakh ha and 1.7 MT, respectively whereas during 2016-2017 it is increased to 1.56 Lakh ha and 1.8 MT, respectively (National Horticultural Board, 2018). The jackfruit tree is well suited to grow in tropical lowlands, and its fruit is the largest tree-borne fruit, reaching up to 55 kg in weight, 90 cm in length, and 50 cm in diameter. A mature jackfruit tree can produce about 100 to 200 fruits in a year and is a multiple fruit, composed of hundreds to thousands of individual flowers and edible fleshy petals. Jackfruit is a commonly used fruit in South and Southeast Asian cuisines. At present, jackfruit tree is widely cultivated and is a popular food item throughout the tropical regions. It is the national fruit of Sri Lanka and Bangladesh and the state fruit of Tamil Nadu and Kerala. The state government of Kerala officially declared jackfruit as the official fruit, based on a proposal of the Agriculture Department on March 21,2018. The government also plans to promote the “Kerala Jack fruit” which is rich in organic and nutritious qualities, as a brand in markets across the country and abroad. Kerala is one of the largest producers of jackfruit in the world.

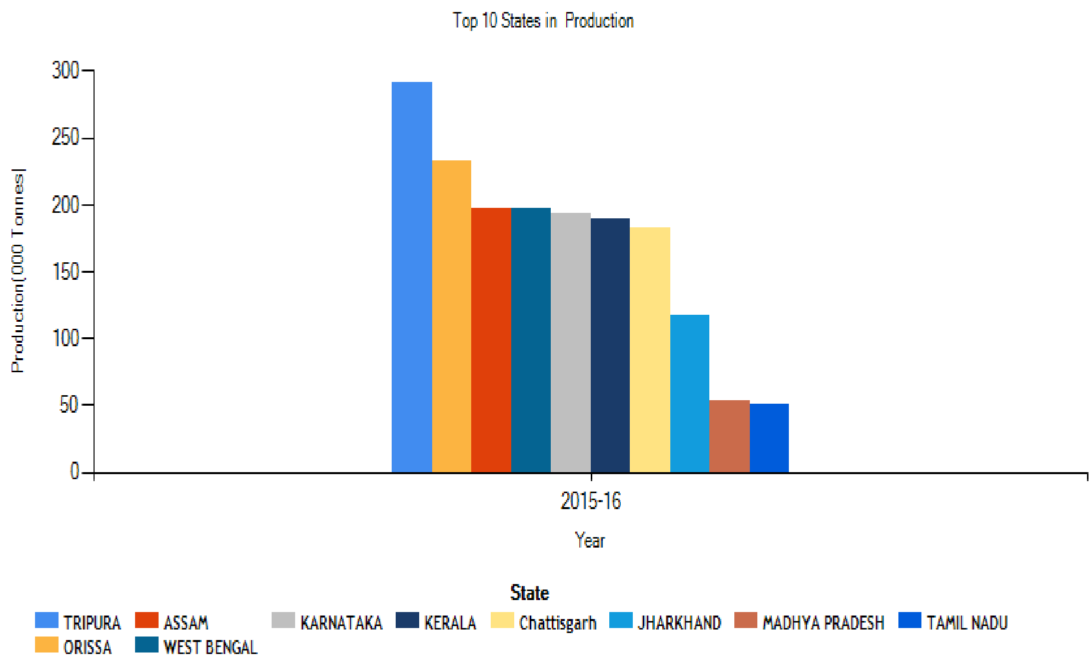


Fig 1.1 Top ten states in jackfruit production

Source: National Horticulture Board (NHB), 2015-2016

In our country, the jackfruit is mainly grown in southern states like Kerala, Tamil Nadu, Karnataka, coastal Maharashtra and other states *viz.*, Assam, Orissa, Tripura, West Bengal and foothills of Himalayas. Kerala had a production of 1.9 Lakh Tonnes in 2015-2016 (National Horticultural Board, 2017).

Jackfruit has a distinctive sweet and fruity flavor. Vegetarians prefer this fruit as a mean substitute due to its texture which is compared to shredded meat. Since jackfruit can withstand the extreme tropical climates, it is used as a major source of carbs and calories for people in developing countries who are at the risk of starvation. Jackfruit is rich in dietary fiber which makes it good bulk laxative. It is a rich source of vitamins A, B and C, potassium, calcium, iron, proteins, and carbohydrates and offers numerous health benefits. The fruit's Iso-flavones, antioxidants and phytonutrients mean that it has cancer-fighting properties. It is also known to help cure ulcers and indigestion. The fresh fruit has significant amounts of flavonoid pigments such as carotene β, cryptoxanthin β, xanthin and lutein. It also contains outstanding amounts of niacin, riboflavin, vitamin B-6 and folic acid.

Jackfruit is a very nutritious fruit which can be transformed into various value-added products. From the tender stage onwards the fruit can be converted as value-added products like dehydrated jack fruit whereas the ripened fruit can be used for making a wide variety of jams, jellies, candy bars, beverages, wine, jack fruit chips and so on. Among these, value added products jackfruit chips have been popularized on all age groups and play an important role in consumer diet.

Frying is a method of food processing using from ancient times, where lipids or oils are used as heat transfer media. Frying is a unit operation in which cooking of raw vegetables or fruits are carried out by hot oil. It results in thermal destruction of micro-organisms and enzymes as well as it reduce water activity at the surface. Hence the shelf life can be improved. In the present era of junk foods fried foods are gaining much market importance. Snack food market has registered an enormous growth among food processing sector in India. Deep fat fried products have a major share in snack food production sector. Frying, especially deep fat frying products is appealing in terms of color, aroma, texture and taste. The absence of suitable replacement for the taste of deep fat fried products increases the consumer demand for fried food products. Different types of frying are deep fat frying, shallow frying, pan frying, sautéing etc. Deep fat frying is the method of frying widely used for industrial purposes. During frying, fats and oils are invariably heated to a temperature about 160-180 ºC or even more as per the frying requirements. The major factors affecting the quality of fried product is frying temperature, frying pressure, frying time, type of oil, size and nature of sample (Ophithakorn and Yaeed, 2018). There are a number of phenomena happening during the process of frying such as cooking, dehydration, oil uptake by the fried products and crust formation. In conventional deep fat frying, the product may contain high as 40% oil and high lipid content which is a source of health concern of the daily consumers. High lipid containing foods cause a number of health hazards and even early deaths. Consumption of such foods causes obesity and development of different chronic diseases such as coronary artery diseases, type-2 diabetes etc. As per studies conducted by National Cancer Institute, under NIH (National Institute of Health, United States)Department of health and human services, there is a high risk of cancer due to consumption of acryl amide compound which is commonly found in baked and fried product had been classified as 'probable human carcinogen' compound by WHO. Keeping all these immediate threats in consideration, the diet and health conscious consumers are switching their eating habits from high lipid containing foods towards nutritious foods. Here comes the importance of vacuum frying, which is considered to be the alternative method to conventional frying.

Vacuum frying is new technology which uses a very low pressure and temperature rather than atmospheric deep fat frying to improve the quality attributes of food products. In vacuum frying the food is heated at very low pressure (mostly less than 10 kPa). At such reduced pressures, the boiling point as well as smoke point of oil gets reduced. The absence of air during the frying process inhibits oxidation including lipid oxidation and enzymatic browning and thus could retain color and flavor. Vacuum frying offers a minimal change in oil quality and desired organoleptic properties without loss in nutritional value. It is widely used for processing various foods, mostly vegetables and fruits. Vacuum frying offers to improve the quality attributes of fried foods rather than atmospheric frying. It maintains color and flavor of the product. Moreover, oil used in vacuum frying can be reused to several times without affecting its quality thus increasing its economic feasibility.

Jackfruit chips are generally prepared from mature and ripen jackfruits. The traditional frying of ripened jackfruit is not feasible due to high sugar content. Higher frying temperature causes charring of fruit and negligible moisture removal from fruit. Vacuum frying technique is an alternative method in this case. Hence a research work entitled "Development and Evaluation of Vacuum Fried Jackfruit Chips *(Artocarpus heterophyllus)"* was selected with the following objectives.

- To optimize the pre-treatments and process parameters for vacuum fried jackfruit chips
- To conduct shelf life studies of vacuum fried chips under passive and active packaging

Review Of Literature

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work by various research workers related to the traditional methods of frying, vacuum frying, pretreatments, storage and quality parameters of fried chips.

2.1 JACKFRUIT

Jackfruit is dicotyledonous compound fruit of the jack tree (*Artocarpus heterophyllus*) which belongs to the family Moraceae grow in many of the tropical countries of the southeast Asia but is particularly abundant in India and Bangladesh (Mondal and *et.al*.,). Jackfruit is a huge tree that grows to as high as 30 m, larger than mango, read fruit etc. it is widely cultivated in tropical regions of Indian sub-continent, Thailand, Malaysia Indonesia and Brazil for its fruit, seeds and wood. The tree grows better in tropical rainy and humid climates but rarely survives cold and frosty climatic conditions. As the durian fruit, the outer surface of the jackfruit is also covered by blunt spikes which become soft as the fruit become ripened. Its interior consists of eye catching orange-yellow color edible bulbs and each bulb consists of sweet flush(sheath) that encloses a smooth, oval, light, brown seed (Golden berg *et al.*,).

Table 2.1 Proximate composition of jackfruit (*Artocarpus heterophyllus*)

Nutritive value of jackfruit	
Constituent	Average value
Moisture (%)	76.2
Energy(cal)	88.0
Protein (g)	1.90
Fat(g)	0.10
Carbohydrate(g)	1.10
Potassium(g)	19.8
Calcium(mg)	20.0
Phosphorus(mg)	41.0
Iron(mg)	0.56
Carotene(mg)	175.0
Thiamine(mg)	0.03
Riboflavin(mg)	0.13
Niacin(mg)	0.40

Source: Rani *et al.*, (2010)

2.2 VALUE ADDITION OF JACKFRUIT

The postharvest loss in jackfruit is around 30-35% during the peak season (Lakshminarayan, 2017). Value addition through processing and preservation has to be considered an important alternative for reducing the postharvest losses of this nutritive fruit and ensure its availability throughout the year (Panja *et al.*, 2016). The market potential of jackfruit can be better exploited, if fruits are made available to consumers in a ready to eat or cooked form throughout the year (Panja *et al.*, 2016).

Baruah *et al.,*2015 conducted study on processing and value addition of jackfruit. They standardized the processing method for jackfruit jam to meet the FPO standards. They concluded that there is immense scope for product development for jackfruit and to enhance farm income through entrepreneurship and industrial exploitation of fruit.

Tanusree *et al.*, (2013) studied on development of value added products from jackfruit for small and medium enterprises. They evaluated various modern technologies for the development of value added product from jackfruit. Value addition in jackfruit was carried out in the form of high moisture products (ready-to-serve beverage, minimally processed bulbs, squash) intermediate moisture products (jam and leather) dehydrated products (chips). They found that developed products were suitable for small and medium enterprises for popularization of jackfruit to a wider region.

2.3 FRYING

Frying is an ancient unit operation which mainly used to produce snack foods and hence to increase shelf life. Frying improves the crust, texture and sensory quality of food by a formation of some fragrance compounds (Bognar, 1998). Frying also inactivates enzymes, reduction of micro-organism and moisture content of foods. Orthoefer (1987) suggested that frying as a fast heating and uniform cooking method than other cooking processes. Frying involves simultaneous heat and mass transfer of food (Sharma and Mann, 2010). While frying food behaves as a colloid non-porous and non-homogenous anisotropic material (Wu *et al.,* 2010).

2.4 FRYING OIL

Ranasalva and Sudheer (2017) conducted a study on vacuum frying of banana. They conducted their study using blended rice bran and palm oil in various proportions to optimize the quality parameters. Vacuum frying did at 100ºC for 10 min show better results. Study concluded frying using the blend of rice bran and palm oil at the ratio 80:20 had a low TPC value (15.7%) and iodine value (86.45 meqO_2/kg) after sixty batches of vacuum frying in banana.

Shaker in 2014 conducted a study on comparison between traditional deep fat frying and air frying for production of healthy fried potato strips. They concluded that changes in some physio - chemical properties (free fatty acids, peroxide value, polar polymer and oxidized fatty acids contents) of oil extracted from fried potato were significantly higher in traditional frying than air frying method.

2.5 DEEP FAT FRYING

Deep fat frying process involved heat and mass transfer and exhibited extensive physical and chemical changes on fried product (Sahin and Sumnu, 2009). Vitrac, *et al.,* (2002) examined the changes in deep fat fried. *viz*., gelatinization of starch, denaturation of protein and development of aromatic compounds through maillard reactions and increase in oil content of food through oil absorption. The quality attributes like flavour, texture and nutrient composition were changed during deep fat frying (Zhang *et al.*, 2012).

The absorption of oil during deep fat frying could be better understood by knowing its heat and mass transfer mechanism. The quality parameters of fried product like oil content, moisture loss and other attributes were highly influenced by its heat and mass transfer (Sahin and Sumnu, 2009). Farkas *et al.,*(1996) reported that before attaining complete frying, the product experienced two phases with four stages in each phase of frying: (1) The non - boiling phase which included first and final stage (initial heating and bubble end point) and (2) The boiling phase which included second and third stage (surface boiling and falling rate stage).

2.6 VACUUM FRYING

Vacuum frying is a new and promising technology in which samples were fried under low pressure, which lowers the boiling point of the water in foods and smoking point in oil (Shahraki and Mashkour, 2012). Vacuum frying process retains the colour, texture and reduced the production of acrylamide content of fried products. Vacuum frying enhances the organoleptic and nutritional properties in fried products (Jorge *et al.,* (2012).

Vacuum frying is an alternative frying technique where frying is done under reduced pressure (Troncoso *et al.,* 2009). This frying condition rendered to produce superior quality of fried product with low oil content and retained the colour (Song *et al.*, 2007).

Garcia *et al.,* in February 2016 studied the effects of processing conditions on the quality of vacuum fried cassava chips. They concluded that vacuum frying of pre-blanched cassava chips is an alternative to frying at atmospheric conditions.

Fan *et al.,* in 2005 studied the effect of various pretreatments on the quality of vacuum fried carrot chips and concluded that pretreatments (blanching, blanching and air drying, blanching and osmotic dehydration, blanching, osmotic dehydration, followed by freezing) prior to vacuum frying significantly affected water content, fat content and water activity of carrot chips.

Praneeth *et al.,* (2016) conducted study on emerging techniques for healthier frying for production of reduced-fat beetroot chips. They concluded that vacuum frying could be an efficient alternative method of frying and could be used to reduce oil content during production of fried foods such as beetroot chips

Ranaselva *et al.,* (2017) studied the effect of pretreatments on quality parameters of vacuum fried ripened banana chips. In their analysis, they revealed that untreated products were superior not only in terms of quality, but also in terms of reduced cost and time for the protocol.

Tanushree *et al.,* (2017) conducted a study on quality attributes of effect of vacuum frying on quality attributes of jackfruit bulb slices. They concluded that jackfruit chips of optimum quality could be obtained from ripened sweet jackfruit slices if the material is fried at 90ºC for 25 min.

Xu-duan *et al.,* (2008) concluded in their study on effect of various pretreatments on quality attributes vacuum fried shiitake mushroom chips that vacuum fried chips with osmotic dehydration had the lowest oil uptake and best color property.

Zhu *et al.,* (2015), conducted study on effect of coating and pre-drying on vacuum fried peas and concluded that oil absorption had a reciprocal relationship with moisture content retained in the vacuum fried peas. The crispness of the vacuum fried peas was superior in vacuum-microwave pretreatment.

2.6.1 Vacuum Fryer

Garayo *et al.,* (2002), designed a vacuum fryer and produced vacuum fried potato chips with decreased oil content compared to atmospheric deep fat frying. And in his study on feasibility of fried potato chips in a vacuum fryer, the fried chips were lighter, softer and had higher volume shrinkage compared to atmospheric frying.

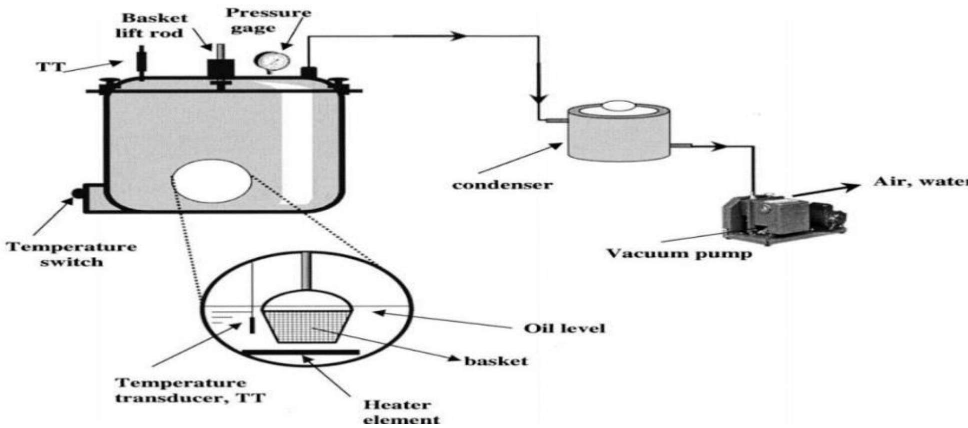


Fig 2.1 Vacuum frying system experimented with potato chips (Garayo *et al.,*)

Ranaselva *et al.,* in the year 2017 issued a thesis on development and evaluation of a vacuum frying system for banana chips (musa spp.). In their study the developed a batch type vacuum fryer having a capacity of 12 kg/hr and evaluated the feasibility of preparing banana chips. They concluded that the developed vacuum fryer could be efficiently used for the production of vacuum fried ripened banana chips. This vacuum frying system consisted of two chambers namely; oil storage (length 835 mm and 356 mm diameter) and frying chamber (length 984 mm and 406 mm diameter) were made of stainless steel (SS 316). Vacuum frying system was controlled by a microprocessor and PID (Proportional Integral Derivative) controller. The de-oiling system was mounted inside the frying chamber with frying basket.

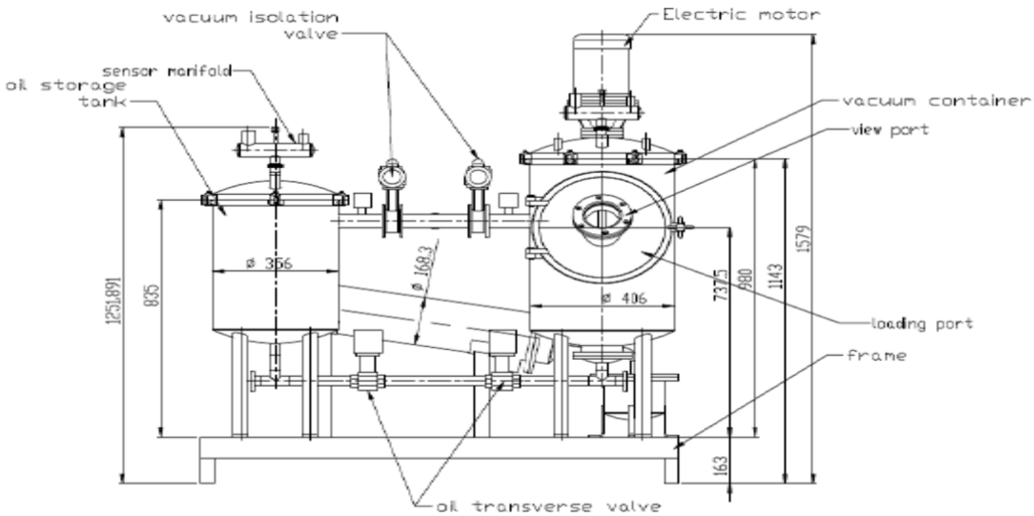


Fig 2.2 Schematic diagram of vacuum frying setup (Ranaselva and Sudheer)

Yamsaengsung *et al.*, (2011) developed vacuum frying system (Fig.2.3) and studied the effect of vacuum frying on structural changes of banana chips. The system comprised of a liquid ring vacuum pump for the production of vacuum in frying chamber. The heat was supplied through the gas cylinder with external flame to heat the oil in frying and storage chambers. The results of SEM showed that frying time slightly increased the size of bananas chips and shape factor.

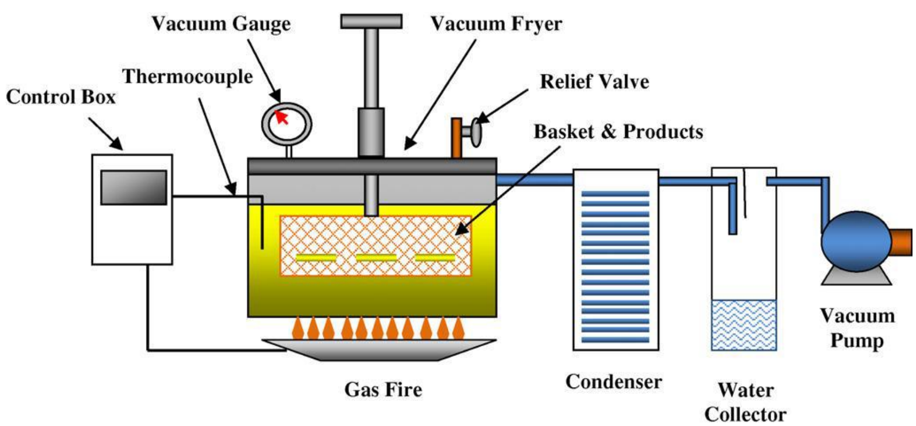


Fig 2.3 Schematic diagram of vacuum frying setup (Yamasaengsung *et al.*,)

Su *et al.*, (2016) developed microwave assisted vacuum frying system to improve the quality of the product and to reduce the oil uptake in potato chips. The microwave devices were uniformly located around the vacuum chamber. The centrifuge was connected at the top of the frying chamber and oil storage chamber. The heating coils were provided for heating the oil at frying and storage chamber. Vacuum pump was used to produce the vacuum in both the chambers. The microwave heating power of vacuum frying was 4000 W. The study revealed that microwave with vacuum fried products had a better result than the vacuum fried potato chips.

2.6.2 Process Parameters

The frying temperature, pressure and time were the major parameters optimized based on the fried product quality. A study conducted by Garayo and Moreira (2002) on vacuum frying of potato chips showed that high frying temperature (144°C) combined with low pressure of 3.11 kPa favored faster rate of moisture removal. The optimized frying conditions to attain highest moisture in fried product was 360 s frying time at 3.11 kPa and 600 s at 16.661 kPa with frying temperature of 144°C.

Pan *et al.,* (2015) illustrated that frying temperature significantly affected the oil absorption and moisture loss in vacuum fried breaded shrimp. The oil content increased with increased temperature (90, 100 and 120°C). The shrimp fried at temperature of 120°C, frying pressure of 20 kPa for 12 min showed highest oil content of 0.25 ± 0.019 g oil/g dry solid.

Pan *et al.,* in the year 2005 conducted a study on vacuum frying of carrot. They optimized temperature, pressure and time as 100°C, 5 kPa, and 15 min respectively and increasing the dry matter content of the carrot slices reduce the surface shrinkage.

Dueik and Bouchon 2011 had a study on vacuum frying of carrot and in their experimental studies; they could decrease the acryl amide formation up to 94%

2.6.3 Pre-Treatments of Vacuum Frying

Pre-treatment is to reduce the oil absorption in the fried product and it improves the quality of the fried products.

2.6.3.1 *Freezing*

Fan *et al.,* (2005) conducted pre-treatment of carrot with a combination of 30% mixed aqueous solution of malt and dextrin (2:1) for 1 h and stored overnight at -18°C. The results revealed that pre-treatment of freezing at -18ºC was an alternative method for improving quality of the product.

Vacuum fried carrot chips pre-treated with maltodextrin solution and freezing absorbed high oil during frying. The oil content was significantly higher (52%) for the frozen pre-treated product and low oil content (20%) was observed in maltodextrin treated sample (Shyu *et al.,* 2005).

Diamante *et al.,* (2011) reported that no significant difference was observed in moisture content of fried kiwi fruit pre-treated with freezing along with soaking in 35% maltodextrin solution and without soaking.

Hasimah *et al.*,(2011) was optimized the sensory qualities of vacuum fried pineapple stack. Pre-treatment of freezing at -20°C for 20 h resulted in a vacuum fried product with good textural property and better quality. The oil content of frozen product was higher than maltodextrin pre-treated sample in potato chips (Diamante *et al.* 2011).

Ophithakorn and Yaeed (2016) observed that microstructure change occurs in fish during vacuum frying. Before frying samples were frozen at -20°C until defrosting and defrosted at 4°C overnight in the refrigerator. The frozen fish tofu of vacuum frying had less microstructure changed due to rapid formation of the microstructure pores during evaporation of the ice crystals during frying.

Ranaselva *et al.,* standardized the blend of rice bran and palm oil in the ratio 80:20 and optimized the process parameters as 105°C and 18 kPa and 13 min to have a novel healthy banana chips with low oil content and acryl amide content. They claim to maintain the quality of oil up to fifty two batches of frying.

2.6.3.2 *Blanching*

Blanching is a pre-treatment method, which inactivates the enzymes present in the fruits and vegetables. Hasimah *et al*,.(2011) studied the different pre-treatments to produce high-quality vacuum fried pineapple snacks, blanched at 100°C for 3 min by steam cabinet blancher. The results showed that pre-treated vacuum fried pineapple produced less than 30% oil uptake and moisture dropped from 3.4% to 2.1%.

Pahade and Sakhale (2012) studied the effect of blanching for reduction of oil uptake from French fries. The results revealed that water blanching at 85°C for 6 min and drying at 150°C for 3 min in a conventional oven led to less oil uptake and better sensory attributes in vacuum fried product.

Garcia-Segovia *et al.,* (2016) stated that water blanching of cassava chips and subsequent frying at 70ºC for 10 min had a better retention of colour and less oil uptake. Hong-Wei *et al.,* (2017) stated that thermal blanching as an important operation to inactivate the polyphenol oxidase (PPO), peroxidase (POD).

2.6.3.3 *Drying*

Drying is a convective heat transfer process in which moisture from the product is removed. Drying is an important pre-treatment to improve the quality and shelf life of the dried product.

Debnath *et al.*, (2003) studied the effect of pre-drying on the kinetics of water loss and oil absorption during deep fat frying of chickpeas flour. The results showed that vacuum frying at 175ºC decreased the kinetic coefficient of moisture transfer (0.056-0.039/s) as well as oil transfer (0.063-0.035/s).

Pedreschi and Moyano (2005) studied the effect of pre-drying on quality of potato chips. The samples were blanched in hot water at 85°C for 3.5min and then fried at 180°C. The oil uptake was 50% less in pre-treated sample compared to untreated sample.

2.7 DE-OILING OF FRIED PRODUCTS

The de-oiling mechanism is an essential step in frying process, since the pressure gradient immediately after frying is create which provokes a driving force on the surface oil to permeate into the core.

Moreira *et al.*, (2009) reported the effect of de-oiling on vacuum fried potato chips. It was confessed that de-oiling with centrifugal speed of 280 rpm showed 33.5% reduction whereas at 140 rpm 17.31% reduction was observed.

Diamante *et al.*, (2011) blotted vacuum fried kiwi fruit slices using dry paper towel and then centrifuged it at 750 rpm for 4 min to remove the surface oil. Fang *et al.*, (2011) centrifuged vacuum fried purple yam chips at 450 rpm for 5 min to remove 50% surface oil.

Ravli *et al.*,(2013) elucidated that de-oiling (750 rpm for 40 s) was a decisive step after vacuum frying of sweet potato chips and concluded that de-oiling resulted in 60% reduction of oil content than traditional frying.

Ranasalva and Sudheer, (2017) studied the effects of post centrifugation (de-oiling) on quality of vacuum fried banana chips. The effects of centrifuging speed (400, 600, 800 and 1000 rpm) and time (0, 3, 5, 7, 9 min) on vacuum fried banana chips at 100ºC for 12 min. The oil content of de-oiled chips reduced to 90.9% in vacuum fried banana chips at a speed of 1000 rpm for 5 min.

2.8 CHANGES IN PROPERTIES OF FRYING OIL

Frying oil undergoes several chemical changes during frying. They get hydrolysed with water, oxidized with oxygen and air, isomerise and polymerise short chain reactions to form free radicals (Choe and Min, 2007). Peroxide value (PV), free fatty acid (FFA) and total polar compounds (TPC) were the major indicative parameters of oil quality (Melton *et al.*, 1994).

2.8.1 Total Polar Compounds (TPC)

Polar compounds signifies the presence of tocopherols, mono and di-glycerides, free fatty acids and other fat soluble compounds excluding triglycerides (Fritsch, 1981). Also, Lalas (2009) reported that TPC was the most reliable compound for measuring the quality of frying oil. In many countries including India, the acceptable polar compound is 25% by weight. This compound mainly includes five compounds *viz.,* polymers and dimmers of triglycerides, oxidised triglyceride monomers, diglycerides and free fatty acids (Farhoosh *et al.*, 2011).

Amany *et al.*, (2012) conducted experiment to obtain high-quality potato chips and fried oil. Initially polar compound of sunflower oil was 0.01%. During frying, some fats and oils undergo oxidation and hydrolysis process to the polar compound. The result showed after 24 h of vacuum frying, sunflower oil liberated less than 25% of total polar compounds.

2.9 PRODUCT CHARACTERISTICS OF VACUUM FRYING

2.9.1 Moisture Content

Shyi-Liang and Hwang (2001) studied the effect of process condition on vacuum fried apple chips. The results showed that after frying at 90ºC for 5 min moisture content of VF-apple chips increased to 8% and frying at 100 ºC for 20 min reduced the moisture content to 2%. Su *et al.*, (2016) studied the moisture content of novel micro-assisted vacuum fried potato chips. The moisture content of both vacuum fried and micro-assisted vacuum frying potato chips reduced from 80% to 6%, because of the application of microwave energy.

Ren *et al.*, (2018) investigated the effects of pre-treatments on vacuum fried shiitake mushroom chips. The results revealed that combination of blanching-osmotic-freezing produced low moisture content (2.52 kg/kg db) compared to other pre-treated vacuum fried shiitake mushroom chips.

2.9.2 Oil Content

Fan *et al.,* (2006) studied the effects of pre-treatment on vacuum fried carrot chips. The study showed that the blanching-cum-osmotic (0.23 kg/kg db) fried pre-treated sample had minimum oil uptake than other pre-treated VF-carrot chips. Mariscal and Bouchon (2008) conducted study on comparison of vacuum frying and atmospheric frying of apple slices. Their results showed that the highest oil uptake was observed for atmospheric fried apple chips, whereas the lowest was for pre-dried vacuum fried apple chips.

Maity *et al.,* (2017) did experiment on vacuum frying of jackfruit by using different pre-treatments. Result showed that, the oil uptake of partially dried jackfruit chips, pre-frozen sample and control (untreated) were 28.3%, 33.1% and 30%, respectively.

2.9.3. Water Activity

The threshold limit of water activity for the microbial growth in dehydrated products is 0.6. Perez-Tinoco (2008) found that, water activity of vacuum fried pineapple chips was less than 0.29 aw.

Dueik *et al.,* (2010) reported that, the water activity of vacuum fried carrot chips was 0.44 aw which is well below the tolerance limit. Sothornvit (2011) studied the effect of post frying and edible coating on vacuum fried banana chips. The result revealed that gum coated with high centrifuge speed had less water activity than other pre-treated vacuum fried banana chips.

Ren *et al.,* (2018) stated the water activity of pre-treated (Blanching + osmotic + coating) vacuum fried Shiitake mushroom chips was 0.25 aw which was less than the other pre-treated sample.

2.9.4 Bulk And True Density

Yauge and Moreira (2011) stated that, bulk density decreased from initial value of 1103 kg/^{m3} to 453 kg/m^3, while true density increased from 1088 kg/m^3 to 1404 kg/m^3 in vacuum fried potato chips.

Ravli *et al.,* (2013) conducted two stage vacuum frying of sweet potato chips. The results revealed that during single stage frying bulk and true density were decreased and increased under the dual stage vacuum frying.

2.9.5. Colour Values

Mariscal and Bouchon, (2008) observed the major changes in colour values of L* (Lightness) and a*(red-green chromaticity) during atmospheric frying and vacuum frying. The overall L* and a* values decreased during atmospheric frying with increased frying time.

Perez-Tinoco, (2008) reported that vacuum fried pineapple chips at 112ºC produced a better colour values of L*(81.2), a*(9.12) and b*(41.29) than at other frying temperatures.

Dueik and Bouchon (2011) studied the colour values of vacuum fried carrot, apple and potato chips. The results revealed that L* value of vacuum fried chips was consistently higher than atmospheric fried chips. Similar trend was observed in case of a* (redness) and b* (yellowness) values.

Goswami *et al.,* (2015) stated the lightness of the fried chips is important criteria for consumer acceptance. Maity *et al.,* (2017) reported effects of pre-treatments on physico-chemical properties of vacuum fried jackfruit chips. The results revealed that untreated and frozen pre-treated sample had good colour values than other pre-treated vacuum fried jack fruit chips.

2.9.6 Texture

The textural property is important parameter for all food products, especially in fried products. The chips produced from the vacuum and atmospheric frying had no significant difference in texture. However, pre-treatments like blanching cum drying, gum coated created difference in textural changes in fried products (Sahin *et al.,* 2005).

Yamsaengsung *et al.,* (2011) revealed that during storage the hardness value of vacuum fried potato chips increased due to presence of moisture. In this study during storage hardness value ranged from 16.51 N to 11.79 N at fourth day of studying.

Dueik and Bouchon (2011) experimented on vacuum and atmospheric frying of carrot chips and results concluded that the frying technology significantly ($p<0.05$) affected the textural properties of products.

.2.10 PACKAGING AND STORAGE STUDIES

Illeperuma and Jayasuria (2002) used nitrogen flushing in aluminum pouches laminated with polyethylene for osmotic dehydrated bananas and extended its shelf life upto eight months of storage without affecting its sensory attributes.

Fan *et al.,* (2007) studied the storage stability of carrot chips. They stored the chips in 25 µm low-density polyethylene (LDPE) film with 95% of nitrogen gas flushed and had a shelf life of 6 months.

Presswood (2012) reported that vacuum fried beef could store up to 32 weeks at 15-25ºC temperature under aluminum foil laminated pouches with reduced water vapour transmission rate.

Esana *et al.,* (2015) reported that sweet potatoes fried at 108ºC for 9 min and vacuum packed in polyethylene bags had a shelf life of 30 days.

Materials And Methods

CHAPTER III

MATERIALS AND METHODS

This chapter constitutes the detailed description about the materials used and the methods adopted for the "Development and evaluation of vacuum fried jackfruit chips (*Artocarpus heterophyllus)".* This chapter elaborates the approach followed to accomplish the objectives of the study.

3.1 PROCUREMENT OF RAW MATERIALS

The ripened varikka variety of jackfruit with suitable maturity indices, procured from the Instructional Farm, KCAET, Tavanur was considered for the study.

Plate 3.1 raw jackfruit

3.2 SAMPLE PREPARATION FOR FRYING:

Ripened whole jackfruits of firm variety with an average weight of 8–10 kg, devoid of any visible microbial infection or mechanical fissures were chosen for the experiment. The bulbs were given a vertical cut to remove the seed. Each pitted bulb was vertically cut into uniform slices (4 × 0.5 × 0.5 cm) are shown in plate 3.1.

3.3 VACUUM FRYING SYSTEM

Batch type vacuum frying system of 3 kg capacity was used for preparation of fried jackfruit chips. The vacuum frying system consists of two chambers i.e. frying and oil storage chamber. Frying chamber and oil storage chamber were made of stainless steel (SS 316) and chambers were provided with heaters of 3 kW and 1.5 kW. Vacuum frying system was controlled by a microprocessor and

PID (Proportional Integral Derivative) controller. A de-oiling system was mounted inside the frying chamber with frying basket holder (Ranasalva, 2017).

3.3.1 De-Oiling System

De-oiling system consisted of 0.5 hp motor (Make: Prime motors, India) with 6 poles and rotates at 1000 rpm. The motor was mounted at the top of the frying chamber and connected to frying basket holder at the other end. The frying basket holder was fastened with a screw mechanism to contain the frying basket during frying and de-oiling. Frying basket was made of stainless steel (SS 316) with curved bottom (30º) provided with closure. The curved bottom of frying basket aided in the easy draining of oil after frying (Ranasalva, 2017).

3.3.2 Pressure System

The Pressure system was constructed with pressure transmitter (Make: SETRA, India) and its measuring range was 0 to 250 KPa. The pressure was maintained by using 2 hp water ring vacuum pump (Make: Sabara, India) of 30 m3/kg capacity. The compound dial gauge type of instrument was used for measurement of pressure (-1 to 4 kg/cm^2) in storage and frying chamber. In frying basket two separate pneumatically operated spherical disc butterfly valves (Make: AIRA, India) were attached with each chamber to create a vacuum inside the chambers. The pressure difference was created through vent valves by using nitrogen gas, between the chambers, to transfer oil. Nitrogen gas was used to maintain the oil quality, as creation of pressure gradient using air enhances the chance of oxidative rancidity. The oil was transferred from the storage tank to frying tank and vice versa through SS ball valves. Plate 3.2 represents the vacuum frying system used for the present study (Ranasalva, 2017).

3.3.3 Cooling System

The cooling system included a cooling tower of 10 L capacity attached with 1 hp water pump (Make: Protech, India) with a head flow of 5 to 10 lpm. Vapour removed during frying process was condensed using the shell and tube heat exchanger. The vapour was collected through a closed basin fitted with a ball valve (Ranasalva, 2017).

3.4 VACUUM FRYING PROCESS

The vacuum frying process could be divided mainly into four stages: depressurization, frying and de-oiling, pressurization, and cooling (Ranasalva and Sudheer KP 2017). The steps involved for vacuum frying process in the developed vacuum fryer is illustrated below.

3.4.1 Sample Loading

The prepared samples were weighed initially and loaded into previously washed frying baskets. The two frying baskets were loaded with equal quantity (approx. 950 - 1000 g each) of samples of samples in order to have a balance during de-oiling. The loaded frying baskets were kept inside frying chamber using basket holder and chamber was closed tightly.

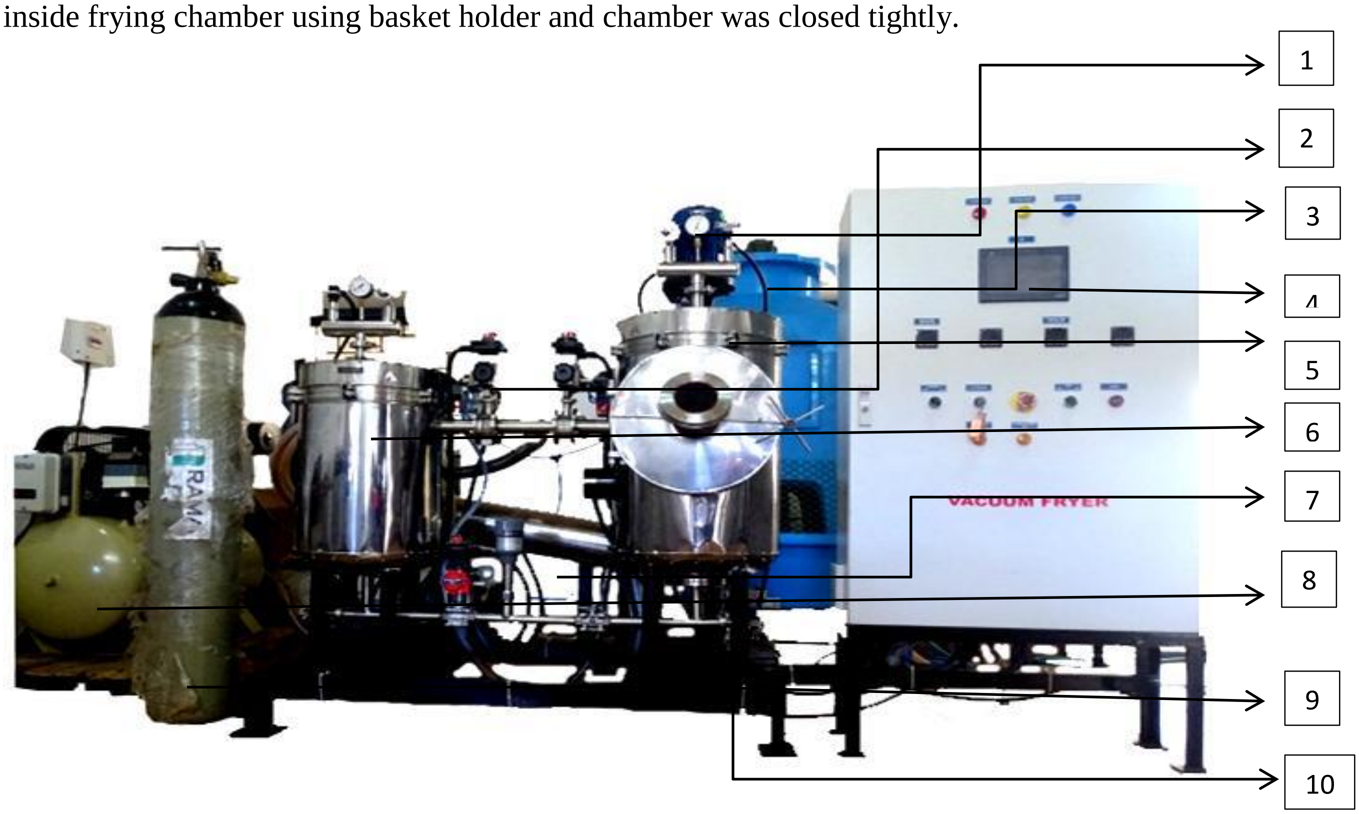


Plate 3.2 Vacuum frying system for jackfruit chips

1. De oiling motor   2. Vacuum valve   3. Control panel

4.Cooling tower   5. Frying chamber   6. Storage chamber

7. Condenser 8. compressor9. Oil flow 10. Nitrogen cylinder (Ranasalva, 2017)

3.4.2 Frying Oil

The frying oil (29 - 30 L) was filled into storage chamber by opening the top lid of storage chamber. Blended oil (Rice bran oil and palm oil in a ratio 80:20) selected as frying oil (Ranasalva and Sudheer 2017).

3.4.3 Depressurization Phase

This phase is basically a creation of low pressure inside the storage and frying chambers. Low pressure (6 - 10 kPa) was created by opening the vacuum valve connected with storage and frying chambers. Simultaneously, the frying chamber was heated to the desired frying temperature

3.4.4 Frying and Deoiling Phase:

Frying was performed when vacuum frying chamber attained the set temperature and pressure. The following changes in pressure occurred between the storage and frying chambers during this phase. The vent valve of storage chamber was opened to increase the pressure by using nitrogen gas and oil inlet valve was also opened. Due to pressure gradient created between storage chamber (high pressure) and frying chamber (low pressure) oil gets transferred in to frying chamber through oil inlet valve. The vent valve and oil inlet were then closed. The loaded jackfruit slices were immersed in oil for a set frying time. During frying process, the frying basket was rotated at a speed of 30 rpm using de-oiling motor attached in it. After completion of frying, the pressure gradient was created to transfer the oil from frying chamber to storage chamber. The vent valve of frying chamber and oil inlet valve was opened for favoring the creation of pressure gradient (storage chamber with low pressure and frying chamber with high pressure) oil to transfer from frying chamber to storage chamber. The vent valve and oil inlet valve were then closed. The pressure was reduced again inside the frying chamber prior to de-oiling. The de-oiling motor was then set to higher rpm (1000 rpm) for desired time. The removal of surface oil from fried jackfruit chips was effected through a centrifugation process. (Ranasalva and Sudheer K P 2017)

3.4.5 Pressurization and Cooling Phase

The vacuum was then released in frying chamber using vent valve and the product was unloaded, allowed to cool till it reaches room temperature. The vacuum fried jackfruit chips were packed using active packaging with nitrogen (N_2) flush in LDPE and Laminated pouches, and Retort pouches, stored at room temperature for further analysis.

Stages		Characteristics
Phase 1	Depressurization	Reduction in pressure and increase in temperature to desired level was achieved in storage and frying chambers.
Phase 2	Frying and de-oiling	Frying was carried out at standardized temperature, pressure and time. De-oiling was done by centrifugation of fried samples to remove its surface oil.
Phase 3	Pressurization	Fried and de-oiled product was brought to atmospheric pressure.
Phase 4	Cooling	Product temperature was brought down to room temperature before packaging and storage.

Table3.1: Stages of vacuum frying

(Ranasalva, 2017)

The performance evaluation of vacuum frying of jackfruit chips and blend of rice bran (brand: PAVIZHAM, Kerala, India) and palm oil in the ratio of (80:20) was done. The procedure is explained under various experiments, viz; Experiment I: To optimize the pre-treatments for vacuum fried jackfruit chips. Experiment II: effects of process parameters on the physical properties of vacuum fried jackfruit chips .Experiment III: Optimization of packaging materials.

EXPERIMENT I:

3.5 OPTIMIZATION OF PRE-TREATMENTS FOR VACUUM FRIED JACKFRUIT CHIPS.

Based on the preliminary studies of vacuum frying of jackfruit, a combination of temperature (100ºC) (Shyi-Liang and Hwang, (2001); Diamante *et al.*, (2012)), pressure (6 kPa) (Dueik *et al.*, (2010); Maity *et al.*, (2014)) and time (12 min) (Ranasalva and Sudheer (2015); Tarzi *et al*,. (2011)) for the pre-treatment study were selected. The various pre-treatments were adopted for reducing oil uptake and to improve the quality parameters of the fried product. Pre-treatments like blanching, freezing, drying were selected for this study.

Independent variables	**Dependent variables**
1. Control (untreated) 2.Blanching 3.Drying 4.Freezing	Vacuum fried jackfruit chips properties (Water activity, moisture content, color , hardness)

Table 3.2: Experimental design of vacuum frying of jackfruit chips with different pre-treatments

3.5.1 Blanching

Sliced jackfruit of 0.5 mm thickness was hot water blanched at 80°C for 1, 2 and 3 min and optimized for 1 min by peroxidase test.

3.5.2 Drying

Sliced jackfruit of 0.5 cm thickness was dried for 3 h at 105°C.

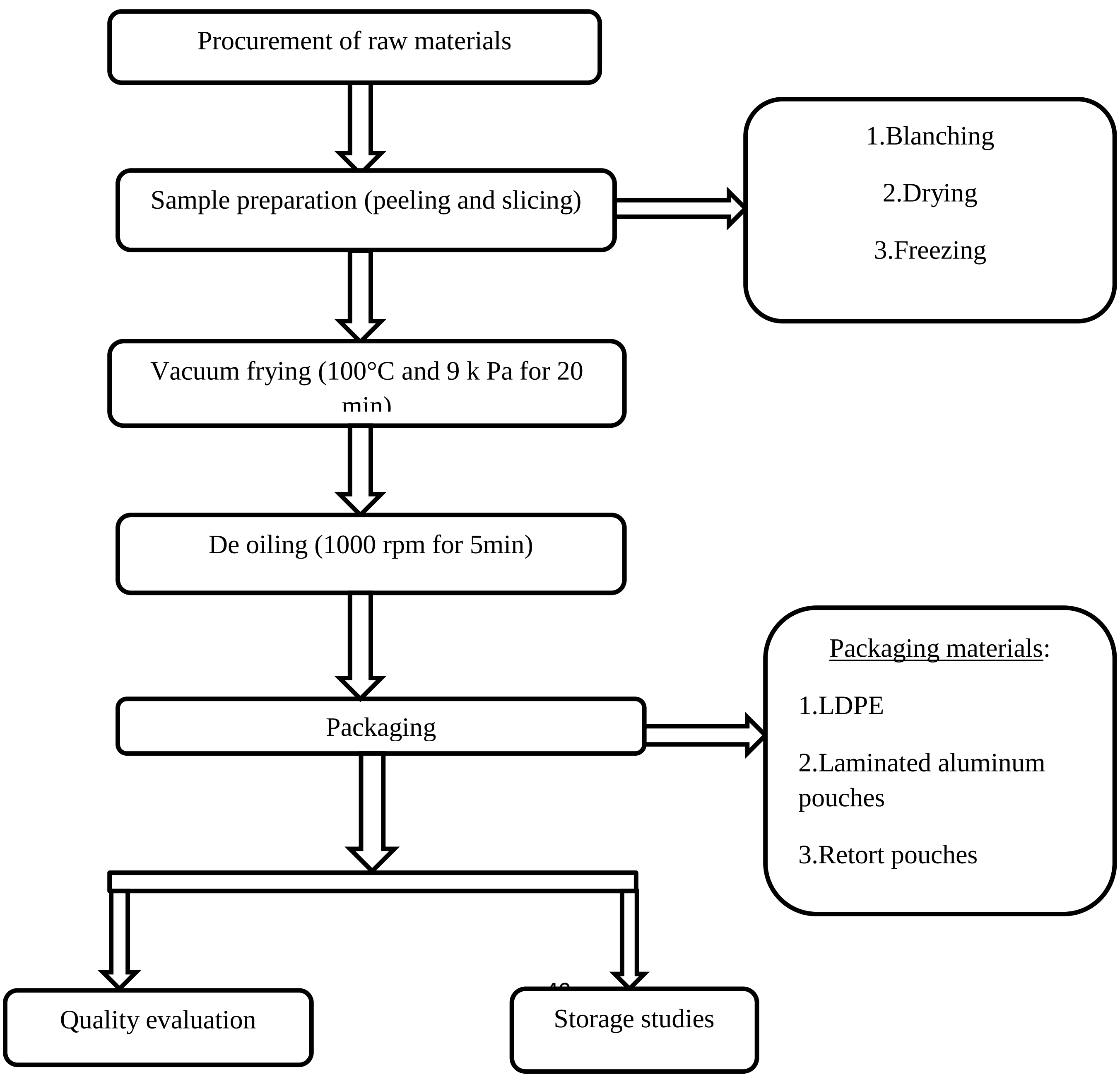
3.5.3 Freezing

Sliced jackfruit of 0.5 cm thickness kept for deep freezing at, -30ºC for 8 h (Arlai *et al.*, 2014).

3.5.4 Atmosphere Frying

The atmospheric frying was carried out by immersing the sample in hot oil, at a frying condition of temperature 165ºC, pressure of 101 kPa and time of 15 min. After each frying process, the samples were removed from the frying vessel and hold in stainless steel sieve to facilitate draining of oil.

Fig.3.1 Process flow chart for vacuum frying of jackfruit chips with different pre-treatments



The pretreatments (untreated, blanching, drying, freezing and atmospheric frying) were optimized based on the quality parameters of vacuum fried jackfruit chips *viz.,* water activity, oil content, moisture content, color and texture. The quality parameters were estimated based on the standard procedures. The optimized pre -treatment was only considered for the next experiments.

EXPERIMENT II.

3.6 STANDARDIZATION OF PROCESS PARAMETERS FOR THE PRODUCTION OF VACUUM FRIED JACKFRUIT CHIPS

The experiment II was performed for optimization of process parameters *viz*, temperature, pressure and time of frying for the production of vacuum fried jackfruit chips. Based on previous reviews, blended rice bran and palm oil in the ratio of 80:20 was selected for vacuum frying. De-oiling was carried out by centrifugation at a speed of 1000 rpm for 5 min. The experiments were conducted with 2 frying temperatures (100 º C and 110 º C) , 2 vacuum pressures (9 kPa and 12 kPa) and 2 time of frying (18 min and 20 min). The experiment consists of 8 treatments in 2 replications.

JF1: 100 º C, 9 kPa, and 18 min

JF2: 100 º C, 12 kPa, and18 min

JF3: 100 º C, 9 kPa, and 20 min

JF4: 100 º C, 12 kPa, and 20 min

JF5: 110 º C, 9 kPa, and 18 min

JF6: 110 º C, 12 kPa, and18 min

JF7: 110 º C, 9 kPa, and 20 min

JF8: 110 º C, 12 kPa, and 20 min

3.7 QUALITY PARAMETERS OF VACUUM FRIED JACKFRUIT CHIPS

3.7.1 Moisture Content

The moisture content of the vacuum fried Jackfruit chips was determined by gravimetric method. Moisture content was calculated by weight loss after drying 3 g of coarsely ground sample in hot air oven dryer at 105ºC for 24 h (AOAC, 1986).

$$\text{\% Moisture content} = \frac{w1-w2}{w1} \times 100 \ldots\ldots\ldots (3.1)$$

Where,

W1- wet weight, g

W2- dry weight, g

3.7.2 Water Activity

The water activity of the vacuum fried Jackfruit chips were determined by using water activity meter (Model: Aqua lab, Decagon Devices Inc., Pullman (Wa), USA) (Perez-Tinoco *et al.*,2008). The water activity meter showed in Plate 3.3

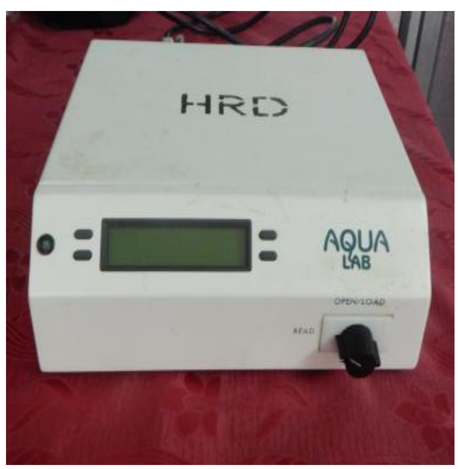


Plate 3.3 Water activity meter

3.7.3 Oil Content

Oil content of vacuum fried Jackfruit chips as analysed by Soxhlet apparatus (Pelican Equipments, Soc plus model: SOCS 06 ACS, India) and test was performed in triplicates (Garayo and Moreira, 2002). The Soxhlet apparatus is shown in plate 3.4.The oil content of vacuum fried Jackfruit chips was determined by the following equation;

$$\textbf{\% oil content} = \frac{W2-W1}{W}\ X\ 100 \quad \ldots\ldots\ldots.. (3.2)$$

Where,

W- Weight of thimble with sample, g

W1- Weight of empty beakers, g

W2- Weight of beaker with final extracted oil, g

Plate 3.4 Soxhlet apparatus

3.7.4 Texture Analysis

Hardness is a measure of force required to rupture the food products and it is deliberated in Newton (N). The Texture Analyser (TA.XT Texture Analyser, stable micro system) was used for the determination of crispiness and hardness of vacuum fried jackfruit chips and it is shown in plate 3.5

In texture analyser test were conducted for individual jackfruit chips and the required values are obtained from a graph. During testing process, the probe is allowed to move from a top portion to downwards to fracture the sample for a specified distance of 20 mm. Once the probe touched the sample, the maximum force required to rupture the chips were observed and compared between the samples. The crispiness test for vacuum fried jackfruit chips test was conducted in triplicates in texture analyser. The TA settings used for the test is given below.

TA setting

Test Mode	: Measuring force in compression
Option	: Return to start
Pre-test speed	: 1.50 mm/sec
Test speed	: 2.00 mm/sec
Post-test speed	: 10.00 mm/sec
Distance	: 20.00 mm
Trigger type	: Auto (force)
Trigger force	: 5.0
Probe	: Blade set (HDP/BS)

Plate 3.5 Texture Analyser

3.7.5 Bulk Density

The bulk volume of vacuum fried jackfruit chips was determined by liquid displacement method (Da-Silva and Moreira, 2008). In an experiment, 1g of jackfruit chips were weighed and the volume in the apparatus was recorded with and without sample. The bulk density of chips was then determined by dividing the weight of the chips by its bulk volume. The bulk density of vacuum fried bitter gourd chips was determined by using following equation (Ravli *et al.,* 2013).

$$\rho = \frac{Ws}{Vb} \quad \text{..................(3.3)}$$

Where,

Ws – Weight of the de-oiled sample, g

Vb – Bulk volume of sample, ml

3.7.6 True density

The true density of vacuum fried bitter gourd chips was determined as per the method recommended by Deshpande and Poshadri (2011) and was calculated by the following equation

$$\rho = \frac{Ms}{Vt} \quad \text{............(3.4)}$$

Where, Ms - Weight of de-oiled sample, g

Vt - True volume of the sample ml

3.7.7 Color Values

The color of the vacuum fried jackfruit chips was determined by using a Hunter lab Colorimeter – Color flex EZ diffuse model. It works on the principle of focusing the light and measures energy reflected from the sample across the entire visible spectrum. Colorimeter having standard observer curves such as red, green and blue colors. The primary lights required matching a series of colors across the visible spectrum and mathematical model used to describe the colors are called Hunter model. This colorimeter expressed the colors on L*, a*, and b*. The L* value represents lightness its ranging from, 0 (blackness) to 100 (whiteness), a* represents +ve (redness) and –ve (greenness) and b* represents +ve 60 (yellowness) and –ve 60 (blueness) (Maity *et al.*, 2014). The color of the jackfruit chips was measured by using CIELAB scale at 10˚ observer at D65 illuminant with 50 mm diameter measuring space. Before measuring color instrument should standardize by placing black and white standard tiles. The deviation from color of the samples with the standard was also observed and recorded in the computer interface.

The total color difference (ΔE) between raw (L0*, a0*, b0*) and fried jackfruit chips (L*, a*, b*) was determined using the equation 3.8 which is adopted by Afjeh *et al.*, (2014). Hunter lab colorimeter showed in fig.

$$\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2}$$

…………. (3.5)

3.8 OIL QUALITY PARAMETERS

3.8.1 Total Polar Compounds

The total polar compounds of oil measured by using Testo 270º (Make: Italy) instrument. In this instrument measures, TPC based on the dielectric constant of oil and value is directly converted into percentage weight of TPC (Guillén and Uriarte, 2012). The oil to be tested was pre-heated to 40ºC in a glass beaker. The probe with a sensor of Testo 270º was inserted into pre-heated oil sample. Care should be taken to avoid touching of the sensor at the bottom of the beaker. The digital display on the instrument shows the TPC in percentage. The Testo 270º instrument used for the measurement of TPC is shown in plate 3.6.

Plate 3.6 Testo 270º

Based on the quality parameters of vacuum fried jackfruit chips, the best combination of process variables were standardized.

EXPERIMENT III

3.9 STORAGE STUDIES OF OPTIMIZED VACUUM FRIED JACKFRUIT CHIPS

The optimized vacuum fried jackfruit chips were packed into three different packages. The vacuum fried chips were packed in LDPE of 400 gauge thickness, laminated aluminum pouches of 0.006-0.008 mm thickness and retort pouch. The packaging was done using nitrogen flush packaging machine (Model: QS 400 V, Sevana packaging solutions, Kerala, India) with 95% of N2 flushing (Fan *et al.,* 2007) in laminated aluminum package and LDPE. The packed samples were stored at room temperature for storage studies. The packaging and storage studies were conducted to optimize suitable packaging material and shelf life for vacuum fried jackfruit chips. The packaging studies were conducted for 90 days and quality analysis was performed at a regular interval of 30 days. The best packaging material and storage period were studied.

3.10 ECONOMIC ANALYSIS

The cost economics was done for the optimized vacuum fried product for commercialization of the product. The cost was determined by standard method with reasonable assumptions. The assumptions like life span of machine, annual working hours (H), salvage value (S), interest on initial cost, repair & maintenance, insurance & taxes, electricity charges, labour wages/person, skilled assistants and manager were used. The details of the cost analysis are given in Appendix A

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Results and Discussions

CHAPTER IV
RESULTS AND DISSCUSSION

This chapter deals with the results of optimization of different pre-treatments, vacuum frying process and product parameters of vacuum fried jackfruit chips. The second phase of study consists of quality evaluation, packaging and shelf life studies of selected vacuum fried jackfruit chips. The salient observations are discussed here.

EXPERIMENT 1

4.1 OPTIMIZATION OF PRE-TREATMENTS FOR VACUUM FRYING OF JACKFRUIT CHIPS

The blend of rice bran and palm oil (80:20) was selected as the frying oil for experimental purpose. In this experiment, standardisation of pre-treatments was done to produce good quality vacuum fried jackfruit chips. Pre-treatments like freezing, blanching and drying were carried out for vacuum frying of jackfruit at processing conditions *viz.,*frying temperature (100ºC), frying pressure (9kPa) and frying time (20 min). Subsequently, the untreated vacuum fried jackfruit taken as the control. The VF-jackfruit chips of different pre-treatments are represented in fig 4.1. The specific quality parameters of pre-treated and control samples were compared with consequent atmospheric fried matured jackfruit chips.

4.1.1 Effects Of Pre-Treatments On Quality Parameters Of Vacuum Fried Jackfruit Chips

The quality parameters of pre-treated vacuum fried jackfruit chips *viz.,* moisture content, water activity, oil content, hardness, colour values (L*, a* and b*) are discussed here.

4.1.1.1 *Water Activity*

Water activity of the pre-treated vacuum fried jackfruit chips significantly changed with different pre-treatments. Fig.4.1 depicts the water activity of VF-jackfruit chips and the corresponding values are tabulated in Table.4.1. The water activity of the VF- jackfruit chips was ranged between 0.444 and 0.557 aw. The water activity of frozen (0.444) pre-treated sample was the least followed by dried (0.480), control (0.487), atmosphere (0.499) and blanched (0.557aw) VF-jackfruit chips. Perez-Tinoco *et al.,* (2008) represented similar results of a_w values for vacuum fried pineapple chips.

4.1.1.2 *Oil Content*

The oil uptake of VF-jackfruit chips was significantly affected by the pre-treatments. Oil content was considerably less in vacuum fried jackfruit chips than atmospheric fried jackfruit chips (Fig. 4.2).The highest oil content of 40.25% was noticed in atmospheric chips followed by frozen (38.44%) pre-treated VF-jackfruit chips. During the evaporation of ice crystals during frying, there will be a rapid formation of microstructure pores and this promotes high oil uptake. The result was in agreement with Ranasalva and Sudheer (2017) who observed a high oil uptake in vacuum fried banana chips pre-treated with freezing. The lowest oil uptake of 33.35% was observed in untreated VF-jackfruit chips. The oil absorption in dried sample (34.25%) was found to be lesser than that of blanched sample (37.76%), this is because the loss of moisture is directly related to oil absorption. Moyanoa and Pedreschi (2006) observed the lowest oil content in drying pre-treated deep fat fried potato chips. Among the above treatments the control (untreated) sample gave comparatively less oil content and better organoleptic quality.

4.1.1.3 *Moisture Content*

Moisture content of pre-treated VF- jackfruit chips significantly varied with different pre-treatments. The effect of moisture content of VF-jackfruit chips on various pretreatments is graphically represented in Fig. 4.3 and the values are shown in Table.4.1. The highest moisture content (0.772%) was observed in frozen sample as well as blanched samples and the least moisture content\ of 0.472% was observed in dried sample. The highest moisture content in frozen sample was due to uniform removal of moisture during vacuum frying of frozen sample with high temperature difference. Fan *et al.* (2006) stated similar trend of moisture reduction in the frozen pre-treated vacuum fried carrot chips. The initial moisture removal of jackfruit slices through drying contributed to low moisture content in the VF-jackfruit chips. Low moisture content was observed in fried potato strips that were air dried prior to frying (Dehghannya *et al.*, 2015). The moisture content of the control and blanched pre-treated VF-jackfruit chips were 0.501 % and 0.735%, respectively. The atmospheric fried jackfruit chips had moisture content of 2.402 % which was much higher than frozen pre-treated sample.

4.1.1.4 *Colour Values*

The colour values of vacuum fried chips showed significant difference with various pre-treatments. The colour values of VF- jackfruit chips are illustrated in Fig. 4.4. The maximum L* of 69.18 was obtained in controlled sample followed by frozen (51.48) and blanched (41.59) sample. The minimum L* value of 21.12 was observed in atmospheric fried chips followed by dried chips (37.3). Controlled jackfruit produced light coloured chips, which is a desirable character. However, dark coloured product was obtained from drying pre-treatment sample. The drying process led to dark colour of fried product.

The a* and b* value of vacuum fried jackfruit showed significant variation with pre-treatments. The a* value of VF-jackfruit chips pre-treated with drying had the highest value of 12.9, which indicates the high red colour in the product. The sample pretreated with drying resulted in dark fried product. The untreated sample had the lowest a* value (2.73). *i.e*, the untreated sample had the value almost similar to the fresh sample (2.31). The blanched (11.93) and frozen (12.67) samples also had high a* values. The highest b* value was recorded in frozen pre-treated vacuum fried jackfruit chips (45.05) followed by control (un-treated) (35.35) sample. The blanched and dried pre-treatment samples also had higher b* values, 33.71 and 3.022 respectively. The jackfruit chips fried under atmospheric conditions were turned darker. The change in colour in fried jackfruit chips is due to the interaction of an amine group with a reducing sugar, which is a non-oxidative browning also known as Maillard reaction(Garayo *et al*.,).

The ΔE (colour difference) value of pre-treated VF-jackfruit chips showed significant difference in different pre-treatments. The colour change (ΔE) with respect to fresh samples (L* 75.37, a* 2.31, b* 36.66) was lowest in controlled sample (6.34) followed by frozen samples (27.35). The detailed colour value of pre-treated vacuum fried jackfruit chips was illustrated in Table.4.1. The colour variation on vacuum frying was comparatively less than atmospheric fried VF- jackfruit chips. Troncoso *et al.,* (2009) reported similar results on the colour analysis of vacuum and atmospheric fried potato slices.

4.1.1.5 *Texture*

The textural changes of pre-treated VF-jackfruit chips exhibited significant difference within treatments. The effect of hardness of vacuum fried chips on pretreatments was shown in Fig 4.5. The higher hardness value of 2.6 N was observed in VF-jackfruit chips pre-treated with drying. The removal of moisture prior to frying made the product compact and hard in drying pre-treated sample (Debnath *et al.,* 2003). Fan *et al.,* (2005) reported that lower breaking force correspond to higher crispiness and Fan *et al,.* (2006) confirmed that crispiness value was higher in case of the drying compared to atmospheric fried and other pre-treatments of vacuum fried carrot chips. The VF jackfruit chips pre-treated with freezing had the lowest hardness value of about 1.65 N, followed by control (1.04 N) products. The retention of moisture in the frozen jackfruit slices increased the rate of mass transfer with high oil absorption that lowered crispiness in the product. Arlai *et al.,* (2014) had also reported that hardness value of vacuum fried okra chips was less when pre-treated with freezing. Hardness value of blanched VF-jackfruit chips was less compared to dried sample (1.76N) and higher than freezed and control VF jackfruit chips.

4.2 OPTIMIZATION OF PRETREATMENTS FOR THE PRODUCTION OF VACUUM FRIED JACKFRUIT CHIPS

Vacuum fried products without any pretreatments (control) gave better quality parameters. Blanched products had a higher water activity, moisture content and oil content. The texture and color of fried products pretreated with drying was not appreciable. Frying done with frozen jackfruit slices had very high oil content even though its water activity was less. The untreated vacuum fried chips had the most desirable characteristics like low water activity, more storage period, retention of color and texture, low moisture content and oil content. Hence untreated vacuum fried chips (control sample) was only considered for further studies.

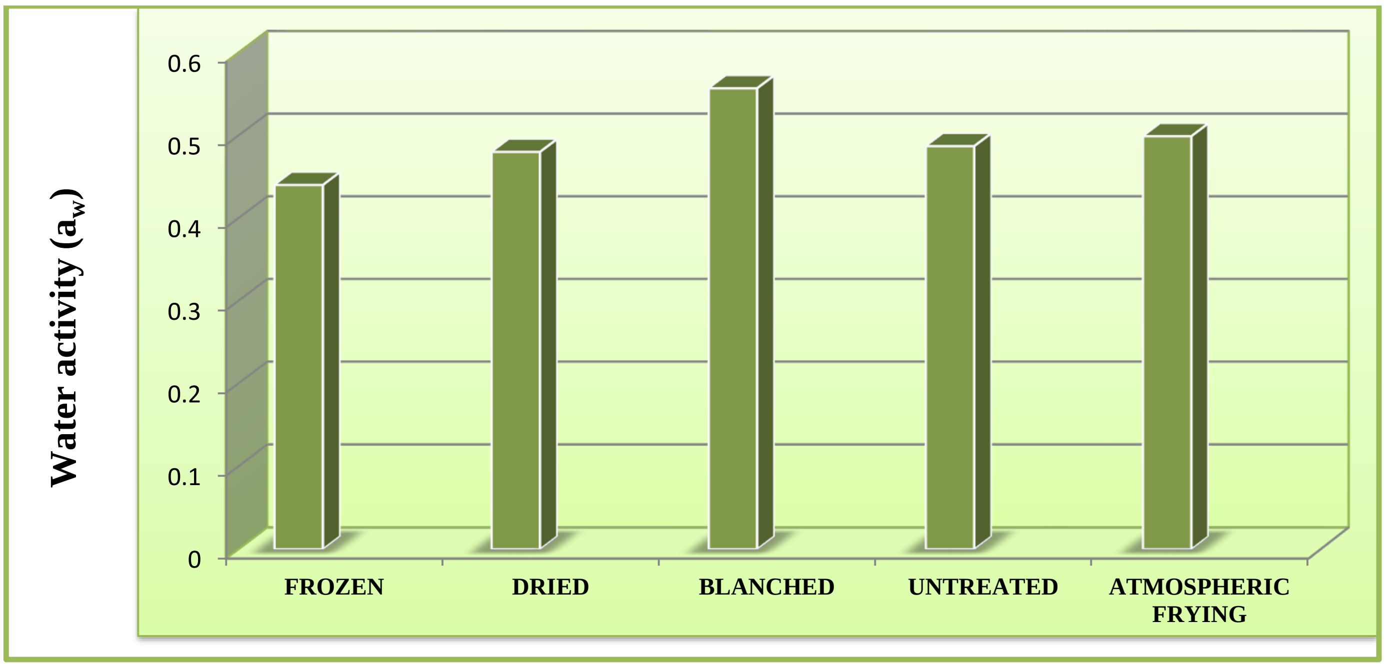

Fig.4.1 Water activity of pre-treated vacuum fried jackfruit chips

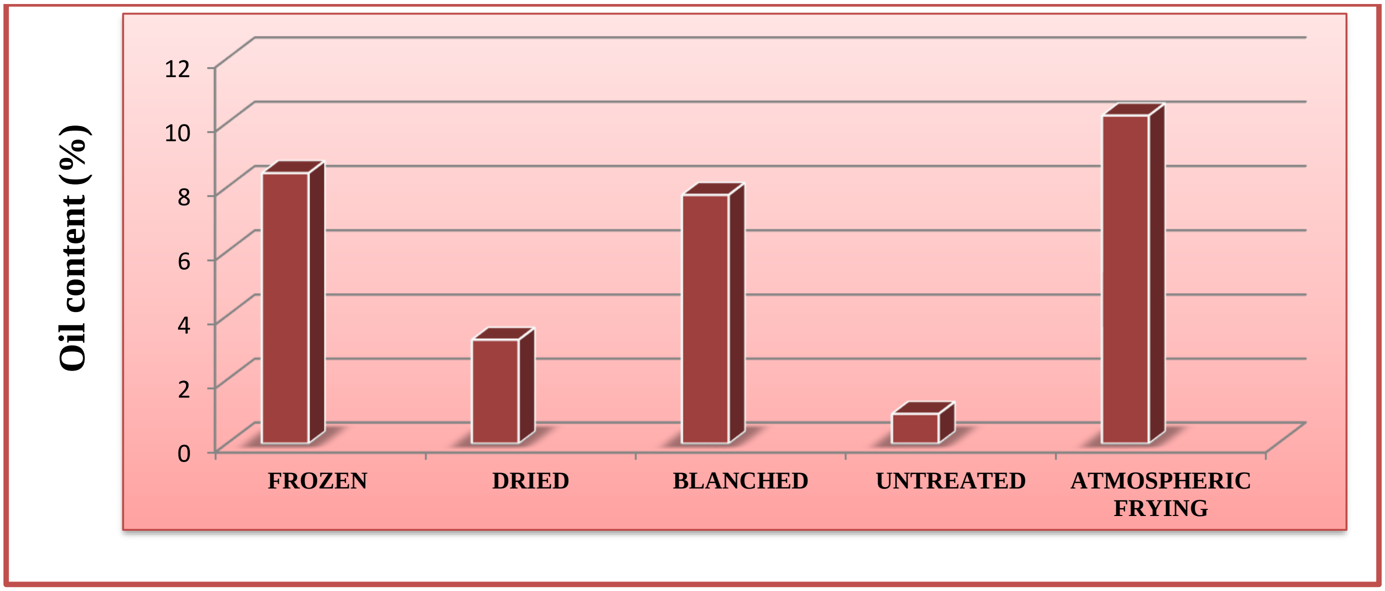

Fig.4.2 Oil content of pre-treated vacuum fried jackfruit chips

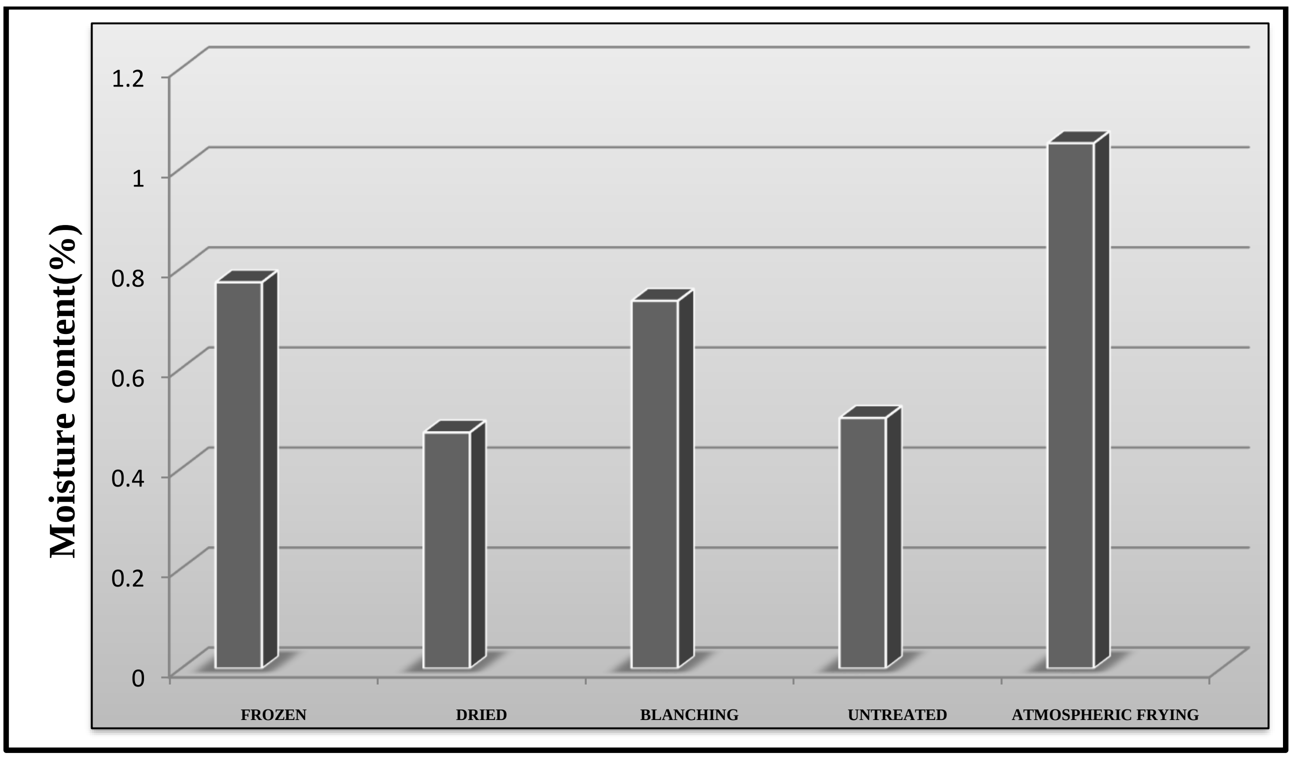

Fig.4.3 Moisture content of pre-treated vacuum fried jackfruit chips

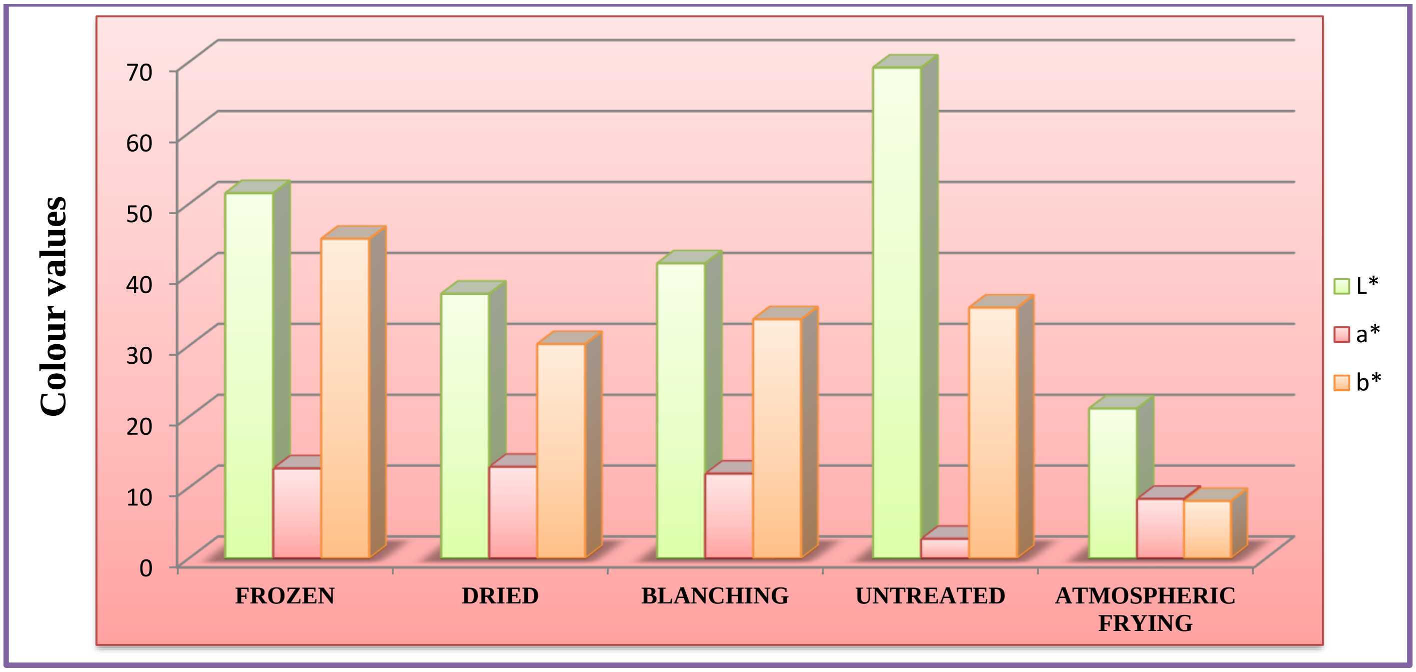

Fig.4.4 Colour values of pre-treated vacuum fried jackfruit chips

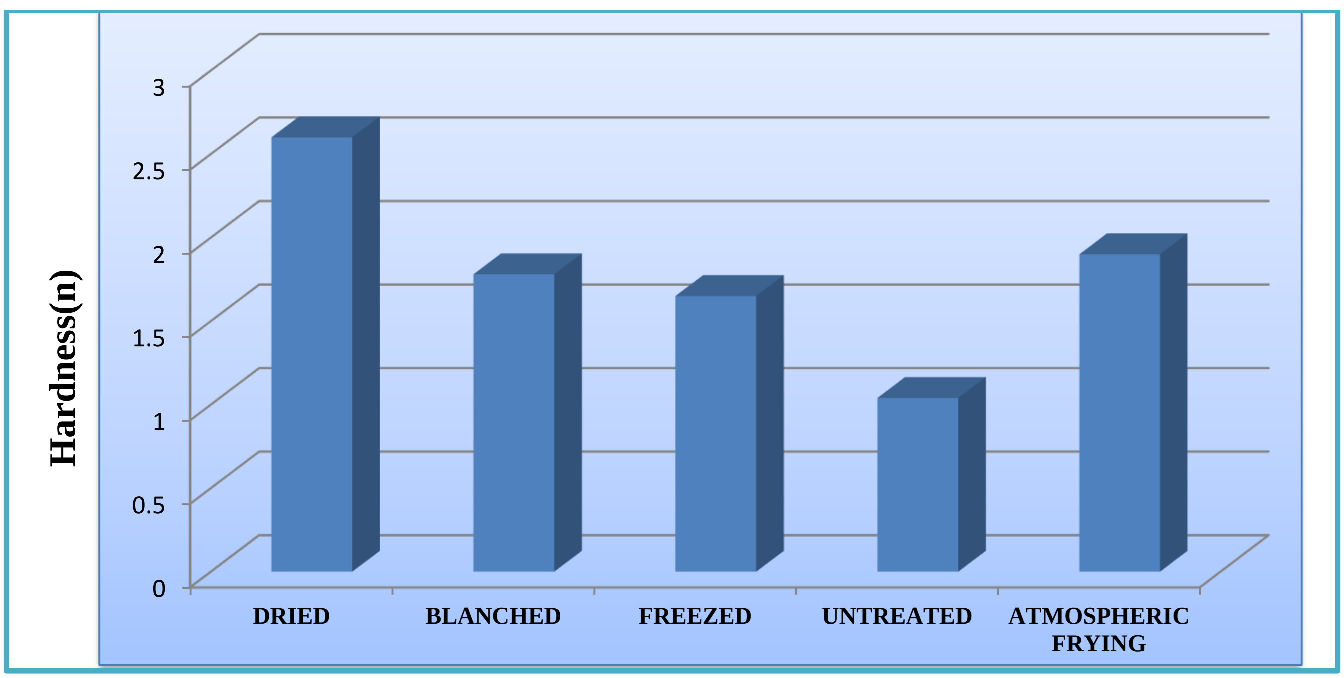

Fig.4.5 Hardness value of pre-treated vacuum fried jackfruit chips

EXPERIMENT - II

The experiment II was performed for optimization of process parameters *viz,* temperature, pressure and time of frying for the production of vacuum fried jackfruit chips. Based on previous reviews, blended rice bran and palm oil in the ratio of 80:20 was selected for vacuum frying. De-oiling was carried out by centrifugation at a speed of 1000 rpm for 5 min. The experiment consists of 8 treatments in 3 replications.

4.2 EFFECTS OF PROCESS PARAMETERS ON PHYSICAL PROPERTIES OF VACUUM FRIED JACKFRUIT CHIPS

The results of the analysis of quality attributes such as moisture content, water activity, oil content, hardness, colour changes, energy content and acrylamide content of vacuum fried jackfruit chips are shown in Table 4.3

4.2.1 Moisture Content

The moisture content of VF-jackfruit chips obtained from different processing conditions is shown in Fig. 4.6. The results indicated that frying conditions affected the moisture content. The moisture content ranged from 0.481% to 0.801% in vacuum fried jackfruit chips at different frying parameters. Moisture content of VF-jack fruit chips decreased with increased frying temperature and frying time. This is due to the fact that the more the frying temperature is increased, pressure is lowered and boiling point is reduced. And as a consequence the water in the vacuum fried jackfruit chips will begin to vaporize faster at a higher vacuum level. The low moisture content of 0.481 was observed at frying temperature of 100 ºC, frying pressure of 9kPa for a frying time of 20 min. Since the frying was carried out under vacuum which decreased the boiling point of water, the moisture removal was instantaneous without much warm up phase. High moisture content of 0.801% was observed in VF-jackfruit chips at frying temperature of 100ºC, frying pressure of 12 kPa and frying time of 18 min. Similar results were observed in the vacuum frying of carrot chips at frying temperature of 118ºC (Garayo and Moreira, 2002). There was significant difference in moisture content of VF-jackfruit chips subjected to different frying conditions. The same phenomena were also observed in vacuum fried carrot chips (Fan *et al.*, 2005) and for vacuum fried apple chips (Shyi and Hwang, 2001) and vacuum fried banana chips (Ruttanadech and Chungcharoen, 2015).

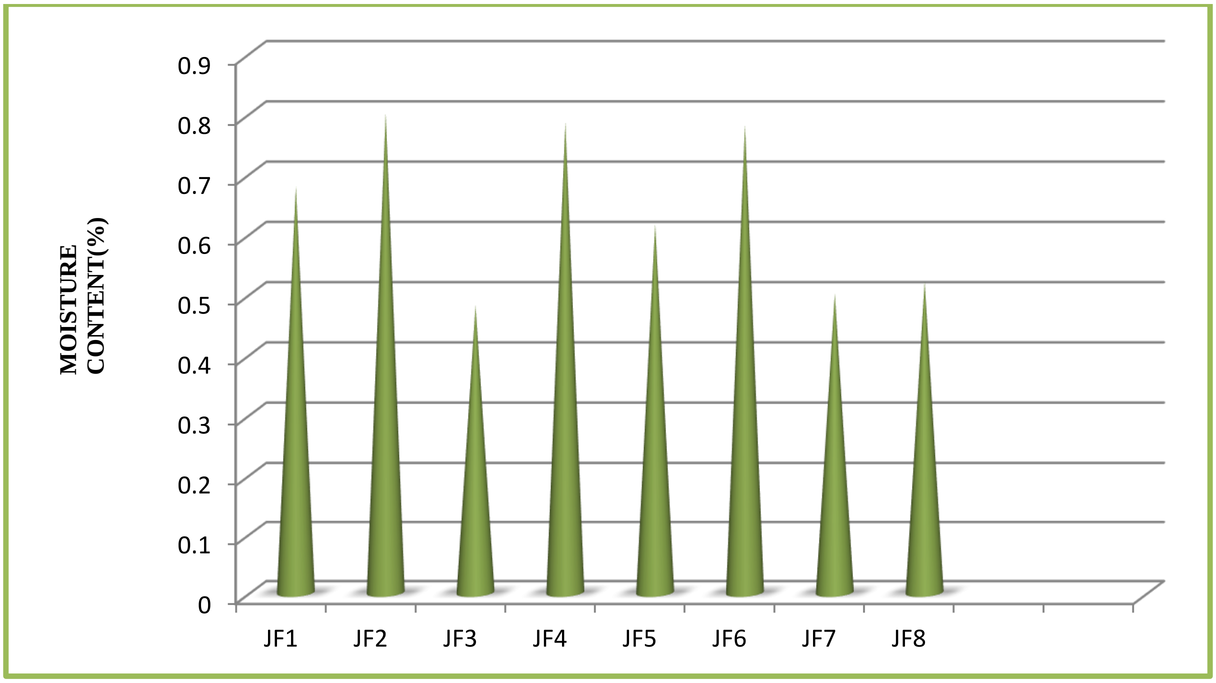

Fig4.6 Changes in moisture content of VF-jackfruit with process parameters

4.2.2 Water Activity

Water activity is an important property which is used to predict the stability and safety of food with respect to microbial growth rate. The water activity of VF-jackfruit chips with different frying conditions is represented in Fig. 4.7.The minimum and maximum activity value of 0.473 and 0.613was obtained at frying condition of 100ºC, 9 kPa and 20 min (JF3) and 100ºC, 12 kPa and 18 min (JF2), respectively. This might be due to high moisture retention at the respective frying temperature, pressure and time. Similar results were observed for vacuum fried carrot chips (Dueik *et al.*, 2010), vacuum fried shiitake mushroom chips (Ren *et al.*, 2018) and vacuum fried bittergourd chips (Pooja *et al.*, 2018). The safe level of water activity for any fried product should be less than 0.6 (Fontana, 1998).

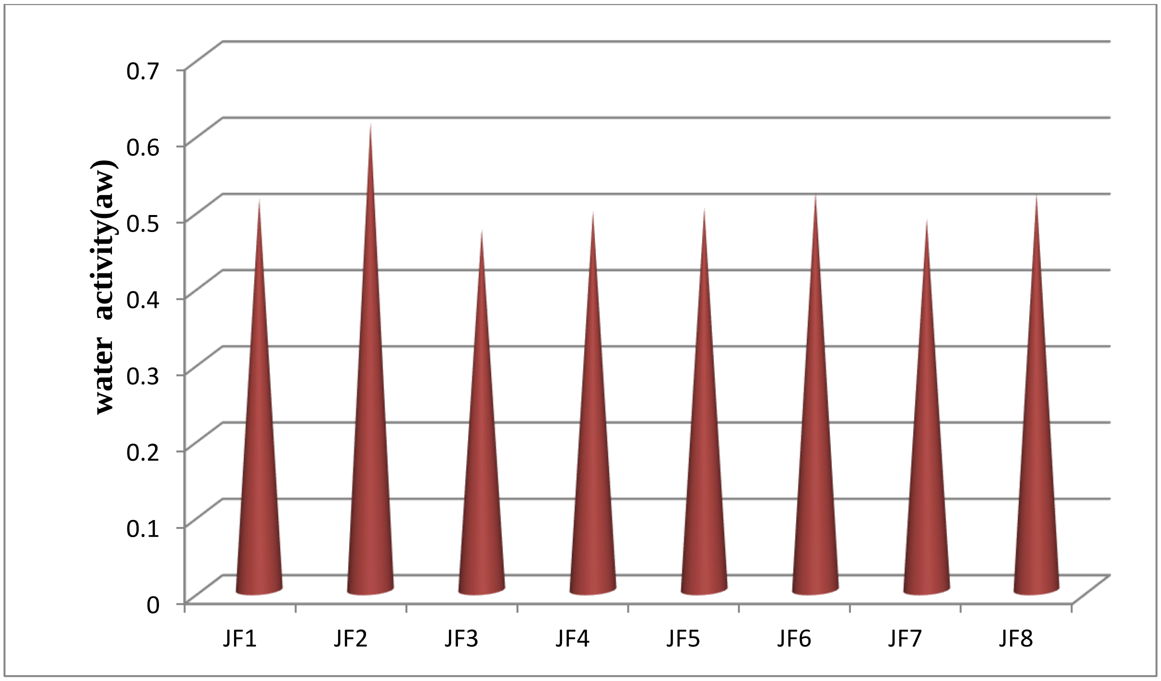

Fig4.7 Changes in water activity of VF-jackfruit with process parameters

4.2.3 Oil Content

Oil content of vacuum fried jackfruit chips is an important parameter in assessing the consumer accessibility of the product. Oil absorption is a complex phenomenon that happened mostly when the product is removed from the fryer during the cooling stage (Sun and Moreira, 1994). Effect of process parameters on oil content of VF-jackfruit chips is shown in Fig. 4.8. The oil content of VF-jackfruit ranged from 28.85 to 34.73% at different frying conditions. The maximum oil content of 34.73% was noted at 110ºC, 9 kPa and 20 min (JF7). Also, the minimum oil content of 20.73% (JF3) was observed in VF-jackfruit chips with frying conditions of 100ºC, 9 kPa and 20 min.

The oil uptake increased at increased frying temperatures. Absorption of oil was found to be related to the loss of moisture from the jackfruit chips. This may be due to the diffusion gradient created by the loss of moisture through the surface making the surface dry (Tanushree *et al.*,2014).The same phenomenon was also observed by Segovia *et al.*, (2016) for vacuum fried cassava chips at different frying temperature and frying time and Ranasalva and Sudheer (2017) for vacuum fried banana chips.

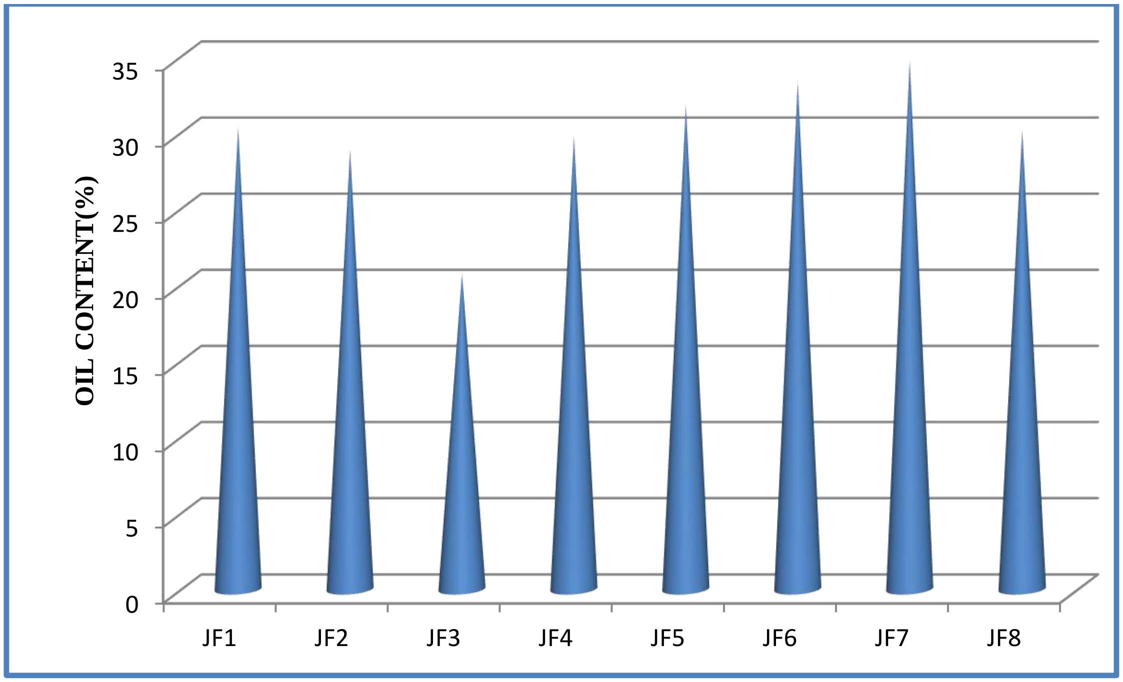

Fig4.8 Changes in oil content of VF-jackfruit with process parameters

4.2.4 Colour Values

The L* values of vacuum fried jackfruit chips obtained from different experiments is shown in Fig. 4.9. The colour values of VF-jackfruit chips significantly varied with different process parameters. The L* values of the vacuum fried jackfruit chips ranged from 66.53 to 70.18. The L* values were seen to be inversely proportional to the frying temperature. A higher L* value was observed in VF-jackfruit chips at frying condition of 100ºC, 9 kPa and 20 min (JF3). Lower L* value of 66.53 was observed in the VF-jackfruit chips at processing conditions of 110ºC, 9 kPa and 20 min (JF7). When frying time was further extended, the L* value decreased at all frying temperatures. Visual observations confirmed the results obtained from colorimeter, since the jackfruit chips fried under atmospheric conditions were darker, more red, and yellowish than jackfruit chips under vacuum. The change in color was due to the interaction of an amine group with a reducing sugar, which is a non-oxidative browning reaction also known as Maillard reaction.

The a* value of VF-jackfruit chips with different processing conditions is shown in Fig. 4.10. The a* value of VF- jackfruit chips ranged between 2.71 to 3.26 in two different frying temperature, pressure and time combinations. The maximum a* value of 3.26 was observed in the VF- jackfruit chips at frying condition of 110ºC, 12 kPa and 20 min (JF8). The minimum a* value of 2.71 was found in the

VF-jackfruit chips at frying condition of 100ºC, 9 kPa and 20 min (JF8). In VF-jackfruit chips, green colour was increased with a high negative value at lower frying temperature, whereas at high frying temperature, a* value changed from green to red colour due to browning reaction. The a* value of VF-jackfruit chips significantly varied with different frying conditions.

The b* value of vacuum fried jackfruit chips with different frying conditions is depicted in Fig. 4.11. The b* value ranged from 29.46 to 35.41 in VF-jackfruit chips at different processing conditions. Higher b* value (35.41) was noted in VF-jackfruit chips at frying condition of 100ºC, 9 kPa and 18 min (JF3). Lower b* value (29.46) was noticed in VF-jackfruit chips at frying temperature (110ºC), frying pressure (9 kPa) and frying time (20 min). A lower value of b* was observed by the increase in frying temperatures. The same phenomenon was also observed, for vacuum fried chicken nugget (Teruel *et al.*, 2014). The b* value significantly varied with different combinations of frying temperature, pressure and time.

The L*, a* and b* values of fresh ripened jackfruit bulb slices was 75.37, 2.31 and 36.66 respectively. The sample of jackfruit chips fried at a frying temperature of 100ºC, a frying pressure of 9kPa and frying time of 20 min showed most precise values of L*(70.18), a*(2.71) and b*(35.41) to fresh sample.

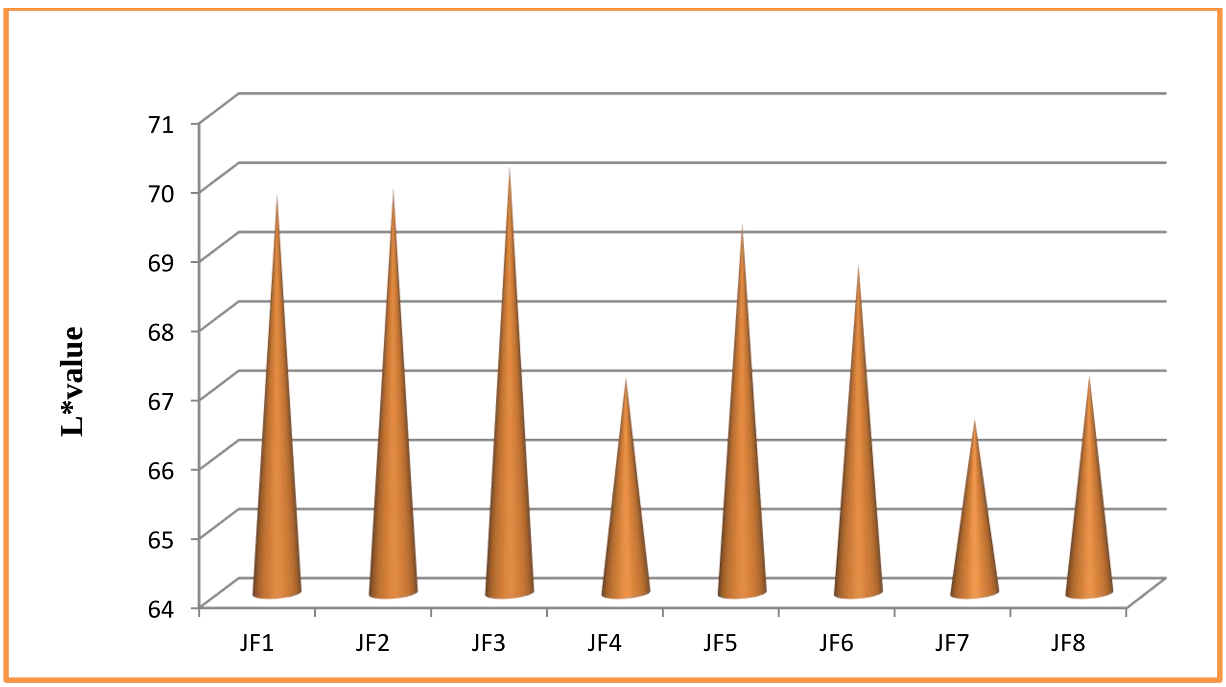

Fig4.9 Changes in L* value of VF-jackfruit with process parameter

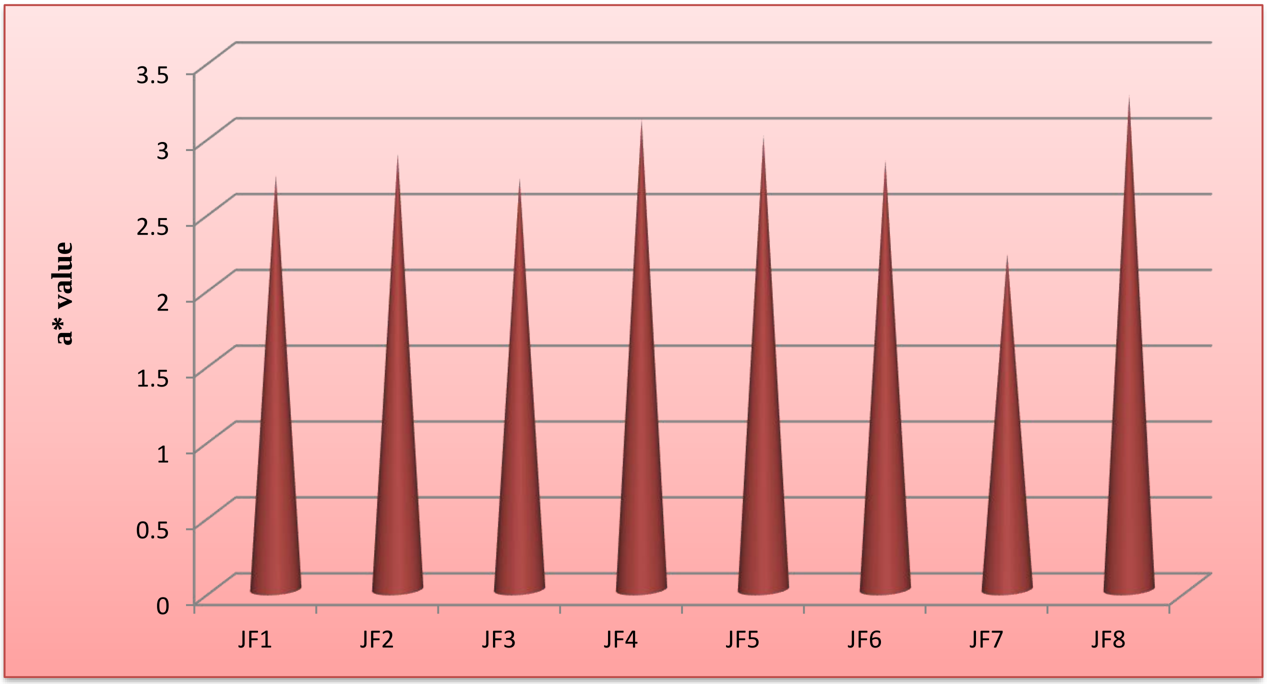

Fig4.10 Changes in a* value of VF-jackfruit with process parameter

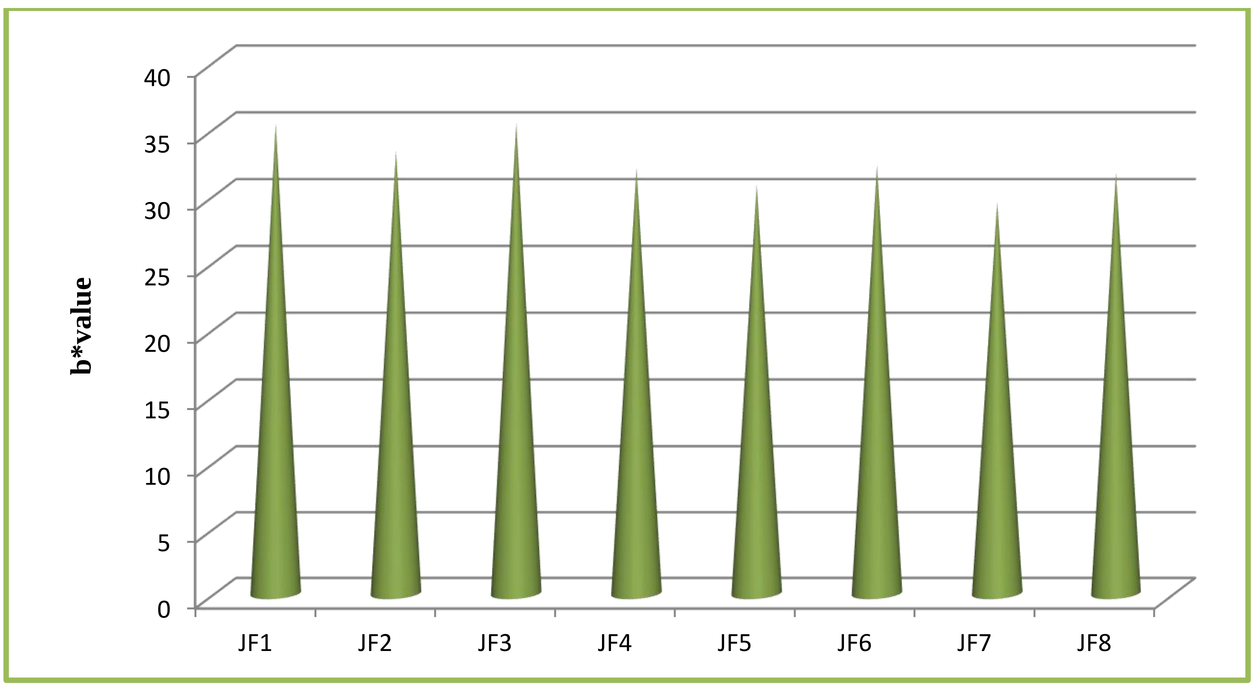

Fig4.11 Changes in b* value of VF-jackfruit with process parameter

4.2.5 Textural Changes

The effect of process parameters on texture in VF-jackfruit chips is highly significant. The hardness value of VF-jackfruit chips with different frying parameters is shown in Fig 4.12. From fig, it is understood that hardness value of VF-jackfruit chips increased with frying temperatures. Hardness value of vacuum fried chips ranged between 1.01N to 2.37 N at different frying temperature (100ºC and 110ºC), frying pressure (9 and 12kPa) and frying time (18 and 20 min). The lower hardness value of 1.01 N was noted in VF-jackfruit chips at frying condition of 100ºC, 9 kPa and 18 min (JF1). The higher hardness value of 2.37 N was observed in VF-jackfruit chips at frying condition of 110ºC, 12 kPa and 20 min (JF8). In case of the VF- jackfruit chips, the hardness value was inversely proportional to the crispiness. The hardness value was high at higher temperature during frying and this is due to loss of moisture. Similar results were observed for increased hardness value of vacuum fried banana chips at 120ºC for 14 min (Yamsaengsung *et al.*, 2011) and vacuum fried potato chips at 144ºC (Garayo and Moreira, 2002).

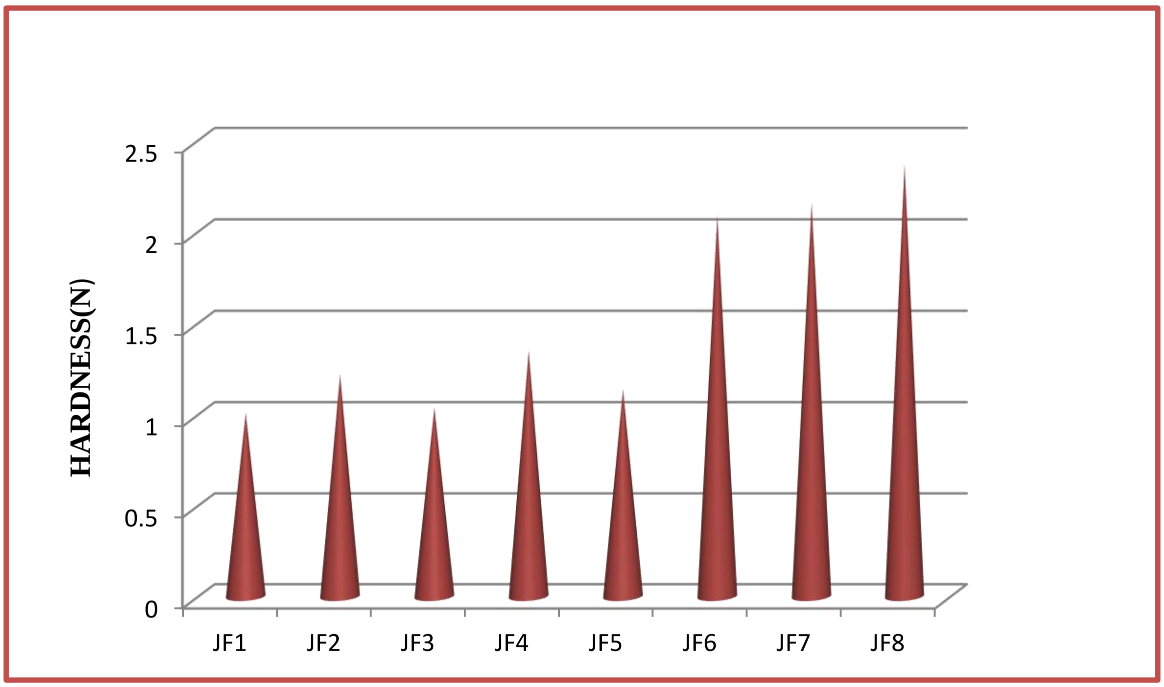

Fig4.12 Changes in hardness value of VF-jackfruit with process parameter

4.3 OPTIMIZATION OF PROCESS PARAMETERS FOR THE PRODUCTION OF VACUUM FRIED JACKFRUIT CHIPS

Different quality attributes such as moisture content, water activity, oil content, hardness, colour changes, energy content and acrylamide content of vacuum fried jackfruit chips were analysed in the study. 8 different combinations of temperature, time and pressure were taken and aforesaid quality attributes were studied. Of these JF3 sample fried at 100ºC, 9 kPa and 20 min gave better result in terms of quality and were considered for storage studies

EXPERIMENT III

4.4 STORAGE STUDIES OF VF-JACKFRUITCHIPS

Storage studies were conducted for 90 days to optimize a suitable packaging material among the existing packaging materials *viz.*, low density polyethylene (stand up pouch), laminated aluminum pouch (one side silver other side transparent), retort pouch. The chips prepared at frying temperature (100ºC), frying pressure (9 kPa) and frying time (20 min) were selected for the study. The packaging materials were optimized based on the quality parameters of VF- jackfruit chips during storage.

4.5 EFFECT OF DIFFERENT PACKAGING MATERIALS ON QUALITY PARAMETERS OF VACUUM FRIED JACKFRUITCHIPS DURING STORAGE

The quality parameters like moisture content, hardness, water activity and colour values were evaluated for 90 days with every 30 days interval.

4.5.1 Moisture Content

The effect of different packaging materials on moisture content of vacuum fried jackfruit chips is displayed in Fig.4.13. The moisture content of stored chips packed in low density polyethylene (LDPE) pouches, laminated aluminum pouches and retort pouches increased from 0.501 to 15.27%, 0.501% to 8.73% and 0.501%to 3.52% at 0^{th} day to 90^{th} days of storage, respectively. The moisture absorption of vacuum fried jackfruit chips packed in retort packaging found to be significantly low compared to other packaging materials during storage. The obtained moisture content was conformation with the results on deep fat frying of jackfruit chips (Sathish Kumar *et al.,* 2016).

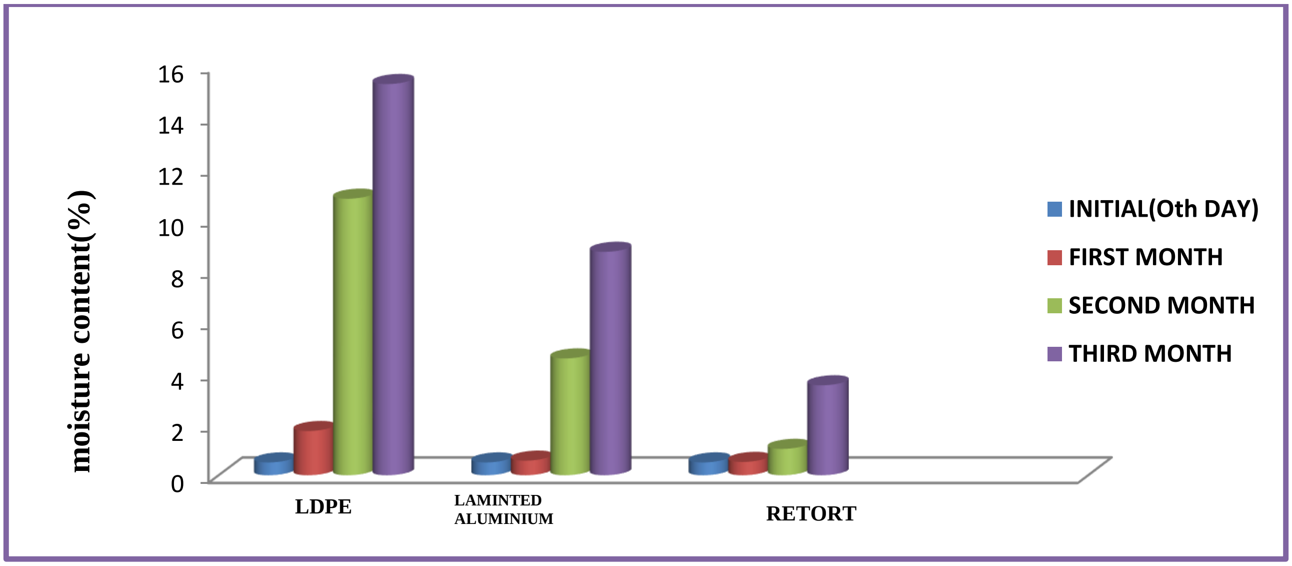

Fig. 4.13 Effect of different packaging material on moisture content of vacuum fried jackfruit chips

4.5.2 Water Activity

The effect of different packaging material on water activity of vacuum fried jackfruit chips is represented in Fig. 4.14. The water activity of the vacuum fried chips stored at 0^{th} day of packaging was 0.487. During storage period, the water activity in low density polyethylene(LDPE) pouches, laminated aluminium pouches and retort pouches increased from 0.487 to 0.725, 0.487 to 0.688, and 0.487to 0.591at 0_{th} to 90^{th}days of storage, respectively. The water activity of vacuum fried jackfruit chips had increased significantly in all packaging materials, except retort pouches.

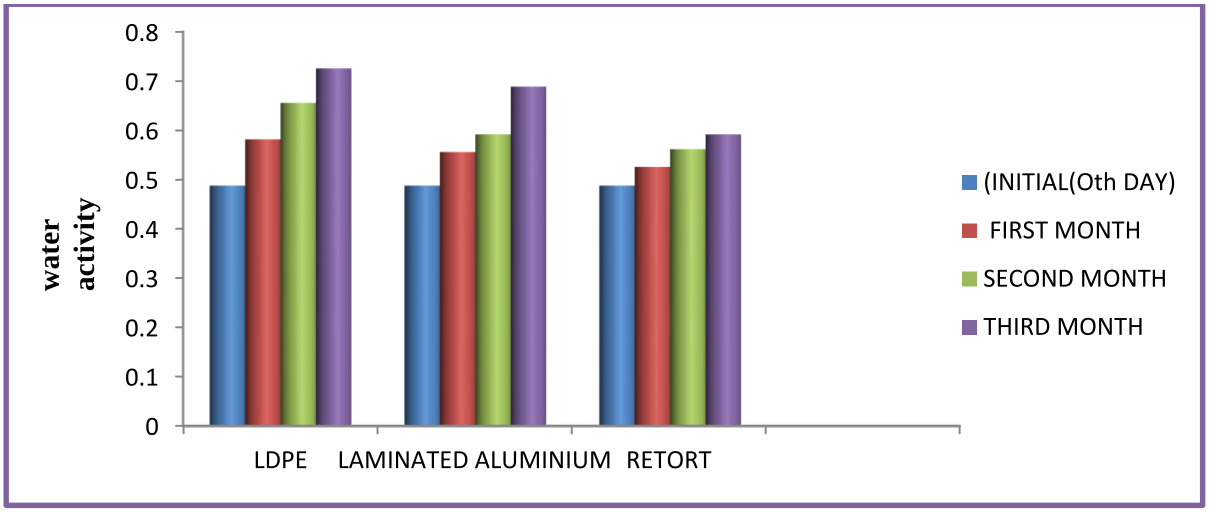

Fig. 4.14 Effect of different packaging material on water activity of the vacuum fried jackfruit chips

4.5.3 Hardness

The effect of different packaging material on hardness of vacuum fried jackfruit chips is shown in Fig. 4.15. The higher hardness value indicated the lowest crispy product. During storage period, hardness value increased due to water absorption. The hardness value of the vacuum fried jackfruit chips in low density polyethylene (LDPE) pouches, laminated aluminium pouches and retort pouches at 0^{th} day and 90^{th} days of packaging were 1.24 N, 1.24N, 1.24N and 2.99 N, 2.71N, 1.78N, respectively. The hardness value was high in laminated aluminium packaging and LDPE compared to retort pouches. On 90_{th} day lower hardness value of 1.78 N was recorded on retort pouches due to less water absorption. The same phenomena were observed by Molla *et al.,* (2008) for deep fat fried jackfruit chips.

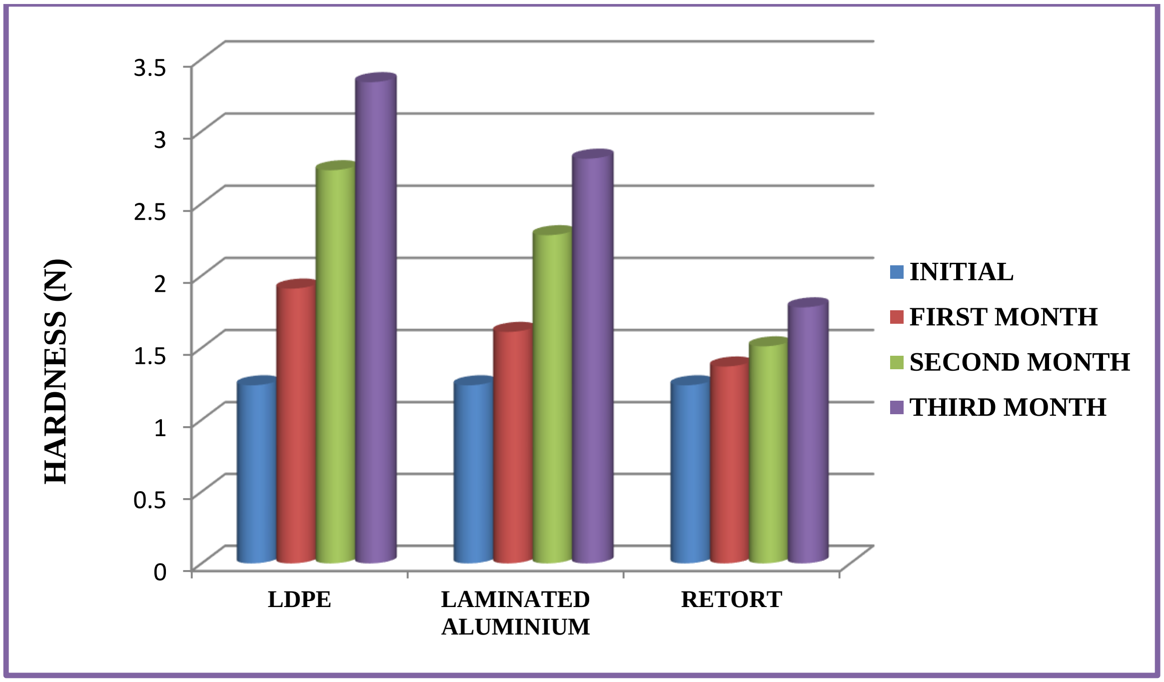

Fig 4.15 Effect of different packaging material on hardness of the vacuum fried jackfruit chips

4.5.4 Colour Values

The L* values of vacuum fried jackfruit chips during storage were graphically represented in Fig.4.16. During storage period,the L* values in low density polyethylene (LDPE) pouches, laminated aluminium pouches and retort pouches decreased from 69.18 to 47.03, 69.18 to 49.27 and 69.18 to 59.65during 0^{th} to 90^{th} days of storage, respectively. The L* value of vacuum fried jackfruit chips were significantly decreased in all packaging materials. Retort packaging found to be good as compared to other packaging material due to less variation of L* value. The effect of different packaging material on a* values of vacuum fried jackfruit chips is illustrated in Fig.4.17. The initial a* value of 2.73 was increased to 10.32, 10.77 and 7.53 in LDPE pouches, laminated aluminum pouches and retort pouches, respectively during the storage period of 90 days. The corresponding b* values in LDPE pouches, laminated aluminum pouches and retort pouches were 35.35 to 30.87, 35.35 to 33.72 and 35.35 to 34.77, respectively .From the graph, it is understood that the colour values of samples packed in retort pouches showed less variation with respect to storage period.

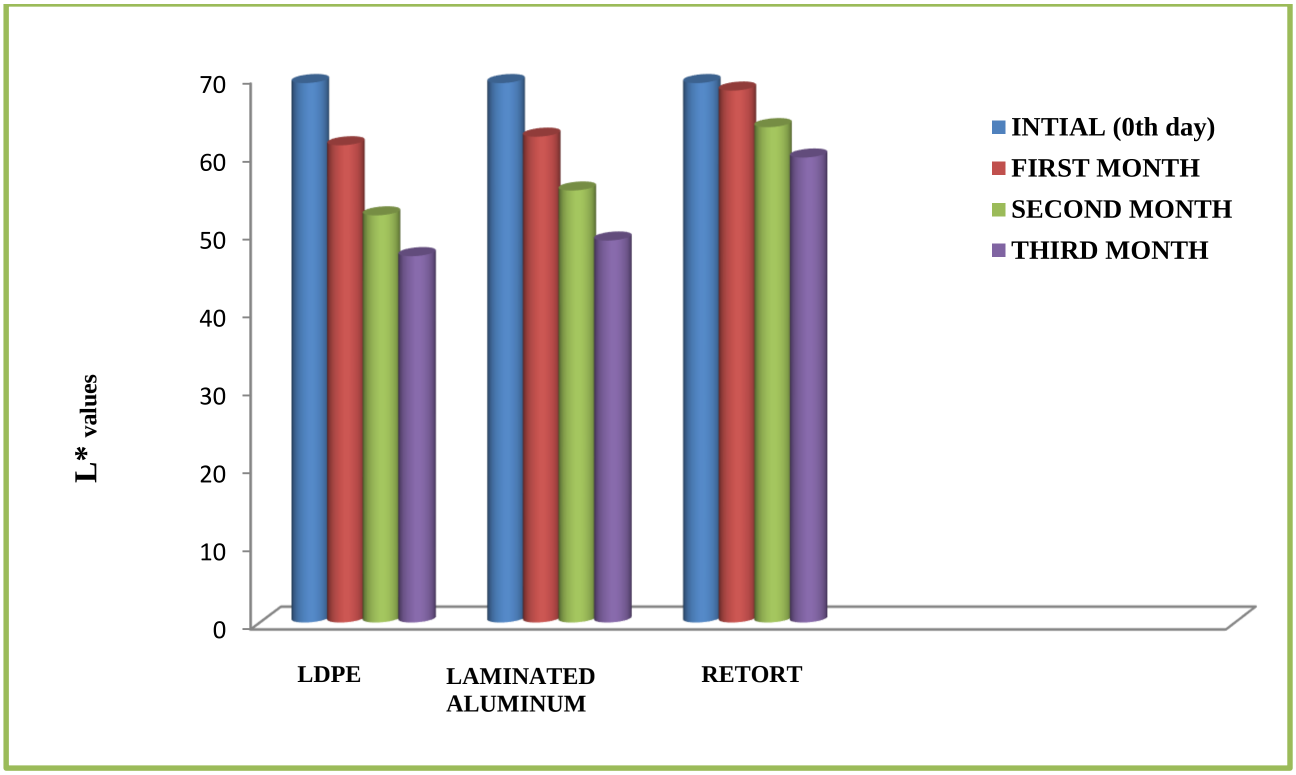

Fig.4.16 Effect of different packaging material on L* values of vacuum fried jackfruit chips

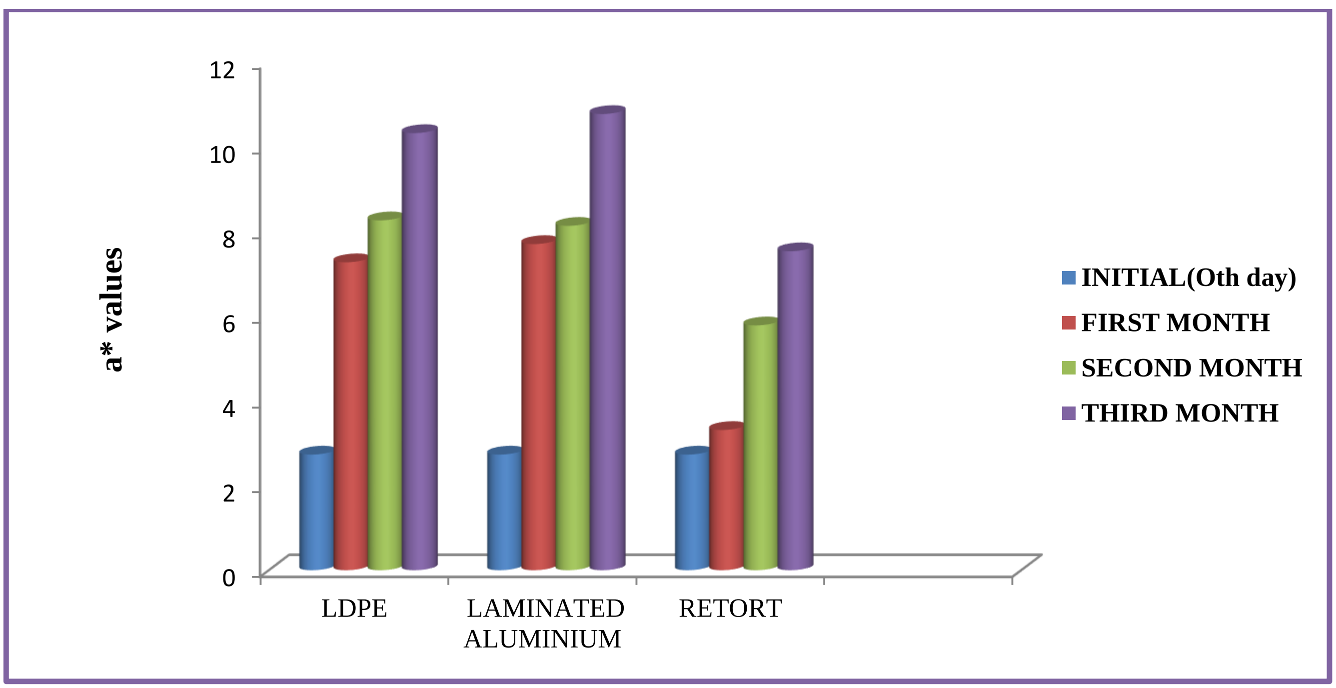

Fig 4.17Effects of different packaging materials on a* values of vacuum fried jackfruit chips

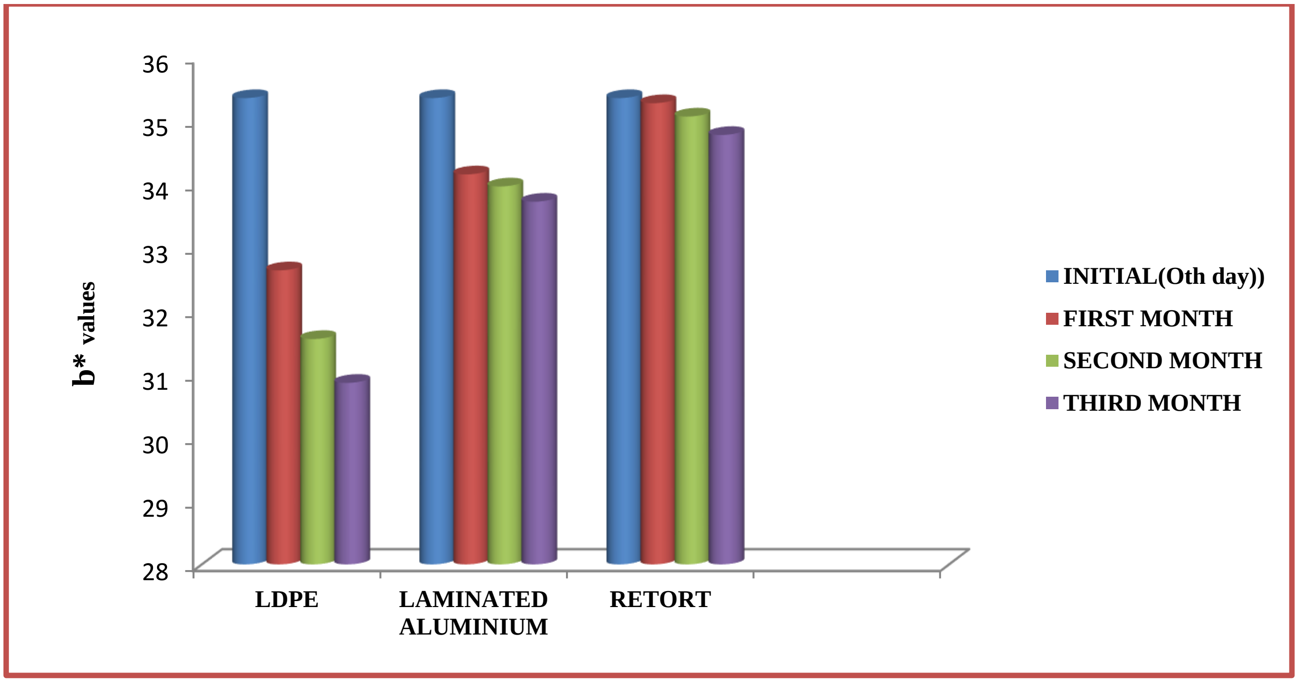

Fig 4.18 Colour values of b* of vacuum fried jackfruit chips with different packaging materials

4.5.5 Bulk Density And True Density

The bulk density of the vacuum fried jackfruit chips during storage is depicted in Fig. 4.19. During the storage period from 0 to 90 days, the bulk density of samples ranged from 0.43 to 0.687g/cm^3. The variation of bulk density value is due to the moisture absorption. Bulk density value of samples packed in LDPE and laminated aluminum pouches were higher than that in retort pouches. The true density of vacuum fried jackfruit chips during storage period is represented in Fig. 4.20. The true density values of stored samples increased from 0.679 and 0.985 g/cm^3.The true density of stored samples increased with increase in storage days. The results were confirmed by Maneerote *et al.*, (2009) regarding the storage of vacuum fried potato chips.

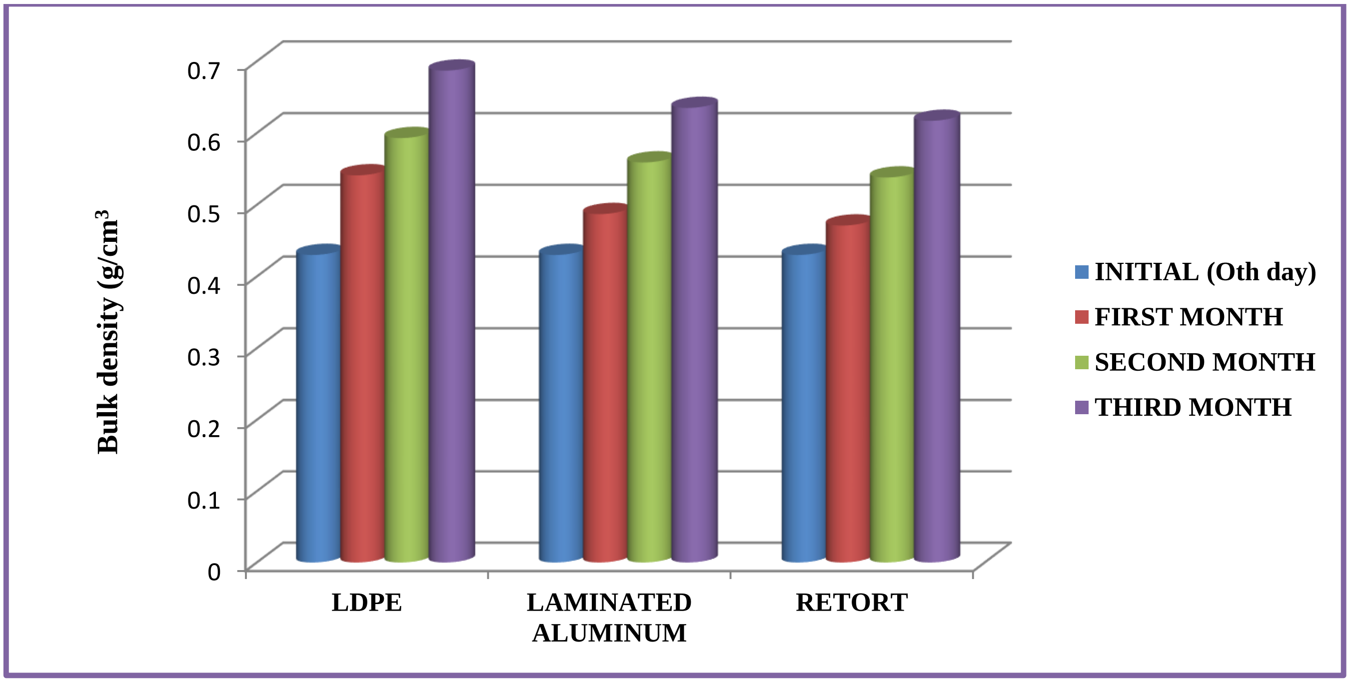

Fig4.19 Effect of different packaging material on bulk density of the vacuum fried jackfruit chips

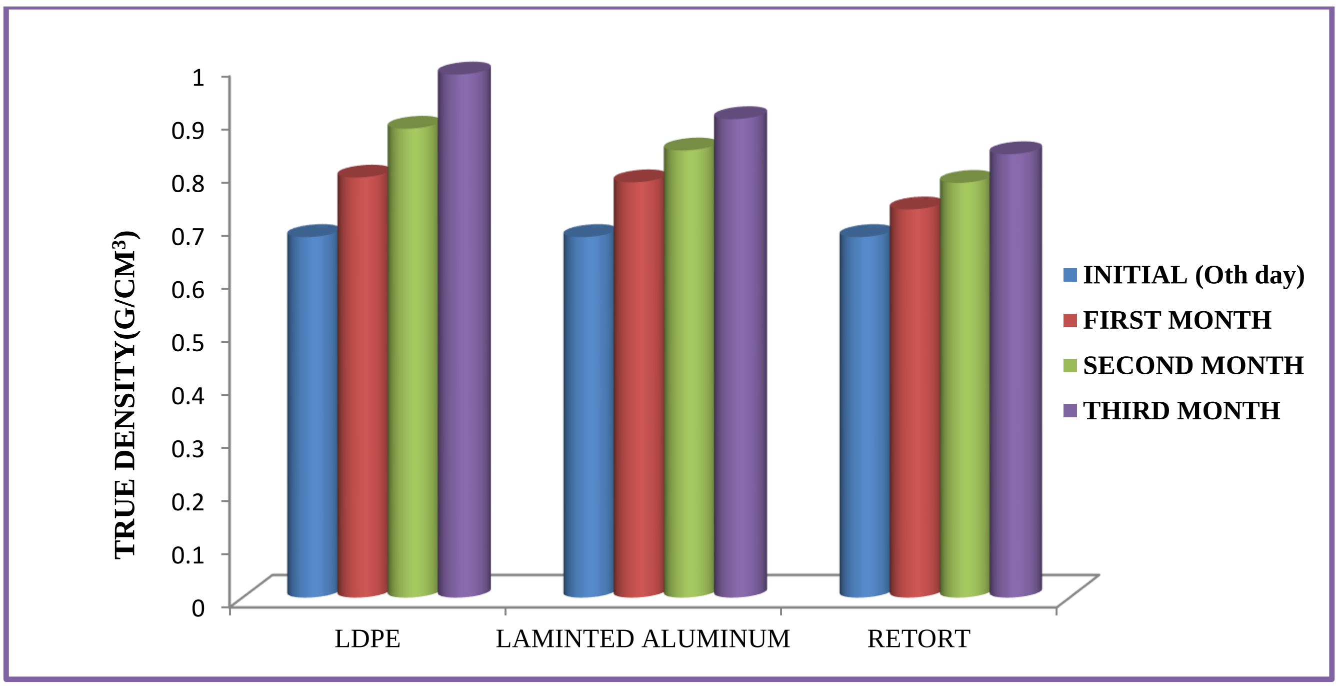

Fig4.20 Effect of different packaging material on water true density of the vacuum fried jackfruit chips

Storage studies were conducted in three different packages. They were low density polythene (LDPE), laminated aluminium pouches, and retort pouches. Of these the fried products stored in retort pouches had the longest storage period. It could retain its textural and other quality parameters (moisture content, water activity, hardness, color values, bulk density and true density) for more than 90 days.

4.6 CHANGES IN THE TOTAL POLAR COMPOUNDS OF BLENDED OIL DURING VACUUM FRYING

The blends of rice bran and coconut oil were evaluated for total polar compounds after its repeated use for several batches of vacuum frying. After every batch of vacuum frying, the product properties was analyzed during the optimization of the process parameters of jackfruit chips. Similarly, after every batch of frying, oil was tested for its total polar compound evaluation. The determination of total polar compounds in frying oil contributes the most important measure of the extent of oxidative deterioration. The total polar compound is important oil quality parameter and it is easily measurable property to decide the usability of oil. Total polar compound was determined after every batch of vacuum frying (100^{o}C ,9KPa for 20 min) after cooling. The threshold level of TPC in edible oil was 25-27%. The TPC of blended oil was increased from 9.3% to 14.5% after 30th batch of vacuum frying, which is well below the threshold limit. This made help to recommended for reuse the oil upto 30 times of vacuum frying. The increased in the extent of polar compounds in the oil indicates the formation of compounds such as triacylglycerols, secondary oxidation of oil (Latha and Nasirullah, 2011)

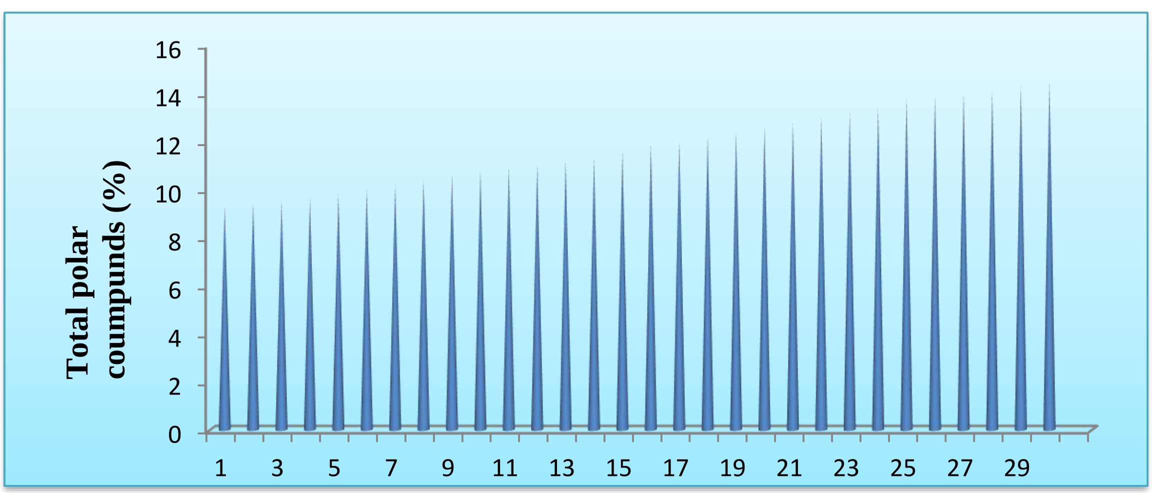

Fig 4.21 Changes of the total polar compounds during vacuum frying

Summary And Conclusion

CHAPTER V
SUMMARY AND CONCLUSION

Jackfruit (*Artocarpus heterophyllus*L.*)* is the largest edible fruit in the world and is the national fruit of Bangladesh. Jackfruit, which was considered as heavenly fruit in ancient people of Kerala, has lost its status and it is one of the under exploited fruits of the state today. It is a rich source of vitamins A, B and C, potassium, calcium, iron, proteins, and carbohydrates and offers numerous health benefits. The fruit's isoflavones, antioxidants and phytonutrients has cancer-fighting properties. It is also known to help cure ulcers and indigestion. The exterior of the fruit is pale green or yellow when ripe. There are two main varieties-*Koozha*chakka and *Varika*chakka. In *Koozha*chakka, the fruits are small, fibrous, soft and mushy, but very sweet carpals. *Varikapazham* is crisp and almost crunchy though not quite as sweet. *Varika* is more important commercially and is more palatable to western tastes. Unripe jackfruits are cooked as vegetables and ripe jackfruit is eaten raw. But a major constraint regarding jackfruit consumption is its limited availability to four to five months. For its extension of storage life and yearlong availability and utilization, many methods of processing are being used since ancient times. Though jackfruit is produced in large quantities, the income derived from jackfruits is minimal due to wastage of this fruit during post-harvest value chain. In jackfruit, the total postharvest losses is estimated approximately 43.5% of the total production (Ahmmad *et.al.,* 2010).

Value addition techniques have a great scope in jackfruit. There are so many value added products of jackfruit *viz.,* chips, pickles, curries, powder and medicinal products that demand a wide marketing scope due to the consumer accessibility in terms of texture and health aspects. At present, fried snacks industry has developed as one of the prime sectors for modern consumers. Deep fat fried products have a key share in snack food production sector and have a better place in traditional celebrations of our country. Due to its unique flavour and texture, it is preferred by all age group people. Deep fat frying is a cooking method in which the food material is submerged in an oil bath. The high oil uptake during frying associates with several health problems *viz.,* hypertension, heart disease, obesity etc. The degradation of oil quality during deep fat frying poses threat to consumer's health. Also, the traditional frying method is not feasible for ripened jackfruit due to higher sugar content. Higher frying temperature causes charring of fruit and negligible moisture removal from fruit. Vacuum frying is a novel technology that fulfills all these objectives. Vacuum frying technology is a promising alternative frying technology to improve the quality of fried products. During vacuum frying, the sample is heated under a negative pressure (9kPa) that lowers the boiling and smoking points of water and oil (Troncoso *et al.*, 2009). The unbound water in the fried food could be rapidly removed when oil temperature reach the boiling point of water. The products of vacuum frying have greater resemblance to the natural jackfruit in terms of nutritional qualities and color. The absence of air during frying inhibits lipid oxidation and enzymatic browning thus preserving the colour and nutrients of sample. Also, the formation of acrylamide, a potential carcinogenic agent could be reduced to negligible amount by adopting vacuum frying technology. Frying under vacuum, reduce the oil retention which offers less oily taste without compromising natural colour, flavour and nutrients of the products. Jackfruit chips are prepared from mature and ripen jackfruits. The current investigation on "Development and evaluation of vacuum fried jackfruit (*Artocarpus heterophyllus*) chips" and was under taken in the Department of Processing and Food Engineering, KCAET, Tavanur. Our study was to check the feasibility of vacuum frying in ripened jackfruit chips which contain high moisture and to evaluate the process and product parameters and storage considerations.

Vacuum fryer is the machine used for vacuum frying. Two types of vacuum fryers are currently in use. They are continuous type vacuum fryers and batch type vacuum fryers. We did our project in a batch type vacuum fryer developed in KCAET campus under the project "Development and Evaluation of a vacuum frying system for Banana Chips (Musa Spp.)" by Ranasalva and Sudheer K P. The vacuum frying system consists of two chambers i.e. frying and oil storage chamber. Frying chamber and oil storage chamber were made of stainless steel (SS 316) and chambers were provided with heaters of 3 kW and 1.5 kW. Vacuum frying system was controlled by a microprocessor and PID (Proportional Integral Derivative) controller. A de-oiling system consisted of 0.5 hp motor (Make: Prime motors, India) with 6 poles and rotates at 1000 rpm. The frying basket holder was fastened with a screw mechanism to contain the frying basket during frying and de-oiling.. The pressure was maintained by using 2 hp water ring vacuum pump (Make: Sabara, India) of 30 m3/kg capacity. Nitrogen gas was used to maintain the oil quality, as creation of pressure gradient using air enhances the chance of oxidative rancidity. The cooling system included a cooling tower of 10 L capacity attached with 1 hp water pump. The vacuum frying process include four stages: depressurization, frying and de-oiling, pressurization, and cooling (Ranasalva and Sudheer KP 2017).

Standardization different pre-treatments were done by comparing the products obtained by blanching (1 min water blanching at 80ºC), drying (at 75ºC) and freezing with control sample. The blended oil (rice bran and coconut oil, 80:20) was used as frying oil and de-oiling was carried out at 1000 rpm for 5 min. The control (un-treated) vacuum fried jackfruit chips had an oil content (33.35

%), moisture content (0.501%), water activity (0.487), hardness (1.04 N), L* (69.18), a* (2.73) and b* (35.35). Considering all the results of quality parameters control (un-treated) sample had found the best results and further optimization of process parameters was carried out by using control sample.

Optimizations of process parameters were done for two different combination of temperature (100 and 110ºC), pressure (9, and 12 kPa) and time (18 and 20 min) under the centrifugation speed of 1000 rpm for 5 min for all treatments. This experiment was done by using completely randomized design with 8 treatments in 2 replications for vacuum fried jackfruit chips. The frying conditions affected the product parameters of vacuum fried jackfruit chips. The vacuum fried jackfruit chips at 100ºC, 9 kPa for 20 min had good results having an oil content (20.73%), hardness (1.04N), water activity (0.473), moisture content (0.481%), L* (70.18), a* (2.71) and b* (35.41).

Packaging and storage studies were conducted for the vacuum fried jackfruit chips prepared at optimized condition. The different packaging materials selected for the study were, low density polyethylene (stand up pouch), laminated aluminium pouch (one side silver other side transparent) and retort pouch. The samples were packed under active MAP(nitrogen filling) and kept it for a period of 90 days .During storage, moisture content, water activity, hardness got increased and colour values decreased with increase in storage period. The samples stored under retort pouch was found to be the best followed by laminated aluminium pouch. The cost of production of vacuum fried jackfruit chips and cost benefit ratio were Rs.617.54/- per kg and 2.83:1, respectively. The TPC of blended oil was increased from 9.3% to 14.5% after 30th batch of vacuum frying, which is well below the threshold limit.

Based on the results following conclusions were made:

- ✓ Vacuum frying technology is a promising technology for production of jackfruit chips.
- ✓ The control (un-treated) VF-jackfruit chips had better quality attributes compared to other pretreated jackfruit chips.
- ✓ The process conditions at 100ºC and 9 kPa for 20 min has produced novel healthy snacks with low oil content.
- ✓ The retort packaging with band sealing was found to be the best for storing vacuum fried jackfruit chips.
- ✓ The storage life of vacuum fried jackfruit chips was estimated as 90 days.
- ✓ Cost of vacuum fried jackfruit chips was found to be Rs. 617.54/- per kg

Future line of work

- Conduct the packaging studies with other different packaging materials for vacuum fried jackfruit chips
- To develop a batch type vacuum fryer with less initial investment for small scale industries.
- To check the feasibility of vacuum frying for other fruits and vegetables with high moisture content.

References

REFERENCES

Abbas-Ali, M., Hassan-Ali, A.N., Latip, R.A., Othman, N.H., Majid, F.A.A., and Salleh, L.M.2013.Effect of heating at frying temperature on the quality characteristics of regular and high-oleic acid sunflower oils.*Act. Sci. Pol. Technol. Aliment*. 12(2): 159-167.

Abdel-Monem, S.A.I., Ali, R.F.M., Askar, M., and Samy, M.W. 2013.Impact of pre-treatments on the acrylamide formation and organoleptic evolution of fried potato chips.*Am. J. Biochem. Biotech*.9(2): 90-101**.**

Abdel-Razek, A.G., Ragab, G.H., and Ali, H.S. 2012 Effect of pretreatments and frying time on physical and chemical properties of cottonseed oil.*J. Appl. Sci. Res*. 8(11): 5381-5387.

Abdulla, G., Gehan, A., Shourbagy, E., and Sitohy, Z.M. 2013.Effect of pre-drying, blanching and citric acid treatments on the quality of fried sweet potato chips.*Am. J. Food Technol*. 9(1): 39-48.

Afjeh, F.A., Bassiri, A., and Nafchi, A.M. 2014. Optimization of vacuum frying parameters in combination with osmotic dehydration of kiwi slices to produce healthy product. *J. Chem. Hlth. Risks*.4(1):13–22.

Ahromrit, A. and Nema, P.K. 2010.Heat and mass transfer in deep-frying of pumpkin, sweet potato and taro.*J. Food Sci. Technol.* 47(6): 632-637.

Albert, S. and Mittal, G.S. 2002.Comparative evaluation of edible coatings to reduce fat uptake in a deep-fried cereal product.*Food Res. Int.* 35: 445-458

Amany-Basuny, M.M., Shaker-Arafat, M., and Azza-Ahmed, A.A. 2012. Vacuum frying: An alternative to obtain high quality potato chips and fried oil. Glo. Adv. Res. J. Microbiol. 1(2): 019-026..

Association of Official Analytical Chemists (AOAC). 1980. *Official Methods of Analysis*, *31th ed.* Washington, DC.

Association of official analytical chemists (AOAC). 2005. Official Methods of Analysis of the AOAC International. 18th edn. Gaithersburg, MD, USA.

Barua, I., Sahin, S., and Sumnu, G. 2009. Acrylamide formation in different batter formulations during microwave frying.*Food Sci. Technol*. 42: 17–22.

Bekas, W., Kowalska, D., and Kowalski, B. 2006. Acrylamide in commercial potato chips from warsaw market. *Polish J. Food Nutr. Sci*. 56(4): 391-394.

Blumenthal, M.M. and Stier, R.F. 1991. Optimization of deep-fat frying operations.*Trends Food Sci. Technol.* 2: 144-148.

Bognar, A. 1998.Comparative study of frying to other cooking techniques influence on the nutritive value.*Grasas. Y. Aceites*. 49(4): 250-260.

Bordin, K., Kunitake, M.T., Aracava, K.K., and Trindade, C.S. 2013.Changes in food caused by deep fat frying.*Arch. Latino Am. nutr*.63(1): 2013.

Borse, V.H. and Mishra, A.A. 2014. Studies on effect of different frying temperatures on physico-chemical properties of bitter gourd chips.*Int. J. Res. Eng. Adv. Technol.* 2(3): 2320 – 8791.

Brncic, S.R., Lelas, V., Rade, D., and Simundic, B. 2004. Decreasing of oil absorption in potato strips during deep fat frying.*J.Food. Eng.* 64: 237–241.

Carla, V. Y. and Moreira, R. G. 2011.Physical and thermal properties of potato chips during vacuum frying.*J. Food Eng.* 104: 272-283.

Charlie, E. and Min D.B., Fruit and vegetable production in India.Asian J. Food Agric. Ind. Special Issue. S 318- S 324

Chatzilazarou, A., Gortzi, O., Lalas, S., Zoidis, E., and Tsaknis, J. 2006. Physicochemical changes of olive oil and selected vegetable oils during frying. *J. Food. Lipids*. 13: 27–35.

Daniali, G., Jinap, S., Zaidul, S.I.M., and Hanifah, N.L. 2010. Determination of acrylamide in banana based snacks by gas chromatography-mass spectrometry. *Int. Food Res. J.* 17: 433-439.

Da-Silva, P.F. and Moreira, R.G. 2008.Vacuum frying of high-quality fruit and vegetable-based snacks.*Food Sci. Technol*. 41: 1758-1767.

Debnath, S., Rastogi, K.N., Krishna, A.G., and Lokesh, B.R. 2012. Effect of frying cycles on physical, chemical and heat transfer quality of rice bran oil during deep-fat frying of poori: An Indian traditional fried food. *Food Bioproducts Processing*.90: 249–256. .

Dehghannya, J., Enayat-Allah, N., and Ghanbarzadeh, B. 2015.Frying of potato strips pre-treated by ultrasound-assisted air-drying.*J.Food Processing Preservation.*1-10.

Deshpande, H.W. and Poshadri, A. 2011. Physical and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours. *Int. Food Res. J.* 18: 751-756.

Diamante, L. M., Press-wood, H. A., Savage, G. P., and Vanhanen L. 2011. Vacuum fried gold kiwifruit: Effects of frying process and pre-treatment on the Physico-chemical and nutritional qualities. *Int. J. Food Res*. 18: 632-639.

Diamante, L. M., Savage, G.P., and Vanhanen, L. 2012.Optimisation of vacuum frying of gold kiwifruit slices: application of response surface methodology. *Int. J. Food Sci. Technol*. 47: 518–524.

Diamante, L.M., Savage, G.P., Vanhanen, L., and Ihns, R. 2011. Vacuum-frying of apricot slices: effects of frying temperature, time and maltodextrin levels on the moisture colour and texture properties. *J. Food Processing Preservation*: 1745-4549.

Diamante, L.M., Shi, S., Hellmann, A., and Busch, H. 2014. Vacuum frying foods: products, process and optimization. *Int. Food. Res. J*. 22(1): 15-22.

Din, A., Bukhari, S.A.H., Salam, A., and Ishfaq, B. 2011. Development of functional and dietetic beverage from bitter gourd.*Internet J. Food Safety*. 13: 355-360.

Dueik, V. and Bouchon, P. 2011. Vacuum frying as a route to produce novel snacks with desired according to quality attributes according to new health trends. *J. Food Sci.* 76 (2): 188-195.

Dueik, V., Robert, P., and Bouchon, P. 2010. Vacuum frying reduces oil uptake and improves the quality parameters of carrot crisps. *Food Chem.* 119: 1143-1149.

Efird, J.T., Choi, Y.M., Davies, S.W., Mehrao, S., Anderson, E.J., and Katunga, L.A. 2014. Potential for improved glycemic control with dietary momordicacharantia in patients with insulin resistance and pre-diabetes.*Int. J. Environ. Res. Public Hlth.*11: 2328-2345.

Ekanayake, S., Jansz, E.R., and Nair, B.M. 1999. Proximate composition, mineral and amino acid content of mature canavalia gladiate seeds. *Food Chem*. 66: 115-119.

Esana, T.A., Sobukolaa, O.P., Sannia, L.O., Bakareb, H.A., and Munoz, L. 2015. Process optimization by response surface methodology and quality attributes of vacuum fried yellow fleshed sweet potato (*Ipomoea Batatas L.)* chips. *Food Bioproducts Proc*. 95: 27-37.

Fan, H. Y., Sharifudin, M. S., Hasmadi, M., and Chew, H. M. 2013.Frying stability of rice bran oil and palm olein.*Int.Food. Res. J*. 20(1): 403-407.

Fan, L.P., Zhang, M., and Mujumdar, A.S. 2006.Effect of various pre-treatments on the quality of vacuum-fried carrot chips.*Drying Technol*. 24: 1481–1486.

Fan, L.P., Zhang, M., and Mujumdar, A.S. 2007.Storage Stability of Carrot Chips.*Drying Technol*. 25: 1537–1543.

Fan, L.P., Zhang, M., Gong-nian, X., Jin-cai, S., and Tao, Q. 2005.The optimization of vacuum frying to dehydrate carrot chips.*Int. J. Food Sci. Technol*. 40: 911-919.

Farhoosh, R., Kenari, R.E., and Poorazrang, H. 2009. Frying stability of canola oil blended with palm olein, olive, and corn oils. *J. Am. Oil Chem. Soc.* 86: 71–76.

Farkas, B.E. and Hubbard, L.J. 2000.Analysis of convective heat to transfer during immersion frying.*Drying Technol*. 18(6): 1269-1285.

Fisher, R.A. and Feynman, R.P. 2007. Completely Randomized Designs.*J. Hist. Biol.* 40(2): 295-325.

Fontana, A.J. 1998. Water activity: why it is important for food safety. *In Proceedings of the 1st NSF International Conference on Food Safety*.pp.177–185.

Freitas, D.G.C., Shirley, A.G.B., Patricia, P., Farayde, M.F., Fernanda, P.C.Q., and Vicente, E. 2009.Reducing of fat uptake in cassava product during deep-fat frying.*J. Food Eng*. 94: 390-394.

Gadiraju, T.V., Patel, Y., Gaziano, J. M., and Djousse, L. 2015. Fried food consumption and cardiovascular health: A review of current evidence. *Nutrients*. 7: 8424–8430.

Garayo, J. and Moreira, R. 2002. Vacuum frying of potato chips.*J. Food Eng.* 55: 181–191.

García-Segovia, P., Urbano-Ramos, A.M., Fiszman, S., and Martínez-Monz, J. 2016. Effects of processing conditions on the quality of vacuum fried cassava chips (*ManihotesculentaCrantz*). *Food Sci. Technol.* 69: 515-521.

Garmakhany, A.D., Aghajani, N., and Kashiri, M**.** 2011. Use of hydrocolloids as edible covers to produce low fat French fries.*Latin. Am. Appl. Res*. 41:211-216.

Gharachorloo, M., Ghavami, M., Mahdiani, M., and Azizinezhad, R. 2010.The effects of microwave frying on physicochemical properties of frying and sunflower oils.*J. Am. Oil Chem. Soc.* 87: 355–360.

Gopala Krishna, A.G., Khatoon, S., and Babylatha, R. 2005.Frying performance of processed rice bran oils*. J. Food Lipids.* 12: 1–11.

Goswami, G., Bora, R., and Rathore, M.S. 2015. Oxidation of cooking oils due to repeated frying and human health. *Int. J. Sci. Technol. Manag*. 4(1).495-501.

Granda, C. and Moreira, R.G. 2005.Kinetics of acrylamide formation during traditional and vacuum frying of potato chips.*J. Food.Process. Eng*. 28: 478–493.

Granda, C., Moreira, R.G., and Tichy, S.E. 2004. Reduction of acrylamide formation in potato chips by low-temperature vacuum frying. *J. Food Sci*. 69: 405-411.

Guillén, M.D. and Uriarte, P.S. 2012. Simultaneous control of the evolution of the percentage in weight of polar compounds, iodine value, and acyl groups proportions and aldehydes concentrations in sunflower oil submitted to frying temperature in an industrial fryer. *Food Control*. 24: 50-56.

Gupta, M., Sharma, S., Ajay, K., Gautam., and Bhadauria, R. 2011. Momordicacharantialinn. (Karela) natures silent healer. *Int. J. Pharma. Sci. Rev. Res.* 11(1): 32-37.

Gutierrez, R., Gonzalez, O., and Dobarganes, M. C. 1988. Analytical procedures for the evaluation of used frying fats. In: Frying of Food: Principles, Changes, New Approaches (G. Varela, A. E. Bender and I. D. Morton, Eds.). Ellis Horwood Series in Food Science and Technology, Chichester, U.K. p.141-154.

Hasimah, H.A., Zainon, I., and Norbaiti, B. 2011. Effect of pre-treatments on sensory characteristics of vacuum fried pineapple snack - a preliminary investigation. *Int. Soc. Hortic. Sci*. 555-558.

Hong-Wei, X., Pan, Z., Li-Zhen, D., El-Mashad, H.M., Xu-Hai,Y., Mujumdar, A.S., Zhen-Jiang, G., and Zhang, Q. 2017. Recent developments and trends in thermal blanching – A comprehensive review.*Inf.Processing. In. Agric*. 4: 101–127.

Illeperuma, C.K. and Jayasuriya, P. 2002. Prolonged storage of karuthacolomban mango by modified atmosphere packaging at low temperature.*J.Hortic. Sci. Biotechnol.* 77 (2).153-157.

Ismed. 2016. Effect of frying time and temperature on characteristics of carrot (DaucusCarota, L.) chips using vacuum frying. *Int. J. Adv. Res.* 4(11): 348-353.

Jaya, S. and Das, H. 2003. Sensory evaluation of mango drinks using fuzzy logic. *J. Sensory Stud*. 18: 163-176.

Jorge, M.B., Rosa, O., and Salvador, L.M. 2012. Influence of temperature on heat transfer coefficient during moderate vacuum deep-fat frying. *J. Food Eng*. 113: 167-176.

Joseph, B. and Jini, D. 2013. Antidiabetic effects of bitter melon (*Momordicacharantia*) and its medicinal potency.*Asian. Pacif. J. Trop. Dis*. 3(2): 93-102.

Karthickumar, P., Ranasalva, N., and Jeyan, A.M. 2015. The technology of blending edible oils.*Beverage Food World*. 42(12): 29-30.

Kaushik, N., Gondi, A.R., Rana, R., and Rao, P.S. 2015. Application of fuzzy logic technique for sensory evaluation of high pressure processed mango pulp and litchi juice and its comparison to thermal treatment. *Innovative Food Sci. Emerging. Technol*. 32: 70–78.

Kawas, M.L. and Moreira, R.G. 2001. Effect of degree of starch gelatinization on quality attributes of fried tortilla chips. *J. Food Sci*. 66(2): 300-306.

Khan, M.I., Asha, M.R., Bhat, K.K., and Khatoon, S. 2008. Studies on quality of coconut oil blends after frying potato chips.*J. Am. Oil. Chem. Soc*. 85: 1165–1172.

Kharel, G.P. and Khanal, D. 2002.Drying optimization and storage stability of bitter gourd *(Momordicacharantia*L).*J. Sci. Technol*. 4: 83-86.

Kim, D.N., Lima, J., Bae, I.Y., Lee, H.G., and Lee, S. 2011. Effect of hydrocolloid coatings on the heat transfer and oil uptake during frying of potato strips.*J. Food Eng.* 102: 317-320.

Krishnankutty, S., Varkey, G.A., Bhat, A.V., Dhanaraj, S., and Shanthi, N. 1981. Packaging and storage studies of deep fat fried Nendran banana chips. J *Food Sci. Technol.* 18: 104-108.

Kusucharid, C., Jangchud, A., and Thamakorn, P. 2009. Changes in characteristics of palm oil during vacuum and atmospheric frying conditions of sweet potato.*Kasetsart. J.* 43: 298-304.

Kwon, C. W., Kyung-Min, P., Park, J.W., Lee, J.H., Choi, S.J., and Chang, P.S. 2016. Rapid and sensitive determination of lipid oxidation using the reagent kit based on spectrophotometry. *J. Chem.* 1: 1-7.

Lastriyanto, A., Soeparman, S., Soenoko, R., and Sumardi, H.S. 2013. Analysis frying constant of pineapples vacuum frying. *World Appl. Sci. J.* 23 (11): 1465-1470.

Latha, R.B. and Nasirullah, D.R. 2011.Physico-chemical changes in rice bran oil during heating at frying temperature. *J. Food Sci. Technol*. 1-6.

Lazim, M.A. and Suriani, M. 2009. Sensory evaluation of the selected coffee products using fuzzy approach.*Int. J. Math. Computational Sci*. 3(2): 133-136.

Lioumbas, J.S., Christos, A., and Karapantsios, T.D. 2012. Effect of potato deep-fat frying conditions on temperature dependence of olive oil and palm oil viscosity.*J. Food Eng.* 113: 217-225.

Maadyrad, A., Tarzi, B.G., Bassiri, A., and Bamenimoghada, M. 2011. Process optimization in vacuum frying of kiwi slices using response surface methodology.*J.Food Biosci. Technol.*1: 33-40.

Maity, T., Bawa, A.S., and Raju, P.S. 2014. Effect of vacuum frying on changes in quality attributes of jackfruit (*Artocarpusheterophyllus*) bulb slices. *Int. J. Food Sci*: 8.

Maity, T., Bawa, A.S., and Raju, P.S. 2017. Effect of pre-conditioning on physico-chemical, micro structural and sensory quality of vacuum fried jackfruit chips. *An Int. J.* 01: 28.

Maneerote, J., Noomhorm, A., and Takha, P.S. 2009. Optimization of processing conditions to reduce oil uptake and enhance Physico-chemical properties of deep fried rice crackers. *Food sci. Technol.* 42: 805–812.

Mariscal, M. and Bouchon, P. 2008. Comparison between atmospheric and vacuum frying of apple slices. *Food Chem.* 107: 1561–1569.

Ministry Of Agriculture And Farmers Welfare, 2017, National Horticultural Board

Mishra, R. and Sharma, H.K. 2014.Effect of frying conditions on the physico-chemical properties of rice bran oil and its blended oil. *J. Food Sci. Technol*. 51(6): 1076–1084.

Mohammad, R., Moghaddam, A., Rafe, A., and Taghizadeh, M. 2013. Kinetics of color and physical attributes of cookie during deep-fat frying by image processing techniques. *J. Food. Processing Preservation*: 1745-4549.

Mohammed, M. and Wickham, L.D. 1993. Extension of bitter gourd storage life through the use of reduced temperature and polyethylene wraps. *J. Food Quality* .16(37): 1-382.

Molla, M.M., Nasrin, T. A. A., and Islam, M.N. 2009. Study on the suitability of banana varieties in relation to preparation of chips. *J. Agric. Rural Dev.* 7(1&2): 81-86.

Molla, M.M., Nasrin, T., Islam, M.N., and Bhuyan, M.A.J. 2008.Preparation and packaging of jackfruit chips.*Int. J. Sustain. Crop Prod.* 3(6): 41-47.

Moreira, R.G. 2009.Deep-fat frying.Department of Biological and Agricultural Engineering, Texas A&M University.Chapter-7. College Station, TX, USA: 1755-8336.

Moreira, R.G., Da-Silva, P.F., and Gomes, D. 2009. The effect of a de-oiling mechanism on the production of high quality vacuum fried potato chips. *J. Food Eng*. 92: 297–304.

Morrison, W.H., Robertson, J.A., Burdick, D., and Russell, R.B.1973. Deep-fat frying on sunflower oils.*J. Am. Oil. Chem. Soc.* 50: 440-442.

Moyanoa, P.C. and Pedreschib, F. 2006. Kinetics of oil uptake during frying of potato slices: Effect of pre-treatments. *Swiss Soc. Food Sci. Technol.* 39: 285–291.

Mudawi, H.A., Mohammed, S.M.E., and Abdel, M.E.S. 2014.Effect of frying process on physicochemical characteristics of corn and sunflower oils.*Food Public Health*. 4(4): 181-184.

Mukhopadhyay, S., Mujumdar, G.C., Goswami, T.K., and Mishra, H.N. 2013.Fuzzy logic approach for sensory evaluation of *chhanapodo. Food Sci. Technol.* 53: 204-210.

Naimeh, K., Mohsen, E., and Zahra, E.D. 2016. Effect of active edible coatings made by basil seed gum and thymol on oil uptake and oxidation in shrimp during deep-fat frying.*Carbohyd.Polym*. 137: 249-254.

Nayak, P. K., Dash, U., and Rayaguru, K. 2016. Quality assessment of mustard oil in deep fat frying.*Asian J. Dairy Food Res*. 35(2): 168-171.

NHB [National *Horticulture* Board]. 2017. Annual Report. 2016-2017. Ministry of Agriculture & Farmers Welfare, Gurugram, 43p.

Norizzah, A. R., Junaida, A. R., and Maryam, A. L. 2016.Effects of repeated frying and hydrocolloids on the oil absorption and acceptability of banana *(Musa acuminate)* fritters.*Int. Food Res. J.* 23(2): 694-699.

Nunes, Y. and Moreira, R.G. 2009.Effect of osmotic dehydration and vacuum-frying parameters to produce high-quality mango chips. *J. Food Sci*. 74(7): 355-362.

Ophithakorn, T. and Yaeed, S. 2016. Influence of temperature on microstructure and oil content in vacuum frying of fish tofu. *Int. J. Adv. Agric. Environ. Eng.* 3(1): 2349 -1523.

Ophithakorn, T. and Yaeed, S. 2016. Influence of temperature on microstructure and oil content in vacuum frying of fish tofu. Int. J. Adv. Agric. Environ. Eng. 3(1): 23

Orthoefer, F.T. 1987. Oil use in the food-service industry.*J. Am. Oil Chem. Soc*. 64(6): 795-799.

Pahade, P. K. and Sakhale, B. K. 2012.Effect of blanching and coating with hydrocolloids on reduction of oil uptake in French fries.*Int. Food Res. J.* 19(2): 697-699.

Pan, G., Ji, H., Liu, S., and He, X. 2015.Vacuum frying of breaded shrimps.*Food Sci. Technol.* 62: 734-739.

Pandey A. 2009. Batch vacuum frying system analysis for potato chips. *J. Food Process Eng.* 1-11.

Paul, S.R. 2011. Food frying (Volume-III).*Department of Biological and Agricultural Engineering, University of California, Davis, California, USA*: pp.1.

Pedreschi, F. and Moyano, P. 2005. Effect of pre-drying on texture and oil uptake of potato chips.*Swiss. Soc. Food Sci. Technol*. 38: 599-604.

Pedreschi, F., Kaack, K., and Granby, K. 2016.Acrylamide generation in pre-treated potato chips.*Agro.Food. Ind*. 19: 04-06.

Perez-Tinoco, M.R., Perez, A., Salgado-Cervantes, M., Reynes, M., and Vaillant, F. 2008.Effect of vacuum frying on main physicochemical and nutritional quality parameters of pineapple chips.*J. Sci. Food Agric*. 88: 945–953.

Piana, M.L., Oddo, L.P., Bentabol, A., Bruneau, E., Stefan Bogdanov, S., and Declerck, C.G. 2004. Sensory analysis applied to honey: state of the art. *Apidologie*.35: 26–37.

Powers, S. J., Mottram, D.S., Curtis, A., and Halford, N.G. 2017.Acrylamide content in potato chips.*Food Additives Contaminants*.1-16.

Presswood, H. 2012. Lipid stability of dehydrated (vacuum fried) beef strips stored in two packaging types. Publication/Sverigeslantbruksunversitet, Institutionenförlivsmdelsvetenskap, No. 360.48 pages. Uppsala, Sweden.

Probir, K.G., Chatterjee, D., and Bhattacharjee, P. 2012. Alternative methods of frying and antioxidant stability in soybean oil.*Adv. J. Food Sci. Technol.* 4(1): 26-33.

Raghav, P. K., Agarwal, N., and Saini, M. 2016. Edible coating of fruits and vegetables.*Int. J. Scient. Res. Modern Educ*. (1)1: 188-204.

Ranasalva N. 2017. Development and evaluation of a vacuum frying system for banana chips *(musa spp.)*. Phd. (Ag. Eng.) thesis, Kerala Agricultural University, Thrissur, 36p.

Ranasalva, N. and Sudheer, K.P. 2015. Effects of vacuum and atmospheric frying on quality of ripen nedran banana. XXIVthICFoST. 18-19, Dec. 2015, Held at College of Food Technology, Parbhani, and Maharashtra. pp.78.

Ranasalva, N. and Sudheer, K.P. 2017a. Effect of post centrifugation (De-oiling) on quality of vacuum fried banana (Nendran) chips.*TheBioscan*. 12(2): 749-753.

Ranasalva, N. and Sudheer, K.P. 2017b. Effect of pre-treatments on quality parameters of vacuum fried ripened banana (Nendran) chips. *J. Trop. Agric.* 55 (2): 161-166.

Rani, A.K., Yella-Reddy, S., and Chetana, R. 2010. Quality changes in Trans and Trans free fats and products during frying, *Eur. Food Res. Technol.* 230: 803–811.

Rani, B., Jat, B.L., Pandey, M., Malhotra, J., Mohan, L., Bugasara, P.S., and Maheshwari, R.K. 2014.Dietetic corollary of *momordicacharantia*for vivaciousness and sanguinity.*Int. J. Pharmaceutical Res. Biosci.*3(2): 141-154.

Rani, B., Jat, B.L., Pandey, M., Malhotra, J., Mohan, L., Bugasara, P.S., and Maheshwari, R.K. 2014.Dietetic corollary of momordicacharantia for vivaciousness and sanguinity.Int. J. Pharmaceutical Res. Biosci. 3(2): 141-154.

Ravindranath, B. 2005.Value addition - an integrated approach. Food plus Souvenir: 46.

Ren, A., Pan, S., Li, W., Chen, G., and Duan, X. 2018. Effect of various pretreatments on quality attributes of vacuum-fried shiitake mushroom chips. J. Food Quality: 2018(4510126): 7.

Romano, R., Giordano, A., Vitiello, S., Grottaglie, L.L., and Musso, S.S. 2012.Comparison of the frying performance of olive oil and palm superolein.*J. Food Sci*. 77(5): 512-531.

Routray, W. and Mishra, H.N. 2012. Sensory evaluation of different drinks formulated from dahi (Indian yogurt) powder using fuzzy logic. *J. Food Processing Preservation*. 36:1–10.

Rubalya-Valantina, S., Arockia-Sahayaraj, P., and Angelin-Prema, A. 2010.Antioxidant stability in palm and rice bran oil using simple parameters.*Rasayan J. Chem*. 3(1): 44-50.

Ruttanadech, N. and Chungcharoen, T. 2015. Effects of temperature and time on the physical properties of banana by vacuum frying technique.*Int. Conf. Adv. Agric. Biol. Environ. Sci. (AABES-2015) July 22-23, 2015 London* (*UK).*

Sahin, S., Sumnu, G., and Altunakar, B. 2005.Effects of batters containing different gum types on the quality of deep-fat fried chicken nuggets.*J. Sci. Food Agric.* 85: 2375-2379.

Satishkumar.,Karthik S.K., Palanimuthu, V., and Munishamanna, K.B. 2016. Study the suitability of packaging material for storage of jackfruit chips. *Int. J. Agric. Sci*. 8(30): 1635-1638.

Segovia, P.G., Ramos, A.M., Fizman, S., and Monzo, J.M. 2016. Effects of process condition on the quality of vacuum fried cassava chips. *J. Food. Sci. Technol*. 69: 515-521.

Sengar, G., Kaushal, P.,Sharma, H.K., and Kaur, M. 2014. Degumming of rice bran oil.*Rev. Chem. Eng*. 30(2): 183–198.

Setyawan, A. D., Sugiyarto, Solichatun., and Susilowati, A. 2013. Physical, physical chemistries, chemical and sensorial characteristics of the several fruits and vegetables chips produced by low-temperature of vacuum frying machine.*NusantaraBiosci*. 5(2): 86-103.

Shahraki, M. H. and Mashkour, M. 2012. Vacuum frying.The 1st Middle-East Drying Conference.February 19-20, Mahshahr, Iran.

Shaker, M. A. 2015. Comparison between traditional deep-fat frying and air-frying for production of healthy fried potato strips. *Int. Food. Res. J*. 22(4): 1557-1563.

Shamla, L. and Nisha, P. 2014. Acrylamide in deep-fried snacks of India.*Food Additives Contaminants*.7(3): 220-225.

Sharma, R. and Mann, B. 2010. Changes occurring in oils and fats during frying. *Dairy Chem. Div.* National Dairy Research Institute. Karnal.pp.1-9.

Shinde, K.J. and Pardeshi, I.L. 2014.Fuzzy logic model for sensory evaluation of commercially available jam samples.*J. Ready Eat Food* .1(2): 78-84.

Shyi-Liang, S. and Hwang, L.S. 2001. Effects of processing condition on vacuum fried apple chips. *Food Res. Int.* 34: 133-142.

Shyu L.S., Lung-Bin H., and Lucy S. H. 1998.Effect of vacuum frying on the oxidative stability of Oils.*J. Am. Oil Chem. Soc*. 75: pp.1393–1398.

Shyu, S.H., Hau, L.B., and Lucy, S.H. 2005.Effects of processing conditions on the quality of vacuum-fried carrot chips.*J. Food Agric.* 85: 1903-1908.

Shyu, S.L. and Hwang, L.S. 2011. Process optimization of vacuum fried carrot chips using central composite rotatable design. *J. Food Drug. Analysis.*19(3): 324-330.

Simon, K.P., Aruna, M., Mandha, J., and Rao, D.S. 2017.Nutritional evaluation and oil blending studies of different oils.*Int. J. Food Sci. Nutr.*2(1): 101-105.

Singh, S., Rathor, Y.K., Porwal, P., and Pandey, R.K. 2017. Anti-radical and microbial analysis of MAP stored Bitter gourd chips Short-running title: MAP storage study of Bitter gourd chips. *Int. J. Curr. Microbiol. Appl. Sci.* 6(2): 1840-1846.

Singh, U. and Sagar, V.R. 2013. Effect of drying methods on nutritional composition of dehydrated bitter gourd (*Momordicacharantia*l.) rings. *Agric. Sustain. Dev*. 1(1): 83-86.

Sonia, N.S. 2014. Development of Nedran Banana Chips With enhanced shelf and Quality.M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 80p.

Sothornvit, R. 2011. Edible coating and post-frying centrifuge step effect on quality of vacuum-fried banana chips. *J. Food Eng.* 107: 319–325.

Stubbs, R.J., Ritz, P., Coward, W.A., and Prentice, A.M. 1995. Covert manipulation of ratio of dietary fat to carbohydrate and energy density: Effect of food intake and energy balance in free living men. *Am. J. Clinic. Nutr.*62: 330-337.

Su, Y., Zhang, M., Zhang, W., Adhikari, B., and Yang, Z. 2016.Application of novel microwave-assisted vacuum frying to reduce the oil uptake and improve the quality of potato chips.*Food. Sci. Technol.* 73: 490-497.

Suryatman, S. and Ahza, A. B. 2016. Process optimization of vacuum fried rice-straw mushroom (*Volvariellavolvacea*) stem chip making. *J. Food Sci. Eng*. 6: 109-120.

Tagalpallewar, G., Shrigod, N., and Sardar, N. 2008.Vacuum frying technology-new technique for healthy fried foods [abstract]. In: Abstracts, *National Seminar on Indian Dairy Industry - Opportunities and Challenges;* 5-6 March, 2008, Anand. Food Processing Technology and Bioenergy, AAU, Anand, p.194.

TanusreeMaity, Bawa, A.S., Raju, P.S., 2014, Effect of Vacuum Frying on Changes on Quality Attributes of Jackfruit (Artocarpusheterophyllus) Bulb slice, *International Journal Of Food Science,* Volume 2014, Article ID 752047.

Tareke, E., Rydberg, P., Karlsson, P., Eriksson, S., and Tornqvist, M. 2002. Analysis of acrylamide, a carcinogen formed in heated food stuffs. *J. Agric. Food Chem*. 50: 4998–5006.

Tareke, E., Rydberg, P., Karlsson, P., Eriksson, S., and Tornqvist, M. 2002. Analysis of acrylamide, a carcinogen formed in heated food stuffs. J. Agric. Food Chem. 50: 4998–5006.

Tarmizi, A.H.A., Niranjan, K., and Gordon, M. 2013. Physico-chemical changes occurring in oil when atmospheric frying is combined with post-frying vacuum application. *Food Chem.* 136: 902-908.

Tarzi, G., Maadyrad, A., Bassiri, A., and Bamenimoghadam, M. 2011. Process Optimization in Vacuum Frying of Kiwi Slices Using Response Surface Methodology. J. Food Biosci. Technol. 1: 33-40.

Teruel, M.R., Garcia-Segovia, P., Martınez-Monzo, J., Belen Linares, M., and Garrido, M.D. 2014.Use of vacuum-frying in chicken nuggets processing.*Innovative Food Sci. Emerging Technol.* 65.

Thakur, M. and Sharma, R.K. 2016. Bitter gourd: Health properties and value addition at farm scale. *Marumegh***.**1(2): 2016.

Tiwari, M.R., Tiwari, K.K., and Toliwal, S.D. 2014. Studies on thermal stability of palm-sesame oil blends during deep fat frying. *J. Sci. Ind. Res.* 73: 153-156.

Torres, J.D., Alvis, A., Acevedo, D., Montero, P.M., and Tirado, F.D. 2017. Optimization of vacuum frying conditions of eggplant (*Solanummelongena*l.) slices by response surface methodology. *Int. J. Sci.* 42(10).

Troncoso, E., Pedreschi F., and Zuniga R. N. 2009. Comparative study of physical and sensory properties of pre-treated potato slices during vacuum and atmospheric frying. *Food Sci. Technol.* 42: 187-195.

Tyagi, V.K. and Vasishtha, A.K. 1996. Changes in the characteristics and composition of oils during deep fat frying.*J.Am.Oil Chem. Soc.* 73(4): 499-505.

Valantina, S.R., Sahayaraj, P. A., and Prema, A.A. 2010. Antioxidant stability in palm and rice bran oil using simple parameters.*Rasayan J. Chem.* 3(1): 44-50.

Wexler, L., Perez, A.M., Cubero-Castillo, E., and Vaillant, F. 2016. Use of response surface methodology to compare vacuum and atmospheric deep-fat frying of papaya chips impregnated with blackberry juice. *J. Food*: 01-09.

Wu, M., Hu, X., Ge, B., Zhao, G., and Wang, Z. 2010. Process optimisation of the bitter gourd (Momordicacharantia) concentrated juice preparation for a freeze-dried powder. *Int. J. Food Sci. Technol.*45: 2553–2559.

Xiang, C.P., Wu, C.Y., and Wang, L.P. 2000.Analysis and utilization of nutrient composition in bitter gourd *(Momordicacharantia). J. Huazhong. Agr. Univ.* 19: 388-390.

Yamsaengsung, R., Ariyapuchai, T., and Prasertsit, K. 2011.Effects of vacuum frying on structural changes of bananas. J. Food. Eng. 106: 298–305.

Zhu, Y., Zhang, M., and Wang, Y. 2015. Vacuum frying of peas: effect of coating and pre-drying. *J. Food Sci. Technol*. 52(5): 105–3110.

Appendix

APPENDIX A

Economic Analysis of Developed Vacuum Fried Jackfruit Chips

Estimation cost of vacuum fried jackfruit chips

Cost of machineries and building cost:

Vacuum frying machine cost**=** Rs. 14, 00, 000

Slicer cost= Rs. 25, 000

Cooling chamber cost = Rs. 5, 00, 000

Packaging machine cost = Rs. 40, 000

Building cost (2000 sq.ft) @ 1500/sq.ft= Rs. 30, 00, 000

Miscellaneous item= Rs. 1, 00, 000

Total cost = 50, 65, 000

Assumptions

Life span (L) = 10 years

Annual working hours (H) = 275 days (per day 8 hours) = 2200 hours

Salvage value (S) = 10% of initial cost

Interest on initial cost (i) = 15% annually

Repair &maintainece = 10% of initial cost

Insurance & taxes = 2% of initial cost

Electricity charges = Rs. 7/unit

Labour wages/person = Rs. 600/day (2 Persons)

Skilled assistants (2 Ns @ 500/day) = Rs. 1000/day

One manager @ 700/day = Rs. 700/day

Total fixed cost

i. Depreciation = $\frac{C-S}{L*H} * \mathbf{100}$ $=\frac{5065000-506500}{10*2200}$=207.20/h

ii. Interest = $\frac{c+s}{2} * \frac{i}{H} = \frac{5065000-506500}{2} * \frac{15}{100*2200}$**=189.93/h**

iii. Insurance & taxes = 2% of initial cost

$=\frac{2}{100*2200}*5065000$=46.045/h

Total fixed cost = i + ii + iii **= 443.175/h**

2. Total variable cost

i. Repair & maintenance = 5% of initial cost

$= \frac{5}{100*2200}*2532500$=57.55/h

ii. Electricity cost

a. Energy consumed by the vacuum fryer = **30 kWh**

Cost of energy consumption/h = power x duration x cost of 1 unit

= 30x8x7

=1680/h

b. Energy consumed by slicer, cooling = 2 kw/h

tray and packaging machine

Cost of energy consumption/h = power x duration x cost of one unit

= 2 x 8x 7

= 112/day

iii. Labour cost (5 persons) **=** Rs. 2500/day

iv. Packaging cost = Rs. 2500/day

v. **Cost of raw material for preparation of vacuum fried jackfruit chips**

Sl. No.	Raw materials	Quantity (kg)	Unit rate (per kg)	Total amount (Rs.)
1	Jackfruit	1200	30	36000
2	Frying oil	150	100	15000

Total variable cost = I +ii+ iii+ iv+ v =58208.81/ day

Therefore total cost of production of 100 kg of vacuum fried jackfruit chips

= Fixed cost + Variable cost

= 3545.4+ 58208.81

= Rs. 61754.21/100kg of vacuum fried jackfruit chips

= Rs. 617.5424/ kg of vacuum fried jackfruit chips

The market selling price 1kg of vacuum fried jackfruit chips is Rs. 1750/ kg

Cost benefit ratio = $\frac{1750}{617.54}$= 2.83

The benefit ratio for the production of vacuum fried jack fruit chips was found to be 2.83:1.

APPENDIX B

Sl no.	Parameters	Freezing	Drying	Blanched	Untreated	Atmospheric frying
1	Water activity	0.444	0.48	0.557	0.487	0.499
2	Oil content (%)	38.44	34.25	37.76	33.35	40.23
3	Moisture content (%)	0.772	0.472	0.735	0.501	1.05
4	Hardness (N)	1.65	2.6	1.76	1.04	1.9
Colour values						
5	L*	51.48	37.3	41.59	69.18	21.12
6	a*	12.67	12.9	11.93	2.73	8.37
7	b*	45.05	30.22	33.71	35.35	8.07
8	ΔE	27.35	40.03	35.24	6.34	61.61

Table.4.1 Changes in quality parameters of pre-treated vacuum frying jackfruit chips

APPENDIX C

Sl No	Treatments (VF-JF)	Temperature (°C)	Pressure (kPa)	Time (min)
1	JF1	100	9	18
2	JF2	100	12	18
3	JF3	100	9	20
4	JF4	100	12	20
5	JF5	110	9	18
6	JF6	110	12	18
7	JF7	110	9	20
8	JF8	110	12	20

Table 4.2Treatments details for optimization of process parameters

Treatments	Water activity (a_w)	Moisture content (%)	Oil content (%)	Hardness (N)
JF1	0.513	0.679	30.35	1.01
JF2	0.613	0.801	28.85	1.22
JF3	0.473	0.481	20.73	1.04
JF4	0.497	0.786	29.71	1.35
JF5	0.501	0.616	31.78	1.14
JF6	0.522	0.781	33.35	2.09
JF7	0.487	0.501	34.73	2.16
JF8	0.520	0.527	30.15	2.37

Table 4.3 Quality attributes of the Vacuum fried jackfruit chips

Treatments	L*	a*	b*	ΔE
JF1	69.78	2.73	35.35	5.756787298
JF2	69.86	2.87	33.29	6.483101110
JF3	70.18	2.71	35.41	5.353372769
JF4	67.13	3.10	32.01	9.494429946
JF5	69.35	2.99	30.78	8.442582543
JF6	68.76	2.83	32.23	7.974170803
JF7	66.53	2.21	29.46	11.40156130
JF8	67.15	3.26	31.67	9.662867069

Table4.4 Changes in colour values of vacuum fried jackfruit chips

DEVELOPMENT AND EVALUATION OF VACUUM FRIED JACKFRUIT CHIPS (*Artocarpus heterophyllus*)

By

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ABSTRACT OF THE THESIS

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DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

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ABSTRACT

Jackfruit is a unique tropical fruit that has increased popularity worldwide in recent years for its immense health benefits as well as its texture and flavor. The high postharvest losses and the seasonal availability of jackfruit increase the scope of advanced processing technologies. Snack food market has registered an enormous growth among food processing sector in India. Deep fat fried products have a major share in snack food production sector. Frying, especially deep fat frying products is appealing in terms of color, aroma, texture and taste. The absence of suitable replacement for the taste of deep fat fried products increases the consumer demand for fried food products. Vacuum frying technology has a tremendous scope as an alternative to unhealthy atmospheric frying and is slowly becoming a buzz choice in snack food industry. The health benefits and the attractive physical properties such as color, crispiness, flavor etc. demands the consumer acceptance the vacuum fried chips. As the boiling point and smoke point is decreased due to the reduced pressure applied, thermal degradation of oil and loss of nutrients at high temperature can be checked. And the absence of oxygen during the process inhibits the lipid oxidation and enzymatic browning which helps to maintain the color and flavor of the raw feed. The vacuum frying system consists of two main chambers namely, frying chamber and oil storage chamber. A de-oiling system is attached to frying chamber to remove the oil content in the final vacuum fried product. This vacuum frying system used for the study was of batch type and had a capacity of 2 kg/ batch with oil tank storage of 30 L. After every batch of vacuum frying, chips and oil were collected for analysing the quality. The blended oil (rice bran and palm oil at 80:20) was used as frying oil and de-oiling was done at a speed of 1000 rpm for 5 min. Different pre-treatments were done for vacuum fried jackfruit chips. Control (Un-treated) sample had the best qualities with less oil content (33.35 %), moisture content (0.501 %), hardness (1.04 N), water activity (0.487). Quality parameters like moisture content, water activity, oil content, bulk density, true density, hardness, colour values of vacuum fried jackfruit chips were analysed at different frying conditions. The treatment condition at 100ºC, and 9kPa vacuum for a duration of 20 min produced jackfruit chips with good quality parameters with less oil content(20.73%), hardness (1.04N), water activity (0.473), moisture content (0.481%), L* (70.18), a* (2.71) and b* (35.41). The retort pouches with band sealing retained the quality of jackfruit chips during the storage period. The TPC of blended oil was increased from 9.3% to 14.5% after 30th batch of vacuum frying, which is well below the threshold limit. The threshold level of TPC in edible oil was 25-27%. This made help to recommended for reuse the oil upto 30 times of vacuum frying.