COMMERCIAL UTILIZATION OF JACKFRUIT SEED

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TAVANUR-679573, MALAPPURAM

KERALA, INDIA

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology

In

Food Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Processing and Food Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM

KERALA, INDIA

2019

DECLARATION

We hereby declare that this project report entitled **"COMMERCIAL UTILIZATION OF JACKFRUIT SEED"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur

Date:

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(2015-06-001)

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CERTIFICATE

Certified that this project report entitled **"COMMERCIAL UTILIZATION OF JACKFRUIT SEED"** is a record of project work done jointly by: AARCHA VALLATH (2015-06-001), AMRUTHA K P (2015-06-003), BASIL M (2015-06-007), HARIKRISHNAN M P (2015-06-009) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to them.

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ACKNOWLEDGEMENT

Words are no substitute for thoughts and feelings. It is more so when we, the project team, wish to express our sincere thanks to our project guide, **Er. George Mathew**., associate professor, Department of P&FE, KCAET, Tavanur, for his valuable guidance, encouragement and advice throughout the project work.

We also extend our sincere thanks and gratitude to **Dr.Prince M v.**, Head of the department,P&FE and **Smt. Sreeja R**., Assistant Professor, Department of P&FE for their support and encouragement. We are extremely thankful to our co- guide **Er. Claudia K L**., Assistant Professor (C), Department of P&FE for her support and valuable suggestions in the completion of our project successfully.

We would also like to thank our **parents** for their love and support throughout the project. We also extend our thanks to all the **faculties of library**, KCAET, for their help and support. Last but not the least we thank our sincere friends for their ever-willing help, support and cooperation that helped us to complete the project successfully.

Above all, we bow our head before **The Almighty**, whose grace and blessings have empowered us to complete this toil.

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DEDICATED TO OUR

PROFESSION OF

FOOD ENGINEERING

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SYMBOLS AND ABBREVIATIONS

% Percentage

& and

/ per

< less than

= equal to

> greater than

± plus, or minus

≈ Approximate

AOAC Association of the Official Agricultural Chemists

Al Aluminum

CA Controlled atmospheric

cfu colony forming unit

DF Dilution Factor

et al., and others

etc. etcetera

FDA Food and Drug Administration

Fig. Figure

g gram(s)

HDPE High Density Poly Ethylene

i.e. that is

KCAET Kelappaji College of Agricultural Engineering and Technology

KAU Kerala Agricultural University

kg kilogram

kJ kilo Joules

L Litre(s)

LDPE Low Density Poly Ethylene

Mg milligram

Min minute(s)

ml milliliter

No. Number

PP Poly Propylene

^{o}B Degree Brix

^{o}C Degree Celsius

TSS Total soluble solids

TNTC Too numerous to count

viz., namely

CHAPTER I

INTRODUCTION

India's unique diversity enables availability of all type of fresh fruits and vegetables. Production of horticulture crops like vegetables and fruits is likely to touch a record 305.4 million tonnes in 2017-18 shows that about 1.6% higher than the previous year (2016-2017) and 8% higher than the previous five years' average (agriculture ministry). Due to Non-availability of Post-Harvest & Processing facilities about 20-25% of produce are wasted per year.

Jackfruit (*Artocarpus heterophyllus*) is an important horticulture crop which is produced largely among other crops in India. Jackfruit is believed to have originated in the region of Western Ghats of Indian peninsula (Reddy *et al.,* 2010). It is supposed to have spread from India to the other tropical countries such as Srilanka, Malaysia, Burma, Indonesia, Brazil, Jamaica etc. (Candolle, 1886).

Jackfruit is one of the important underutilized fruits belonging to the family Moraceae and to the genus *Artocarpus* which includes evergreen trees producing more yield than any other fruit tree species and bears the largest edible fruit (Anchanam alagapillai *et al.,* 1996). But it is regarded as a minor fruit and is seldom found in regular plantations. Hence reliable statistics on area and production is not available. This genus comprises of about 100 species distributed in the Indo-Malayan region and China. Among the several species of *Artocarpus* which occur in India, *Artocarpus chaplasha, Artocarpus hirsuta* and *Artocarpus lakoocha* are the important timber yielding trees. Jackfruit tree grows well not only under humid and warm climates of hill slopes, but also in arid plains of south India making it as one of the most suitable fruit crops for dryland horticulture. Jack tree is largely grown in southern states viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh besides, in other states like Assam, Bihar, Orissa, Maharashtra and West Bengal. In Kerala has the largest area (92969 ha) and production (272 million tonne) among others. Jackfruit is largely propagated by seed and being a highly heterozygous and cross-pollinated crop, has resulted in immense variation in the population for yield, size, shape and quality of fruit and period of maturity.

The yield varies from tree to tree and according to age. On an average 5-100 fruits of medium size (6-10 Kg) are borne on adult trees. The jackfruit tree lives for 80 years. The jackfruit prices depend on size, quantity, type of fruit and season. The fruit constitutes three

parts: bulbs (34%), seeds (18%) and rind (48%) respectively. The seed is 2-4 cm long and 1.5 – 2.5 cm thick. There may be 100-120 or up to 500 seeds in a single fruit comprising 5-6% of the total fruit. Generally sweet bulbs are consumed by the people. The remaining parts such as seeds and rind are usually wasted. Jackfruit seed encased in the soft colored edible pulp and constitute to about 5.1-12 per cent of the fruit. It is eaten after roasting or boiling (Rajarajeshwari,1999) which shows the underutilization of the seeds. similar to the jackfruit flush also provide about 135 Kcal/100g of energy. They are not being exploited commercially by the processing industry since it is reported to contain a powerful trypsin inhibitor.

The seeds are generally eaten in boiled or roasted form or used in many culinary preparations, as it contains similar compositions as that of grains. As jackfruit is highly seasonal and seeds have shorter shelf life, hence go as waste during the seasonal glut. So, the seed flour can be an alternative intermediatory product, which can be stored and utilized, both for value addition and to blend with other grain flours without affecting the functional and sensory profile of the final product. Moreover, the incorporation of seed flour to deep fat fried products has found to reduce the fat absorption to a remarkable extent (Rajarajeshwari and Prakash, 1999).

The ripened fruit is normally fibrous and composed of sugars like glucose, fructose, xylose, rhamnose, arabinose and galactose. The seeds are rich source of carbohydrates and proteins and good source of fibre and B-complex vitamins. Chinese consider the jackfruit pulp and seeds useful in overcoming the effects of alcohol. In India too, the jack seed is an important ingredient in antidote preparation for heavy drinkers. The latex from bark contains resin which is used sometimes to plug holes in earthern vats and in other products. The latex from the leaves has got capacity to kill bacteria. Jacalin, the major protein from the jack seeds has proved useful tool for the evaluation of immune status of patients infected with HIV (Morton, 1987). Being a good source of vitamin A, vitamin C and pectin, jackfruit also helps in alleviating the pancreatic ailments and aid in blood purification. Carbohydrates are the main component of the seed in the form of starch for human consumption (Roy *et al.,* 1945). Bobbio *et al.* (1978) have reported that 25-53 per cent starch aided in the formation highly rigid gel. Praveenasri *et al.* (2006) have studied the incorporation of jackfruit seed flour in the manufacture of extruded snacks and vermicelli at varying levels of 30- 50 per cent and reported that incorporation of 40 per cent level gave the best results. Helen *et al.* (2006) have reported that preparation of value-added product “Puttu” (traditional south Indian dish) from jackfruit seed flour with

combination of rice flour. Jackfruit can be considered as complete organic homestead food. Jackfruit was declared officially as state fruit of Kerala in 2018

Since it is underutilized it has to be processed well in the form of ready to cook form and to flour which enables the expanded use of jackfruit seed.

Hence considering the above, an attempt was made to identify the pattern to produce minimally processed product which can be commercialized and a method for conversion of jackfruit seed into flour. Following were the objectives of the study:

1. Production of jackfruit seed powder by wet grinding.
2. Studies on packaging of ready to cook jackfruit seed.
3. Comparison between wet and dry processed jackfruit seed powder.

CHAPTER II
REVIEW OF LITRATURE

2.1 Jackfruit *(Artocarpus heterophyllus)*

Artocarpus heterophllus belong to the Moraceae family, is native to India and seen abundant in Western Ghats. Besides India, jackfruit is commonly grown in home gardens of tropical and sub-tropical countries of Sri Lanka, Bangladesh, Burma, Philippines, Indonesia, Thailand, Malaysia and Brazil. In India, it widely distributed in the states of Assam, West Bengal, Uttar Pradesh, Maharashtra, Kerala, Tamil Nadu and Karnataka and considered to be the "Poor man's food". In Malayalam (regional language in Kerala, India) jackfruit is called as "Chakka" while the ancient Indian Language Sanskrit refers as Atibruhatphala. The morphology of the tree varies with 10-30 m tall; with long tap root and dense crown producing the largest tree born fruit in the world. The fruit weight up to 50 kg, but average weigh is considered to be 10 kg, while only 30-35% of the bulb is edible. In 2018 jackfruit was declared as the state fruit of Kerala by the Kerala government.

Jackfruit is considered as national fruit in Bangladesh and highly appreciated in India due to cheap and availability in summer seasons were food is scarce. The fruit provide 2 MJ of

energy per kg/wet weight of ripe perianth and contain high levels of carbohydrates, protein, starch, calcium and vitamins. Jackfruit is widely used in culinary preparation, baking, baby food, jams, jellies, juice, chips, desserts and the advances in food processing technologies further expanded the possibilities.

2.1.1 Production and cultivation in Kerala

The jackfruit is cultivated in an area of 1,02,552 ha, of which an estimated 1,00,000 trees are grown in backyards and as inter crop in other commercial crops. Kerala has the largest area jackfruit cultivation of about 97,540 ha and production around 348 million fruits (APAARI,2012). Figure 2.1 and Figure 2.2 shows the district wise production and cultivation in Kerala. It shows that the cultivated area of jackfruit in Kerala during 2013-14 was 90,225 ha and jackfruit was widely cultivated in Idukki, Kozhikode and Kannur districts and stand first, second and third position with 16%, 11% and 9% of area respectively. The gross production of jackfruit in Kerala is 294 million fruits with Idukki district holding the top most position (60 million) followed by Kannur district (27 million).

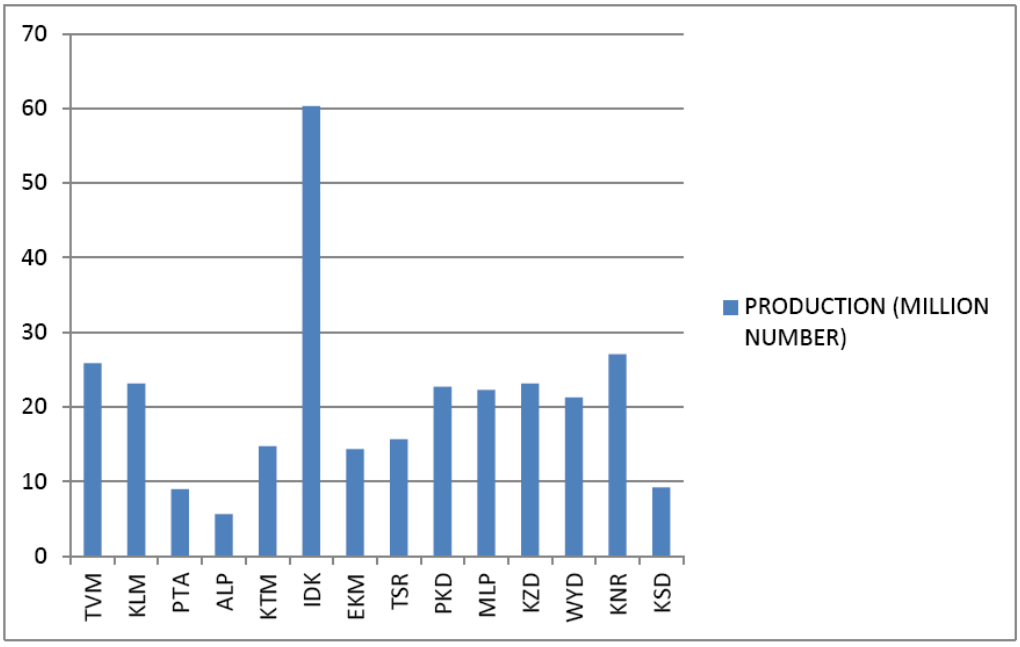
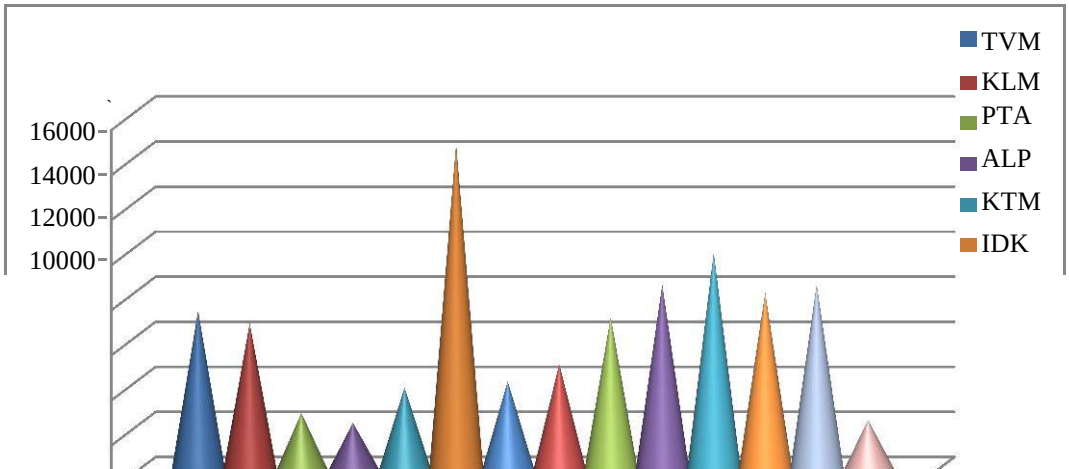


Fig 2.1: District wise production in Kerala (Agricultural Statistics, 2015)



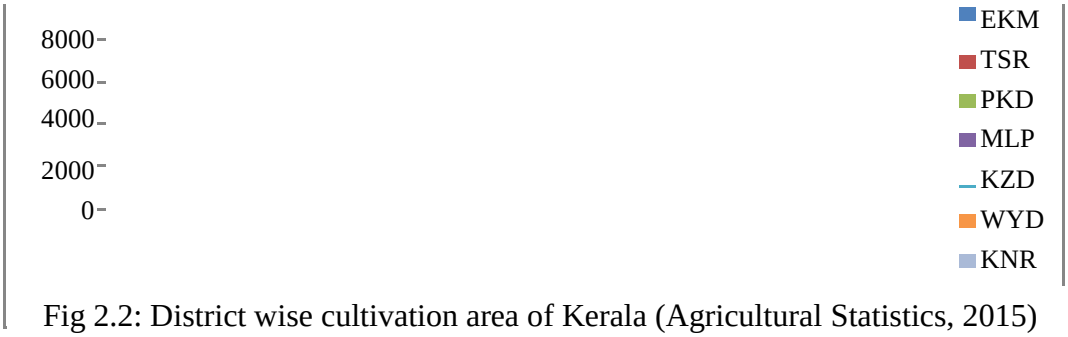


Fig 2.2: District wise cultivation area of Kerala (Agricultural Statistics, 2015)

nd (48%) respectively. Generally sweet bulbs are consumed by the people. The remaining parts such as seeds and rind are usually wasted. Jackfruit seed encased in the soft coloured pulp is edible and constitute about 5.1-12% of the fruit. It is eaten after roasting or boiling (Anon, 1975).

skins, peels and core are left as a waste material after the processing of fruit flush. These wastes constitute about 45% of the total fruit weight and found to be a fairly good source of pectin (Jain and Lal, 1957).

2.1.3 Botanical aspects and variety

Jackfruit tree is an evergreen tree, around 10 to 15 m tall with oval shape dark green leaves. It is a long lived tree having a life span of 60-70 years and contains sticky white latex in all parts of the fruits. The flowery twigs are born primarily on the trunk and main branches. Jackfruit tree is monoecios, male and female flowers are born separately on same tree. The composite fruit may be large as 20 kg or more. Fruit is the primary economic part of tree and used in both stages both mature and immature (Nachegowda *et al*., 2014). Table 2.1 shows the nutritional charecterestcs of young fruit, ripe fruit and jackfruit seed.

Koozha and Varikka are the main two varieties available in Kerala. Jackfruit having thin fibrous and mushy edible pulp which is very sweet and with a strong odour is called Koozha. Varikka is thick, firm, crisp and has less fragrant pulp. Thamarachakka, Nadavalam Varikka, Vakathanam Varikka, Mutton Varikka, Athimathuram Koozha, Ceylon Varikka and Thenga Varikka are the main jackfruit varieties in Kerala. Konkan prolific, Ceylon jack, Hybrid jack, Burliar-1, PLR-1, PPI-1 are few important varieties introduced from the various organizations (Devi *et al*., 2014).

Table 2.1: Nutritional aspects of jackfruit and seed

Composition	Young fruit	Ripe fruit	Seed
Water(g)	76.20 – 85.20	72.00 -94.00	51.00 – 64.50
Protein(g)	2.00 -2.60	1.20 – 1.90	6.60 – 7.04
Carbohydrates(g)	9.40-11.50	16.00 – 25.40	25.80 – 38.40
Fat(g)	0.10 -0.60	0.10 -0.40	0.40 – 0.43
Fiber(g)	2.60 -3.60	1.00 – 1.50	1.000 – 1.50
Total sugar(g)	-	20.60	-
Vitamin A(IU)	30.00	175 -540	10.00 -17.00
Thiamine(mg)	0.05 -0.15	0.03 -0 .09	0.25
Riboflavin(mg)	0.05 -0.20	0.05 – 0.40	0.11 – 0.30
Vitamin C(mg)	12.00 -14.00	7.00 – 10.00	11.00
Energy(KJ)	50.00 -210.00	88.00 – 410 .00	133.00 – 139.00

2.2 Jackfruit seed

Jackfruit seed is a rich source of nutrients. The photochemical content of jackfruit seeds was analysed and high quantity of saponin 9.8% (0.098 g/100g) was found. Saponins have been known for their medicinal uses, including antispasmodic activity, anti-toxicity to cancer cells. Some alkaloids function as spasmolytic, anti-cholinergic and aesthetic agents. The alkaloid content in jackfruit seeds was found to be 1.16% (0.09g/100g) (Burci *et al*). Polyphenolics are known to function as antioxidants through a number of mechanisms including radical scavenging by H-donation, prevention of chain initiation by donating electrons or by binding of transition metal ion catalysts. Flavonoids prevent platelet stickiness and hence platelet aggregation. Colorimetric study of the two extracts of jackfruit seeds showed that dichloromethane: methanol (1:1) solvent system was able to extract more phytochemicals in comparison to acetone.

Figure 2.3 shows the percentage inhibition of DPPH radicals by jackfruit seed extracts. DPPH is a free-radical generating compound and has been widely used to evaluate the free-radical scavenging ability of various antioxidant compounds (Burci *et al).*

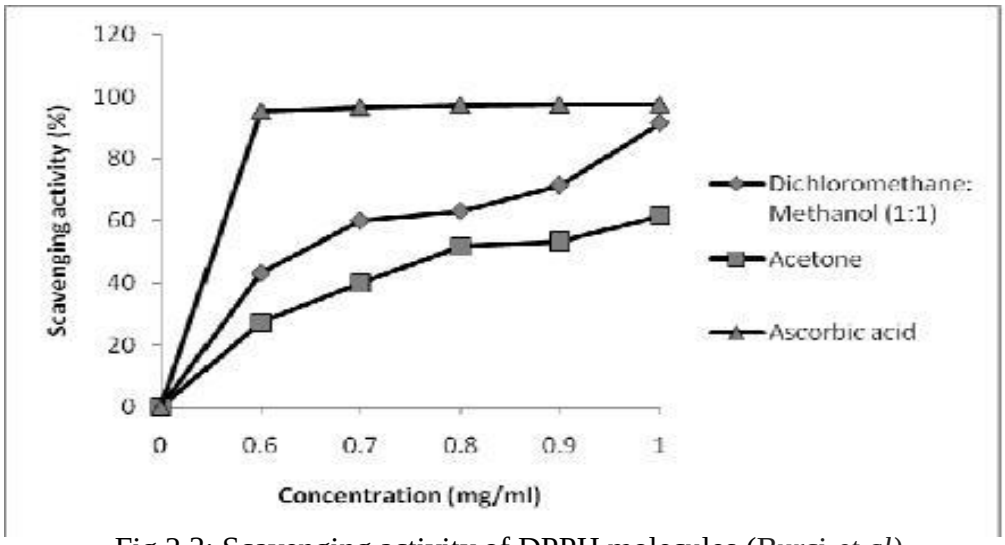


Fig 2.3: Scavenging activity of DPPH molecules (Burci *et al)*

2.2.1 Nutrient composition of jackfruit seeds

Results of the study indicate that the protein content in the jackfruit seed was 7.81-12.46%. Probably the protein content varies from seed to seed and it may also depend on the ripening stage of the seed. (Anon., 1970).

Begum *et al.* (1989) studied the nutritive value of the protein of jackfruit (*Artocarpus integrifolia*) seed meal and effect of supplementing with methionine and tryptophan or milk proteins. Jackfruit seed meal was analysed for chemical/ amino acid composition and found to be good source of protein (13.6%) and iron (11.5%).

The essential amino acid composition showed that seed meal protein was deficient in total S-amino acids (1.77 g/16 g N) and tryptophan (0.6 g/16 g N). They also reported the effect of supplementing jackfruit seed meal with amino acids (methionine and tryptophan) or with milk proteins increases the protein's efficiency. Supplementation with methionine or with methionine and tryptophan brought about significant improvement in the nutritive value raising the protein energy ratio (PER) from 0.43 to 0.73. Supplementation with milk proteins at 1:1 ratio, in a 10% protein diet *al*so showed significant improvement in the protein quality. The protein energy ratio of jackfruit seed meal was 1.65.

Begum and Umapathy (1989) have also studied the effect of partial replacement of cereal in rice and ragi diets by jackfruit seed flour on the nutritive value of diets. They reported that, the effect of replacing 25% of cereal rice and ragi diets by jackfruit seed flour (JFSF) on the nutritive value of the diets by growth experiments in albino rats. The weight gains in rats fed diets based on rice and ragi were 22.9 g and ragi 47.0 g. On replacing 25% of cereal with JFSF the weight gain was 51.8 g and 30.0 g respectively. The result indicates that replacing 25% of rice or ragi by JFSF did not bring about significant difference in the growth promoting value of the diets.

Kumar *et al.* (1998) reported that the proximate composition of the jackfruit seeds of 'Kathari' and 'Bharat' varieties of jackfruit suggests that they are good sources of carbohydrates (26.83-28.01%), protein (6.25-6.75%) and minerals (1.16-1.27%). Fractionation of nitrogen revealed that non-protein nitrogen forms 5.6% and 7.00% of the total nitrogen in 'Kathari' and 'Bharat Baramasi' seeds, respectively. Globulin – nitrogen forms the major portion of total nitrogen in both the varieties. The jackfruit seeds are highly nutritious and provide around 135 Kcal /100 gm. It is a rich source of complex carbohydrates, dietary fiber, vitamins and minerals like calcium, zinc and phosphorous. They contain lignin, isoflavones and saponins, which are called phytonutrients and their health benefits are wide ranging from anticancer to antihypertensive, anti-ageing, antioxidant, anti-ulcer etc. Jackfruit seed powder has the ability to relieve discomfort due to indigestion (Helen *et al.*, 2006).

The moisture content of the jackfruit seed was found to be 64.5%, carbohydrates - 25.8 g, energy -135 Kcal, proteins - 6.6 g, total minerals -1.2 g, iron-1.5 mg, calcium-50 mg, phosphrous-97 mg, fibre-1.5 mg (per 100 g of edible portion) (Praveenasri *et al.*, 2006).

Sharon and Usha (2006) reported that the bread fruit (*Artocarpus altilis Fosberg*) flour contained 65.7% starch, 4.5% protein, 4.3% crude fiber, and 82.2(mg/100 g) calcium, 67.3(mg/100 g) phosphorous, and 5.3(mg/100 g) iron. No significant reduction was observed in the above nutrients during storage except for crude fiber. The moisture content increased significantly from 7.3 to 8.9%. A non-significant increase in the total soluble sugar from 5.5 to 6.2% during storage was observed.

2.3 Jackfruit seed flour

Jackfruit seeds could be used in balanced diets and functional foods which can be consumed safely without any concern of health risk. In countries with high population where the food

requirements are not being fulfilled by seasonal vegetables, jackfruit seeds can be used as a good substitute. As jackfruit seeds have shorter shelf life, they go waste during the seasonal glut. So, the seed flour can be an alternative product, which can be stored and utilized, for value addition. It used to produce a lot of products such as Noodles, Pasta, Snacks, Cakes, bakery products Gluten free biscuits, Nutrient mix and Nutrient drink (Albi Abraham *et al*., 2015)

2.3.1 Nutritional composition of jackfruit seed flour

2.3.1.1 Moisture

Moisture provides a measure of the water content of the seed flour and for that matter its total solid content. It is also an index of storage stability of the flour. The moisture content of the seed flour is 7.758%. The lower the moisture content of flour, the better its shelf stability and the quality. Moisture content of flour generally is depends upon the duration of the drying process. (Albi Abraham *et al*., 2015)

2.3.1.2 Crude Fat

The fat content of the jackfruit seed flour is 2.317% (Albi Abraham *et al*.,2015).

2.3.1.3 Crude Ash

The% ash content of the flour is 2.472% The ash content is the inorganic residue remaining after the organic matter has been burnt away. Ash content of 2.76 – 3.31% (dry matter basis) has been reported for jackfruit seeds. The disparity may be due to varietal differences and the locality.

2.3.1.4 Crude Protein

The percentage of crude protein of the flour is 13.49%. The difference observed may be contributed by varietal differences, maturation of the seeds and environmental conditions. Bobbio *et al*., (1978) reported value of 31.9%. Kumar *et al*., (1988) also reported a protein content of 17.8-18.3% for jackfruit seeds.

2.3.1.5 Crude Fibre

The% crude fibre of the flour is 3.25%. (Albi Abraham *et al.,* 2015).

2.3.1.6 Energy

The caloric value (energy) of the Jackfruit seed flour is 357.66 kcal/100g (Albi Abraham *et al.,* 2015).

2.3.2 Functional properties

2.3.2.1 Water Absorption Capacity

The water absorption capacity of the JSF is 2.916 ml. F.C.K.Ocloo *et al*., (2010) reported the water absorption capacity for the Jackfruit seed flour was 25% (2.5 ml/g). The value is higher than 2.3 ml/g reported for raw jackfruit flour. Water ab-sorption capacity describes flour – water association ability under limited water supply. The disparities observed could be attributed to the method used as well as the varietal differences. The result obtained shows that the flour has a good ability to bind water. This result suggests that jackfruit seed flour could be used in bakery industry.

2.3.2.2 Oil Absorption Capacity

The oil absorption capacity of JSF is 0.884 ml/g. Fat absorption is an important property in food formulations because fats improve the flavour and mouth feel of foods. The disparities observed could be attributed to the method used as well as the varietal differences. The result obtained shows that jackfruit seed flour is a high flavour retainer and may therefore find useful application in food systems such as ground meat formulations (F.C.K.Ocloo *et al*.,2010)

2.3.2.3 Bulk Density

Bulk density is depended upon the particle size of the samples. Its value is 0.873 g/ml. Bulk density is a measure of heaviness of a flour sample. It is important for determining packaging requirements, material handling and application in wet processing in the food industry. The value obtained is higher than that reported in literature. Since flours with high bulk densities are used as thickeners in food products, the Jackfruit seed flour studied could be used as a thickener (F.C.K.Ocloo *et al*.,2010).

2.3.2.4 Swelling Power

The JSF has a swelling power of 5.264. Swelling power is a measure of hydration capacity, because the determination is a weight measure of swollen starch granules and their occluded water. Food eating quality is often connected with retention of water in the swollen starch granules (F.C.K.Ocloo *et al*.,2010).

2.3.2.5 Gelation

The least gelation capacity of the jackfruit seed flour is 17%. The value is comparable with the least gelation concentrations for the raw and heat processed jackfruit flour 16% and 18% (w/v), respectively. Table 2.3 shows Comparison between wheat flour and jackfruit seed flour.These variations may be due to variations in the different constituents of the flour such as carbohydrates, lipids and proteins, which have a significant role on functional properties of flour (Abbey and Ibeh.,1988). Swelling of starch granules occurs in gelation while heating. Hence jackfruit seed flour is a good gelling agent and thickener, useful in food systems such as puddings, sauces, soups etc.

Table 2.2: Comparison between wheat flour and jackfruit seed flour (Proximate Analysis) (Abbey and Ibeh.,1988)

Proximate analysis (%)	**Wheat flour**	**Flour with brown seed coat (without lye peeling)**	**Flour without brown seed coat (with lye peeling)**
Moisture content	11.5	10.7	10.1
Crude protein	8.9	14.02	12.6
Ash	0.63	2.54	2.24
Crude Fat	1.4	4.08	3.37
Crude fibre	0.48	1.8	1.47
Total digestible carbohydrate	76.79	66.86	70.22

2.4 Raw material for minimal processing

Not all types of fruits and vegetables may be suitable for minimal processing. The correct choice of raw material is vital for the production of good quality products (Wiley., 2009). The correct choice of variety is particularly important in case of jackfruit, carrot and potato. that need to have a shelf life of several days after minimal processing.

All minimally processed fruits and vegetables are perishable and demonstrate rapid quality deterioration under ambient storage, due to tissue damage resulting from process

operations such as cutting, slicing, shredding, peeling, trimming, coring etc. (Ahvenainen, 1996). Many visual and organoleptic properties differentiate the diverse varieties of jackfruit for fresh market and minimal processing. So far, no systematic study has been made on the suitability of different varieties for minimal processing of many of the popular fruits and vegetables (Mandhare, 2008).

2.5 Packaging

Minimally processed food products are highly perishable. Such products are often packed in plastic bags or trays over wrapped with a film. The atmosphere within in package is modified by the respiration of the product. Low oxygen levels such as those achieved in modified atmosphere packaging were beneficial in retaining quality of the product such as retarded browning and physiological disorder in shredded cabbage and cut lettuce (Hicks and Hall, 1973)

Sieve and Pal (2006) evaluated the effect of type of polymeric film, its thickness and perforation level on keeping quality of chopped carrots under refrigeration storage condition. The keeping quality was observed in terms of physiological loss in weight, decay, firmness, and shrinkage. Based on these parameters, it was found that thickness and type of film and packages having perforations had no effect on the keeping quality except physiological loss in weight. The low-density polyethylene (LDPE) 100-guage packages with perforation area of 0.0217% that is 4 holes of diameter 1.6mm on each of the LDPE 100-gauge packages, having dimension of 18.5 cm, was found to be the best as these packages increased the storage life of the chopped to 14 days compared to 8 days for control samples.

The effect of different packaging film on quality of “Napoleon” cherry (prunus avium L.”Napoleon”) were studied by Okan *et al*., (2011). Packaging was reported to significantly reduce weight losses, which were 24.08%, 0.5%, 0.39%, and 0.81% for control (unpackaged), polypropylene tray/ biaxial oriented polypropylene film (PP/BOPP), polypropylene tray/ cast polypropylene film, and polyvinyl chloride polyethylene tray/polyethylene terephthalate polyethylene films, respectively.

2.5.1 Modified atmosphere packaging (MAP)

Modified atmosphere packaging (MAP) is a technique used for prolonging the shelf-life of fresh-cut or minimally processed foods. In this preservation technique, the air surrounding the food within the packaging is modified to another composition. By this, the

initial fresh state of the product is prolonged. MAP is used with various types of product, where the composition of gases in the package depends on the type of product, packaging material and storage temperature (Church and Parsons, 1995)

Limbanyen *et al* (1998) reported that a modified atmosphere of 10% oxygen 10% carbon dioxide slowed browning and softening of fresh cut mangoes compared to the control (ambient).

Chantanawarangoon (2000) observed that the visual quality of 'Haden', 'Keitt' and 'Kent' mango cubes stored in 2% O2+10% Co2 was better maintained than those stored in other atmosphere (2%O2 or air + 10%CO2) or in open air (control) during storage at 5°C. The shelf-life of mango cubes dipped in 1% CaCl2 and stored in 2%O2+ 10%CO2 was about 12 days compared to 9 days for those dipped in 1% CaCl2 and stored in ambient. Firmness of mango cubes in all treatments declined during storage. However, rate of softening was slowest in mango cubes stored in 2% O2+10% CO2 environment.

Kupferman and Sanderson (2001) observed that modified atmosphere packaging lengthened the postharvest life of cherry fruit by reducing the rate of growth of decay organisms, retarding softening and retaining stem colour. Modified atmosphere films provided beneficial effects whether they were heat sealed or sealed by turning the bag and closing with tape. Cherries held at 0°C did not benefit from modified atmosphere as much as fruits held at slightly warmer (7◦C) after 14 days.

2.5.2 Vacuum packaging

Application of vacuum packaging technology presents a potential alternative to achieve an inhibition of the progress of deterioration of food stuffs. Vacuum packaging refers to packaging in containers (rigid or flexible), from which substantially all air has been removed prior to final sealing of the package. This method of packaging is actually a form of "Modified Atmosphere" since normal ambient air is removed from the package (John Wiley, 2009)

Vacuum packaging prevented enzymatic browning reaction on the surface of apple slices. However, the beneficial effect of vacuum packaging on apple slices color was offset by a negative effect on firmness. The results of both the calcium treated and the calcium + erythorbic acid treated samples showed that apple slices packaged under vacuum were softer than those packaged without vacuum. The rate of softening was also faster than the samples packaged without vacuum. In another experiment, Jonagold apples slices were packaged under

vacuum at 2 different levels. The lower one at -0.55 bar and the higher one-0.98 bar. It was observed that apple slices packaged at low vacuum were significantly firmer than apple slices packaged at high vacuum at the end of three weeks storage. It was concluded that vacuum packaging helped to prevent discoloration but contributed to softening (Lee and Smith, 1995).

The effect of vacuum packaging on the microbial spoilage of 'ready-to-use' carrot slices and on the effect on shelf-life of the product was studied by Robert K.*et al* (1986). The microbial development on vacuum packaged carrots was slower than that of non-vacuum packaged material. The predominant organisms present were Leuconostoc spp. in the vacuum packs as opposed to Erwinia spp. In the aerobic packs. Vacuum packaging of the sliced carrots significantly extended the shelf-life of the product when stored at 4°C from 5 to 8 days.

Geetha and Thirumaran (2010) investigated the effect of vacuum packaging on the shelf-life of papaya. The fruits were pre-treated with wax, oil, purafil packets and tissue paper wrapping along with the control and were packed in 150-gauge thickness polyethylene film bags under vacuum and another set of these samples without vacuum. The fruits were then stored at ambient and refrigeration temperatures. The shelf-life of the fruits was increased in vacuum packing and ambient temperature up to one and 4 weeks, respectively. The pre-treatment with waxing maintained the quality with minimum changes followed by purafil and oil application. During storage, moisture, acidity, vitamin, and total sugars decreased, whereas reducing sugar and total soluble solids (TSS) increased.

2.5.3 shrink wrap packaging

The shrink wrapped apples with 15 and 25 micron film were stored for 4 weeks at ambient condition (30-38ºC, 52-58% RH) and evaluated for physico-chemical quality in comparison to the apples having no wrap Unwrapped apples were found unacceptable after two weeks due to undesirable loss in physiological weight, colour and firmness; and shriveling of the surface of the fruits. The colour and firmness of the wrapped fruits remained almost unaltered during the period of storage. The study indicated that 25-micron shrinkable film performed comparatively better than 15 microns for wrapping of apple fruit either individually or in a tray of 3 fruits (Abhay Kumar Thakur ,2017)

Shrink wrapping of cucumber followed by storage at 12 ± 1 °C, 90–95% RH was found to be beneficial because it helped to extend the shelf life without deterioration in quality of

fruit. Shrink wrap packaging reduced the weight loss, retained the freshness, colour and firmness of cucumber without any decay. The storage life of shrink wrapped cucumber can be extended up to 15 days at 12 ± 1 °C, 90–95% RH and 5 days at ambient conditions (29–33 °C, 65–70% RH) (Rajinder Kumar Dhall,2011).

2.6 Storage of minimally processed product

2.6.1 Temperature

The storage temperature is one of the important factors affecting the physiology of minimally processed products regardless of the use of packages. They must be handled and stored at less than 5-8°C to achieve a reasonable shelf-life and ensure microbiological safety (Rolle and Chism, 1992).

Fresh-cuts generally are much more perishable than intact products because they have been subjected to severe physical stress, such as peeling, cutting, slicing, shredding, trimming, and/or coring, and removal of the protective epidermal cells. They should be held at a lower temperature than that recommended for intact commodities. Although 0°C generally is the desirable temperature for most fresh-cuts, many are prepared, shipped and stored at 5°C and sometimes at temperatures as high as 10°C. Storage at this elevated temperatures can hasten product's deterioration substantially because the Q10 of biological reactions ranges from 3 to 4 and possibly as high as 7 within this temperature regim (Schlimme, 1995).

The respiration rates of fresh-cut produces increase with temperature and the degree of increase differs with the commodity. In the 0-10°C storage temperature range, the Q10 of several fresh-cuts was higher than the whole product. The Q10 was greater in the 10-20°C temperature range than in the 0-10°C range for 11 of the 15 fresh-cut commodities. The high Q10 of several fresh-cut products in the 10-20°C range was due to the rapid deterioration at 20°C. The high Q10 values, particularly in the 10-20°C range indicated the importance of handling and storing both intact and fresh-cut products at near 0°C if the product was not sensitive to chilling injury (Watada *et al*., 1996).

Storage at 10°C or above allowed most bacterial pathogens to grow rapidly on fresh-cut vegetables. The storage temperature was important when modified atmosphere packaging or vacuum packaging was used (Francis and O'Beirne, 1997). Processing, transport, display

and intermediate storage all should be done at the same low temperature preferably between 2-4°C for produce not sensitive to chilling injury.

Marrero and Kader (2006) reported that temperature had a significant effect both on respiration rate and post-cutting life of fresh-cut pineapples. The end of post-cutting life was indicated by a marked increase in respiration rate followed by visual signs of microbial spoilage. This stage was reached after 4 days at 10 ◦C, 8 days at 7.5 ◦C, 12 days at 5 oC and more than 15 days at 2.2 oC and 0 ◦C.

The refrigeration temperature below 7ºC used in the storage of minimally processed fruits and vegetables extended the shelf-life of products, slowed down the microorganism's growth rate, but was selective for psychotropic microorganisms (Lucimeire *et al*., 2006).

Keeping intact the fresh-cut fruits within their optimum ranges of temperature and relative humidity was the most important factor in maintaining their quality and minimizing post-harvest losses. Above the minimum safe temperature for mango as a chilling-sensitive commodity, every 10°C increase in temperature accelerated deterioration and the rate of loss in nutritional quality by 2 to 3 folds (Adel, 2008).

2.6.2 Microbial contamination

Psychotropic gram-negative rods are the predominant microorganisms on fresh-cut products (Neelima *et al*., 1990). Human pathogens of concern are Listeria monocytogenes, which can grow at refrigerated temperatures, and Clostridium botulinum, Bacillus, and Salmonella spp., and Staphylococcus aureus, could grow at a temperature of 7°C and above (Nguyen-the and Carlin, 1994). Microbial load is a major concern of minimally processed food products since they are consumed raw without any intervening processing step. A number of microorganisms have been found in fresh-cut products, including mesophilic microflora, lactic acid bacteria, coliforms, fecal coliforms, yeasts and molds and pectinolytic microflora. The type and population differ with commodity, sanitation and cultural practices.

Chantanawarangoon (2000) found that after 4 days at 5 °C, both the total microbial and yeast and mold counts of mango cubes in the control increased rapidly. Up to 10 days, there were no significant differences in total microbial and yeast and mold counts of mango cubes among all treatments except the control, which had higher microbial counts than other treatments. After 10 days at 5°C, the microbial counts of mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine and stored in ambient increased more rapidly than those

in treatments that were stored in citric acid. It was clear that treatment with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine was effective in reducing microbial growth on fresh-cut mango cubes for up to 10 days in air and for up to 17 days in controlled atmosphere (2%O2 + 10%CO2) at 5°C. However, after 17 days at 5°C, microbial growth was observed only in the control mango cubes.

Results of microbiological analysis of minimally processed carrot were negative for total or fecal coliforms, anaerobic mesophiles and Salmonella. However, psychrotrophics grew slightly during the storage period of the samples packed under atmospheric, vacuum and modified atmosphere conditions. The minimally processed green pepper contained total coliforms and anaerobic mesophiles and psychrotrophics during the storage period of all treatments (Lucimeire *et al*., 2006).

Marked variation in coliform, yeast and mould was observed in minimally processed carrot samples. The microbial enumeration on the 6th day of ambient storage conditions (0-1.5%CO2 and 17-19%O2) showed that cut carrot cubes in polypropylene (PP) packages had the highest loads for coliform ranging from 4.18-4.45 cfu/10g of sample and for yeasts and mould ranged from 4.34-4.62 cfu/10g. However, in low density polyethylene (LDPE), lower loads for coliform (4.12-4.42 cfu per 10g), yeast and moulds (4.3-4.58 cfu/10g) compared to PP were observed (Mandhare, 2008).

Minimally processed samples of pineapple, cantaloupe, and vegetables salad (cabbage, cucumber, tomato, onion and lettuce) were taken from supermarkets. The total viable counts and number of yeast and mould of the samples ranged from 105-109 cfu/g and 102-108 cfu/g, respectively. Coliform, bacteria and Escherichia coli were observed in all samples, whereas Salmonella spp. was not observed. Microbial contamination of unpeeled cantaloupe and packaged salad was less than that of peeled cantaloupe and vegetables from salad bars. Only 77.8% of unpeeled cantaloupe was in the standard range of Ministry of Health. E. coli in pineapple, was in standard range (<3 MPN/g) but they showed more contamination with yeast and mould. Among the samples tested, the highest contamination was found in vegetable salad. On the other hand, the laboratory prepared minimally processed fruits and vegetables showed less microbial contamination both before and after storage at low temperatures. The results indicated that the prepared samples in laboratory had higher hygienic quality than samples from supermarkets (Romphophak *et al*., 1995).

The microbial counts in ready-to-eat salads and most of the vegetables observed 4.83 cfu/10g of sample were of satisfactory or of acceptable microbiological quality according to public health laboratory service food microbiological guidance (Rocourt *et al*., 2003). In an another study, the enumeration of bacteria and coliforms was conducted to assess the level of post-harvest contamination. The mean value of total bacterial count in vegetables ranged between 109-250 cfu × 104 g-1 and coliforms 29-87 cfu × 104 g-1 (Goyal and Jaj, 2006).

The microbiological analysis of minimally processed carrot cubes indicated that the total aerobic counts were highest for the control samples irrespective of the samples treated with preservatives. The observation of the overall investigation with respect to coliforms, yeasts and mould load was taken and highest counts were observed on carrot cubes treated with citric acid +ascorbic acid + sodium alginate and packed in LDPE package at refrigerated storage. The refrigeration temperature below 7°C helped in extending the shelf-life of the samples with insignificant microorganism's growth rate both in LDPE and in polypropylene (PP) (Mandhare, 2008).

2.6.3 pH and Total Soluble Solids (TSS)

The results reported by Abdul *et al*. (1993) indicated a decrease in pH from 7.0 to 4.0 with minimally processed mixed lettuce and cucumber salad packed under modified atmosphere (3% O2 and 97% N2) after 9 days of storage at 5 °C 12 °C and 21 °C temperatures.

The pH value of fresh carrot samples was observed to be 4.3 and this increased in the range of 4.7-5.8 at the end of the 6th day of ambient storage. In the minimally processed carrots, the average value of pH ranged from 4.9 to 5.9 at the end of 21st day of refrigerated storage. The rate of increase of pH in the experiment during the refrigerated storage was lower than that of ambient storage. Further it was seen that the pH value was less in carrot cube samples in LDPE than in PP. The TSS value decreased up to 4.1 °Brix (PP) at ambient storage from the fresh carrot sample (4.7 °Brix) at refrigerated storage, the rate of decrease was slower. At the end of 21st day of refrigerated storage and the TSS value was found to be in the range of 4.8-5.1 °Brix (Mandhare, 2008).

2.6.3 Ascorbic acid

Ascorbic acid is a reducing compound and most often used as a sulfite replacement (Gardner et al., 1991). It is readily affected by light, oxygen, heat, enzymes and metals. Ascorbic acid is naturally occurring and nutritionally beneficial, but it does not directly inhibit

polyphenol oxidase as sulfur dioxides. It offers only temporary browning and is affected by pH, temperature, enzymes activity and oxygen, iron and substrate concentrates.

Kaur and Kapper (2000) studied the effect of different dip treatments and storage period on the antioxidants activity and biochemical quality of Indian cabbage after minimally processing. A gradual decrease in total antioxidants activity was observed during storage at 6°C with no detectable activity at the end of 9 days in all the dip pre-treatments, except in pre-treatments containing a combination of ascorbic acid and citric acid, and ascorbic acid alone. The incorporation of ascorbic acid and citric acid in the dip water improved the overall appearance and retained the maximum antioxidants activity, ascorbic acid and total carotenoids.

Limbo and piergiovanni (2006) reported that high oxygen partial pressure in combination with ascorbic acid and citric acid prevented enzymatic browning of minimally processed potatoes. The use of additive-based dip treatments in combination with other techniques was beneficial reducing stress- induced metabolism, restricting browning, maintaining firmness and enhancing the sensory characteristics of various minimally processed products with an extended shelf- life. (Raju and Bava, 2006). Cocci et al. (2006) reported that the synergistic effect of ascorbic acid as an antioxidant and citric acid as acidulants minimized the occurrence of browning in minimally processed apples.

Constituents of pretreatment such as ascorbic acid and citric acid were found to be effective anti-enzymatic browning agents. Ascorbic acid function as an anti-browning agent by absorption of molecular oxygen and carboxylic acids such as citric acid inactivates the enzyme polyphenol oxidase by chelating bivalent cat ion (Rico et al., 2007)

Ascorbic acid has an important role as a phytochemical, due to its functionality as antioxidants besides its vitamin C activity. The physiological stress imposed upon fresh-cut commodity results in a significant result in ascorbic acid content. Addition of ascorbic acid content during dip pretreatment resulted in a 3.5-fold increase in ascorbic acid content in pretreated samples. (Saxena et al., 2009). Use of ascorbic acid could maintain the visual quality of the produce through restricted browning.

2.6.4 Acidification

Monroe et al. (1969) observed that natural sugars remained in the finished vegetables, contributed desirable sweetness and provided nutrients for acid tolerant microorganism and thus necessitated additional measures of preservation such as other antimicrobial agents and refrigeration. Stabilization by direct acidification without salt provided a similar degree of preservation. Using this approach, Furia (1972) accumulated substantial information on the technology of producing directly acidified vegetables.

Juliot et al. (1989) evaluated several food grade acidulants for direct acidification of carrot slices for use in salad. Citric acid, acetic acid or fumeric acid provided excellent microbial control and satisfactory flavour quality for carrots in salad.

Some organic acids naturally found in or applied to fruits and vegetables behaves primarily as fungistats and other are more effective in inhibiting bacterial growth. The mode of action of these acids was attributed to direct pH reduction, depression of internal pH of microbial cells by ionization of the un-dissociated acid molecules or disruption of substrate transport by alteration of cell membranes permeability (Alzamora et al., 2000).

2.7 Extraction of jackfruit seed flour

A method to extract an acceptable jackfruit seed flour form the seeds was developed by Munishammanna et al. (2007). To extract jackfruit seed flour, jackfruit seeds were boiled for 15-20 minutes; water was decanted and cooled in order to remove the seeds and outer skin coat. Seeds were cut into 3-4 pieces dried in sunlight or hot air oven (400C) for 48 hours. Dried seeds were ground into flour sieved and stored.

Tulyathan et al. (2002) took three kilo grams of seeds which were treated with 5% NaOH for 2 min to remove the thin brown spermoderm that covered the fleshy white cotyledons to produce jackfruit seed flour. The seeds were then sliced into thin chips and tray dried at 500 – 600C and the chips were ground in a pin mil FFC-23 to 70 mesh flour and packed in plastic pouches, stored in refrigerator (<50C). Yield of the flour was 36.4 per cent.

After consumption of the jackfruit, the seeds are usually wasted. Hence a study was undertaken to prepare products from jackfruit seed flour to improve the consumption. Jackfruit

seed flour was prepared by removing the outer peel and boiling the seeds for 20 minutes in order to inactive the powerful trypsin inhibitor (Helen et al., 2006).

Jackfruit seed flour was produced after outer white peel was removed and the seeds were washed and then boiled for 20 minutes in order to inactive a powerful trypsin inhibitor present. Sample A of the flour was prepared by cutting the seeds into pieces, followed by drying and then finally milling. Sample B was prepared by removing the brown peel adhering to the seed and then following the same procedure as for sample A. Drying was done in a tray dryer at 550C for 29 hours. Sample B gave better sensory characteristic (Praveenasri et al., 2006).

Sharon and Usha (2006) prepared flour from bread fruit (Artocarpus altilis (park) Forsberg). To obtain flour fruits were cleaned, sliced, peeled followed by blanching at 900C with 0.3 per cent citric acid and 1500 ppm SO2 for five minutes and sun dried. The chips were ground sieved and packed for three months and later analyzed for nutritional composition.

2.8 Wet grinding processes

This study attempted to replace the wet grinding process of rice with a freeze grinding process. The freeze grinding process involved soaking the rice samples in liquid nitrogen before grinding in a dry grinding machine. Three different types of grinders (hammer mill, roller mill, and pin mill) were used in both the freeze and the dry grinding processes. Wet grinding resulted in significantly ($P < 0.05$) smaller average particle size and a lower%age of damaged starch than the alternative methods of grinding. Freeze grinding; especially using the hammer mill significantly reduced both the average particle size and the damaged starch content. Moreover, freeze grinding produced a higher yield after sieving in comparison with dry grinding using an identical grinder. In particular, freeze grinding with the hammer mill gave a significantly higher yield after sieving than dry grinding with the hammer mill. The wet grinding process had the significantly highest specific energy consumption (13,868 kJ/kg) due to the large consumption of electrical energy by the many machines in the process. The energy consumption of freeze grinding was similar to dry grinding. Consequently, the freeze grinding process was a viable alternative to the traditional wet grinding process jung et al (2018).

CHAPTER III

MATERIALS AND METHODS

The present study was carried out in the processing and food engineering department of KCAET Tavanur. The details of materials and methods used are presented in this chapter. The following are the list of experiments conducted. All analytical procedures were carried in triplicates unless otherwise indicated:

3.1 Wet process of jackfruit seed to produce flour.

3.1.1 Collection of jackfruit seed.

3.1.2 Procurement of jackfruit seed.

3.1.3 Stone grinding.

3.1.4 Drying of jackfruit seed paste.

3.1.5 Powdering.

3.1.6 Characteristic study of jackfruit seed flour (wet processed jack fruit seed).

3.1.7 Comparison between dry and wet processed flour.

3.2 Packaging studies of jackfruit seed.

3.2.1 Minimal processing of jackfruit seed.

3.2.2 Estimation of physio-chemical characteristics.

3.2.3 Vacuum packaging

3.2.4 Shrink wrap packaging

3.2.5 Microbiological analysis

3.2.6 Evaluation of physio-chemical characteristics

3.2.7 Cost estimation

3.1 Wet process of jackfruit seed to produce flour.

3.1.1 Collection of jackfruit seed.

Seeds from ripened jackfruit were collected from local vendors in Neyyattinkara, Trivandrum and from KCAET Tavanur campus premises.

Plate 3.1 Jackfruit seed

3.1.2 Preparation of jackfruit seed

250 g of seeds were washed and white arils are removed manual by a knife and mechanical methods (jackfruit coat remover which was developed by P&FE department in

KCAET). Seeds were soaked in water for 30 minute, 1 hour and kept overnight. Seeds were cut into small pieces using a knife.

3.1.3 Stone grinding

The cut seeds were grinded using a table top stone grinder.Seeds were introduced to the grinding chamber with 90 ml of water and grinding stones were installed. Seeds were made into a paste within a time period of 15 minutes.

3.1.4 Drying of jackfruit seed paste.

The paste obtain were dried in different temperature combination of 60°C and 70°C using cabinet dryer. The time taken for drying was 3 - 4.5 hours. The paste was converted into brittle form.

3.1.5 Powdering.

The dried paste was powdered using a table top mixer grinder. The time taken for grinding was 1-2 minute.

Plate 3.2 **Plate 3.3 Jackfruit Seed Paste**

Stone Grinding of Jackfruit Seed

3.1.6 Characteristic study of wet processed jackfruit seed flour.

3.1.6.1 Ascorbic acid

Ascorbic acid is a water-soluble vitamin and it also known as vitamin C. It was determined by dye method (Sadasivam and Manickam, 1992). Four per cent oxalic acid, standard ascorbic acid solution in four per cent oxalic acid and dye solution (42 mg of sodium bicarbonate and 52 mg of 2, 6, dichloro phenol indophenols dye in 200 ml of distilled water) were the reagents used for the analysis. Hundred milli gram of pure dry crystalline ascorbic acid was taken and made upto 100 ml using four per cent oxalic acid to get the stock solution. The working standard solution (100 ml) was prepared by diluting 10 ml stock solution using four% oxalic acid. Five milli litre each of working standard solution and four per cent oxalic acid were pipetted into a conical flask and titrated against the dye solution. The end point was delineated as the appearance of pale pink colour which persisted for a few minutes. The titration was repeated three times to get the concordant value. The amount of dye (V1) used was determined and such an amount was regarded as the amount of ascorbic acid present in the working standard solution. Then the sample was made into pulp and 10 ml of the homogenized pulp (VS) was taken and made up to 100 ml with four per cent oxalic acid solution. 10 milli litre of the made up solution was pipetted out into a conical flask and titrated against the dye and the amount used was labeled as V2. The quantity of ascorbic acid (mg) present in 100 gm of sample was calculated as follows.

$$\textbf{Ascorbic acid (mg/100g)} = \frac{.5}{v1} * \frac{v2}{10} * \frac{100}{vs} * 100 \qquad \textbf{(Eqn 3.1)}$$

3.1.6.2 Titrable acidity.

Homogenized pulp (10 g) was made up to 100 ml with distilled water. Ten milli litre of the prepared solution was titrated against 0.1N NaOH solution using phenolphthalein as indicator. The appearance of a light pink colour indicated the end- point. This quantifies the NaOH required to neutralise the juice. Then the titrable acidity was calculated and expressed as% citric acid (Ranganna, 1986). Amount of titrable acidity (Ns) present in 100 g of sample was calculated as follows:

$$Ns\ (\%) = \frac{(\text{Normality of alkali} \times \text{titrate value} \times \text{equivalent weight of acid})}{\text{volume of the sample taken}}$$

(Eqn 3.2)

3.1.6.3 Total Soluble Solids (TSS)

TSS is considered as one of the important quality parameters of fruits and vegetables. It is highly positively correlated with sugar content and measured as °Brix. Sugar content includes carbohydrates, organic acids, proteins, fats and minerals of fruit. Samples were crushed and made into juice. TSS was measured using refractometer (PAL digital hand held pocket refractometer) by standard method.

3.1.6.4 pH

The negative log of the activity of the hydrogen ion in an aqueous solution is referred as pH. Solutions with a pH greater than seven are basic solutions and a solution with pH less than seven are said to be acidic, pH equal to seven being pure water. Foods are classified into different groups based on their pH. pH of the jackfruit seed was measured using digital pH meter. Instrument was calibrated with distilled water and then samples were tested (average value calculated from the three replications). Samples were prepared by homogenizing 10 g of the sample with 10 ml distilled water.

3.1.6.5 Estimation of moisture (AOAC, 1980)

Moisture was determined by taking about 10 g of sample in petri dish and dried in an oven at 60ºC till the weight of the petri dish with its content was constant. Each time before weighing, the petri dish was cooled in desiccators. Moisture content of the sample was expressed in g /100 g of sample wet basis.

3.1.7 Comparison between dry and wet processed flour.

The characteristics of dry processed jackfruit seed flour are estimated and compared with the wet processed one.

3.2 Packaging studies on jackfruit seed

3.2.1 Minimal processing

The minimal processing of jackfruit bulbs involved the following steps as outlined below:

I. Collection of healthy, uniformly matured and ripened jackfruits.
II. Cutting of the fruit into pieces using suitably sharp stainless steel knives smeared with a cooking oil.
III. Separation of bulbs from the fruit.
IV. Separation of seeds from the bulbs.
V. Seeds were cleaned and washed under tap water
VI. White arils were removed
VII. Washed with pure water

3.2.2 Estimation of physio-chemical characteristics.

Ascorbic acid, Titrable acidity, TSS and pH were estimated by the procedures explained in sections **3.1.6.1, 3.1.6.2, 3.1.6.3 and 3.1.6.4** respectively.

3.2.2.1 Estimation of moisture content

The experiment was done according to the standards prescribed by food safety and standards authority of India as follows (FSSAI, 2017)

3.2.3 Vacuum packaging

The experiment was carried out to investigate the influence of vacuum packaging of minimally processed jackfruit seeds by using different packaging materials (plastic) without any pre-treatment, vacuum packaged seeds were stored in refrigeration and room temperatures for a period of 2 weeks and 3 weeks, respectively. The details of the experimental treatments are as follows:

Packaging materials

a. Low density polyethylene (LDPE)-400,500 gauge p_1
b. High density polyethylene (HDPE)-180 gauge p_2
c. Polypropylene (PP)-260 gauge p_3

Storage temperature

a. Room temperature T_1

b. Refrigerated temperature (2-4°C) T_2

Minimal processed jackfruit seeds were filled in above mentioned pouches and placed in the single chamber vacuum packaging**.** Each pouch containing 140 g of samples were placed such that the open face of the pouch lies above the sealing head. The machine was set in "MODE 4' and the vacuum was set at 760 mmHg for the complete removal of air in the pouch. Sealing time was adjusted according to the material used. Cooling time was set at 5sec. The lid was closed to start the operation and after the operation the lid was opened and product was taken out for storage. For obtaining control sample the same was done at 0 mmHg.

Plate 3.4 vacuum packaging machine

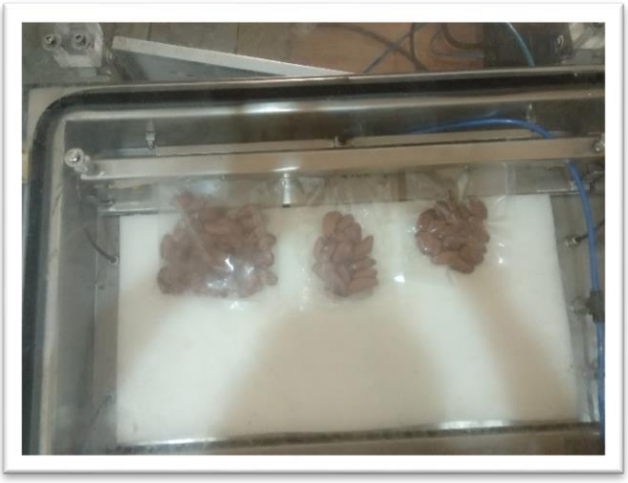


Plate 3.5 sealing

3.2.4 Shrink wrap packaging

50g of the jackfruit seeds were filled in polypropylene pouches of 90 gauge and sealed using a L- sealer and placed above the conveyor of SEVANA shrink wrap packaging machine. Temperature of air blown was set to be 150°C and the conveyor speed is adjusted. Consecutive passes of sample were done to get complete shrinking.

Plate 3.5 Shrink wrap packaging machine

Plate 3.6 shrink wrap packaging of jackfruit seed samples

3.2.5 Microbial analysis.

Standard plate count method

This method allowed the growth of microorganism in nutrient culture petri plate and the colonies developed were counted. one milli litre (WS) of jackfruit seed juice was extracted by crushing using sterile pestle and mortar. It was then added to 90 ml of sterile water (10^{-1}dilution) and shaken well for 10 - 15 minutes to assure uniform distribution of microorganisms followed by serial dilution to obtain 10^{-3} and 10^{-4} dilutions. One milli litre of this diluted sample was transferred to sterile petri plate with a sterile micro pipette for the spore count determination in sterilized product. The plates were rotated clockwise and anti-clock wise for the thorough mixing of dilutent and the medium. Then the petri plates were incubated at 37 °C and 55 °C for one to two days, for the bacterial growth, spore formation and fungal growth. The number of colonies formed was found using colony counter.

3.2.6 Evaluation of physio-chemical characteristics

Ascorbic acid, Titrable acidity, TSS, pH and moisture content for packaged seeds were estimated by the procedures explained in sections **3.1.6.1, 3.1.6.2, 3.1.6.3 ,3.1.6.4 and 3.2.2.1** respectively

3.2.7 Cost estimation

Suitable assumptions and standard procedure were used for the analysis of cost economics. Cost analysis is given in appendix A.

CHAPTER IV

RESULTS AND DISCUSSION

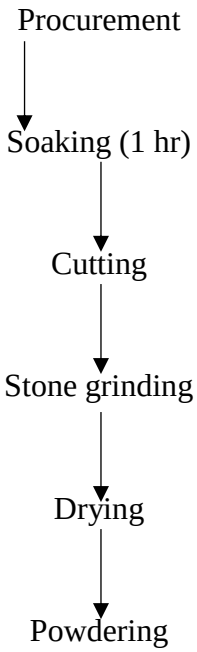
4.1 Wet processing

The yield of jackfruit seed flour by wet processing is shown in the table 4.1. The results shows that there is only slight difference yield of flour by two methods. maximum yield of flour was observed in dry processing.

Table 4.1 Yield of jackfruit seed flour

Method	Temperature (°C)	Initial weight (g)	Yield (g)	%age (%)
Dry	60	250	124	49.6
	70	250	120	48
Wet	60	250	114	45.6
	70	250	112	44.8

4.1.1 Flow chart for wet processing of jackfruit seed



4.1.2 Physio-chemical characteristics

The characteristics were used to compare dry and wet processed flour which is shown in table 4.2

4.1.2.1 Moisture content

Moisture content of jackfruit seed flour was 5.94 per cent per 100 grams.

Table 4.2 Characteristic study of by dry and wet processed jackfruit seed

Method	Sample	Ascorbic acid (mg/100g)	Titrable acidity (%)	TSS (°brix)	pH
Dry	T1 (60 °C)	2	0.6404	8.62	5.4
	T2 (70 °C)	1.8	0.6801	8.61	5.46
Wet	T1 (60 °C)	1.66	0.83252	8	5.05
	T2 (70 °C)	1.53	0.842	8.1	5.56

4.1.3 Comparison between dry and wet processed jackfruit seed

From table 4.2, it is clear that dry processed seed powder has more nutritional benefits over the wet processed one. The change in ascorbic acid was found to be lower at 60 °C and increase in acidity was comparable in both cases. As per the results shown, the increase in pH was also comparable.

In both methods the increase in drying temperature cause decrease in physio-chemical characteristics.

By visual inspection it was clear that the colour of wet processed one was more brownish than dry processed one due to non-enzymatic browning

4.2 Packaging study

4.2.1 Physico - Chemical Characteristics of Minimally Processed Jackfruit Seed.

The Physico – chemical characteristics of minimally processed jackfruit seed are presented in Table 4.3. The average values of the chemical components viz., ascorbic acid, pH,

Titrable acidity and TSS were estimated to be 7.38 mg/100 g, 4.8, 0.29% and 8.010°Brix respectively.

Table 4.3 chemical characteristics of minimal processed jackfruit seed

Chemical characteristics	
Ascorbic acid (mg/100g)	7.38
pH	4.80
Titrable acidity (%)	0.45
TSS(°Brix)	8.010

Plate 4.1 Comparison between wet and dry flours

(A-dry processed B-wet processed)

4.2.2 Moisture content

The moisture content of minimally processed jackfruit seed was found to be 41% in wet basis and as temperature of drying increases the characteristic colour of flour was getting brownish this might be due to the reason of non-enzymatic browning. since the flour containing reasonable amount of protein and starch drying temperature is more significant than the final moisture content.

4.2.3 Shrink wrap packaging

It has been observed that water drops on the interface of the packaging material. This may be due to the condensation of evaporated moisture content from seeds during the packing operation When the product was stored in room temperature, within 1.5 days fungal growth

was observed in the packet. From this it can be concluded that this method may not be suitable for packaging of fresh jackfruit seeds.

Plate 4.2 Fungal attack on the seeds

4.2.4 Vacuum packaging

Influence of vacuum packaging on minimally processed jackfruit seeds using different packaging materials Many research are available on the use vacuum packaging as a potential alternative to achieve an inhibition of the progress of deterioration of foodstuffs and especially in fresh-cut products (Corbo *etal.*, 2010). The results for the experiment conducted under vacuum packaging technique at different packaging materials are detailed here under section 4.2.4.

Plate 4.3 vacuum packed jackfruit seed after tenth day of storage

4.2.4.1 Effect of vacuum packaging on ascorbic acid content (refrigerated temperature)

The results of changes in ascorbic acid content under refrigerated condition are presented in Table 4.4. The ascorbic acid levels in all the samples exhibited slight decrease during storage. Higher retention of ascorbic acid was observed when the packaging material of PP 260 G used (5.08mg/100g). While using LDPE 500G shows better result than LDPE 400 G. The air penetration was more in HDPE 180G package and it gives a shelf life approximately 10 days. The figure 4.1 shows the graphical representation of table 4.4

Table 4.4 Effect of vacuum packaging on ascorbic acid content (refrigerated temperature)

	Ascorbic acid content(mg/100g)

Days	LDPE 400 G	LDPE 500 G	HDPE 180 G	PP 260 G
0	7.68	7.68	7.68	7.68
3	6.90	7.20	6.52	7.30
6	6.40	6.80	5.80	7.01
9	5.90	6.10	4.30	6.40
12	5.20	5.40	-	6.10
14	-	4.63	-	5.08

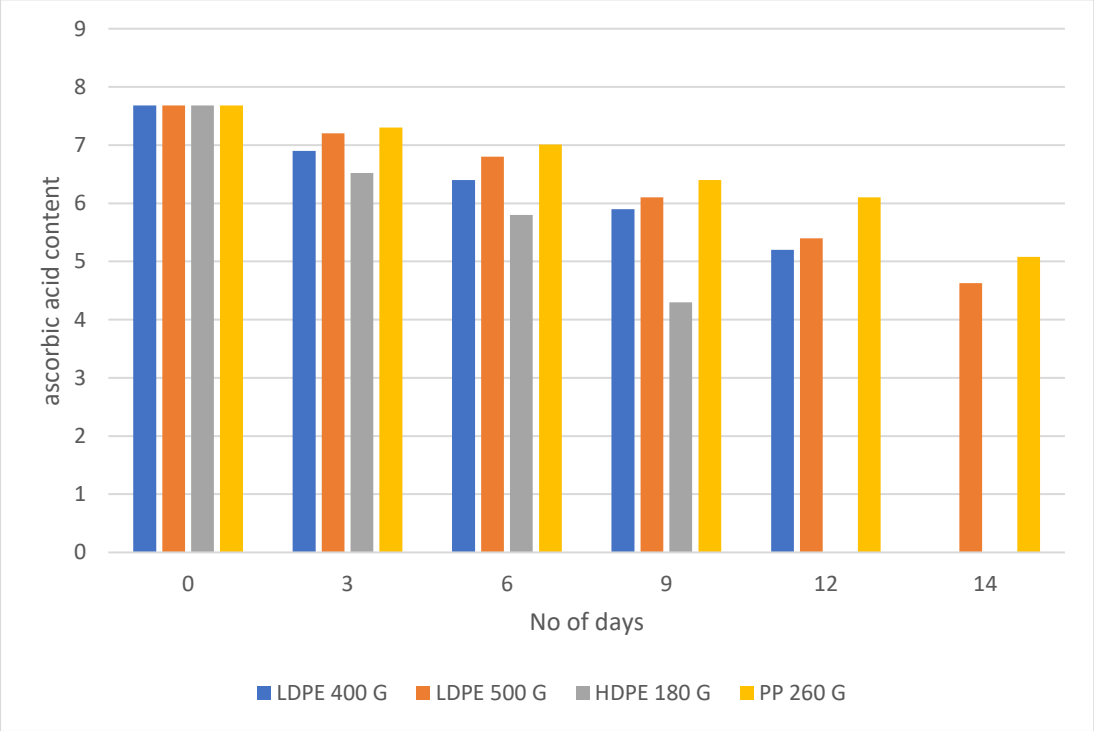


Figure 4.1 change in ascorbic acid during storage period

4.2.4.2 Effect of vacuum packaging on ascorbic acid content (room temperature)

From the table 4.5 we can observe that vacuum packed jackfruit seed stored at room temperature has a maximum shelf life of 9-10 days. LDPE 500G has got more shelf life than that of LDPE 400G because of the air penetration in the lower gauge. HDPE 180G has got the poor storage shelf life of maximum three days and after that, by visual inspection attack of fungi can be found out. PP of 260G has got more shelf life compared to the other packaging materials and got ascorbic retention value of 4.02mg/100ml. this fungal attack can be due to

the moisture penetration through films. The temperature variation can also act as a reason for oxidation of ascorbic acid. Many studies showed that during the storage period of vegetables and fruits the ascorbic acid retention is an important factor to be considered.

Table 4.5 Effect of vacuum packaging on ascorbic acid content (Room temperature)

	Ascorbic acid content(mg/100g)			
Days	**LDPE 400G**	**LDPE 500G**	**HDPE 180G**	**PP 260G**
0	7.68	7.68	7.68	7.68
3	6.00	6.20	5.70	6.56
6	4.70	5.30	-	5.50
9	-	3.90	-	4.02

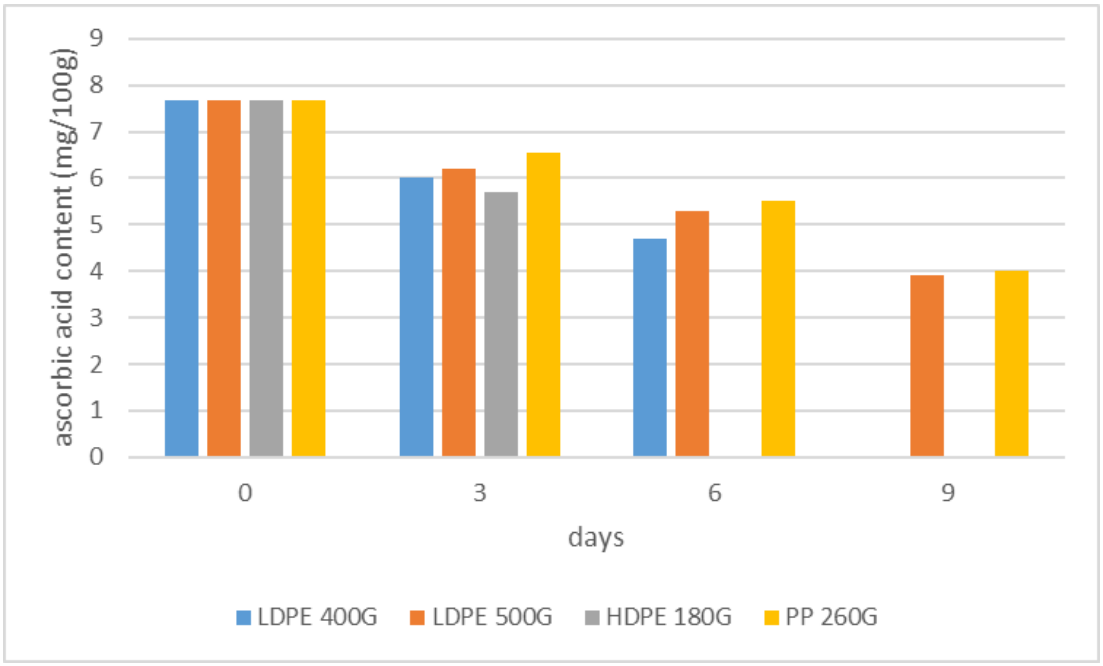


Figure 4.2 Change in ascorbic acid during storage at room temperature.

4.2.4.3 Effect of vacuum packaging on titrable acidity content (refrigerated temperature)

Changes in titrable acidity content under refrigerated condition are presented in Table 4.6. The titrable acidity levels in all the samples exhibited slight decrease during storage. Higher retention of titrable acidity was observed when the packaging material of PP 260G used (0.34%). while using LDPE 500G shows better result than LDPE 400G. The air penetration was more in HDPE 180G package and it gives a shelf life approximately 10 days. The probable reason for this variation may be due to the anaerobic respiration of seeds.

Table 4.6 Effect of vacuum packaging on titrable acidity content (refrigerated temperature)

	Titrable acidity (%)			
Days	**LDPE 400G**	**LDPE 500G**	**HDPE 180G**	**PP 260G**
0	0.45	0.45	0.45	0.45
3	0.39	0.41	0.39	0.41
6	0.35	0.39	0.35	0.40
9	0.31	0.35	0.32	0.38
12	0.29	0.34	-	0.35
14	-	0.32	-	0.34

The figure 4.3 shows the graphical representation of table 4.6

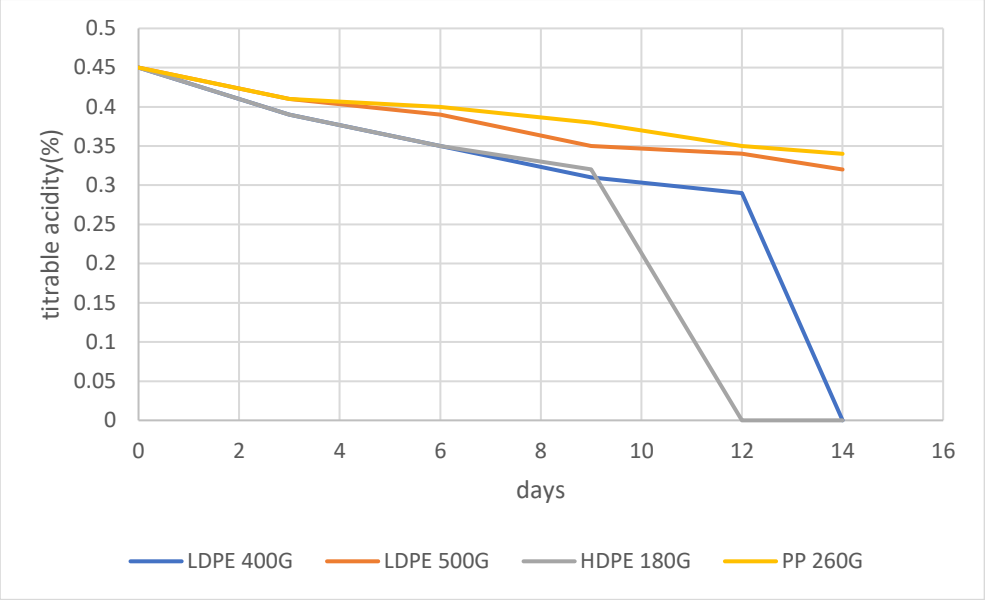


Figure 4.3 change in titrable acidity during storage at refrigerated condition.

4.2.4.4 Effect of vacuum packaging on Titrable acidity content (room temperature)

From the table 4.7 we can observe that vacuum packed jackfruit seed stored at room temperature has a maximum shelf life of 9-10 days. LDPE 500G has got more shelf life than that of LDPE 400G because of the air penetration in the lower gauge. Fungal attack was visible during the third day of storage in HDPE 180G. PP of 260G has got more shelf life compared to the other packaging materials and got titrable acidity value of 0.28%. The temperature difference in storage shows much significant effects on acid content.

Table 4.7 Change in titrable acidity(room temperature).

	Titrable acidity (%)			
Days	**LDPE 400G**	**LDPE 500G**	**HDPE 180G**	**PP 260G**
0	0.45	0.45	0.45	0.45
3	0.30	0.38	0.32	0.40

6	0.21	0.32	-	0.34
9	-	0.25	-	0.28

The figure 4.4 shows the graphical representation of table 4.7.

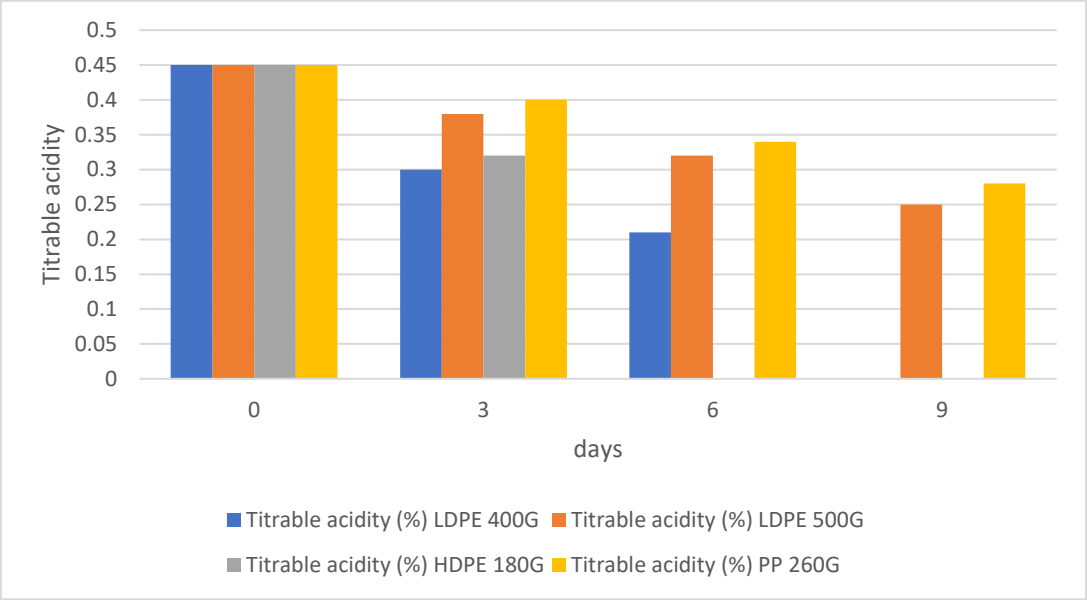


Figure 4.4 Change in titrable acidity during storage at room temperature.

4.2.4.5 Effect of vacuum packaging on TSS content (refrigerated temperature)

Table 4.8 Change in TSS (refrigerated temperature)

	TSS (°Brix)			
Days	**LDPE 400G**	**LDPE 500G**	**HDPE 180G**	**PP 260G**
0	8.01	8.01	8.01	8.01
3	7.8	7.9	7.6	7.7
6	7.6	7.5	7.35	7.5
9	7.3	7.2	7.2	7.3
12	6.9	7.1	-	7.2
14	-	6.8	-	7.1

Changes in TSS content under refrigerated condition are presented in Table 4.8. The TSS levels in all the samples exhibited slight decrease during storage. Higher retention of TSS was observed when the packaging material of PP 260G used (7.1°Brix). While using LDPE 500G shows better result than LDPE 400G. The air penetration was more in HDPE 180G package and it gives a shelf life approximately 10 days. The figure 4.5 shows the graphical representation of table 4.8

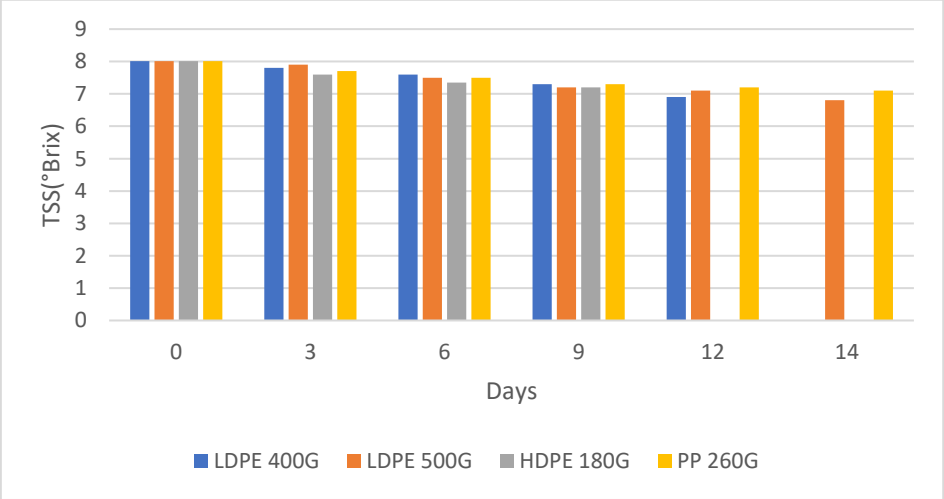


Figure 4.5 Effect of vacuum packaging on TSS content (refrigerated temperature)

4.2.4.6 Effect of vacuum packaging on TSS content (room temperature)

From the table 4.9 we can observe that vacuum packed jackfruit seed stored at room temperature has a maximum shelf life of 9-10 days. LDPE 500G has got more shelf life than that of LDPE 400G because of the air penetration in the lower gauge. HDPE 180G has got the poor storage shelf life of maximum three days and after that fungal attack can be seen visually seen. PP of 260G has got more shelf life compared to the other packaging materials and got TSS value of 6.8°Brix

Table 4.9 Change in TSS (room temperature)

	TSS(°Brix)			
Days	**LDPE 400G**	**LDPE 500G**	**HDPE 180G**	**PP 260G**
0	**8.01**	**8.01**	**8.01**	**8.01**
3	**7.6**	**7.8**	**7.4**	**7.7**
6	**6.9**	**7.1**	**-**	**7.2**
9	**-**	**6.6**	**-**	**6.8**

The figure 4.6 shows the graphical representation of table 4.9

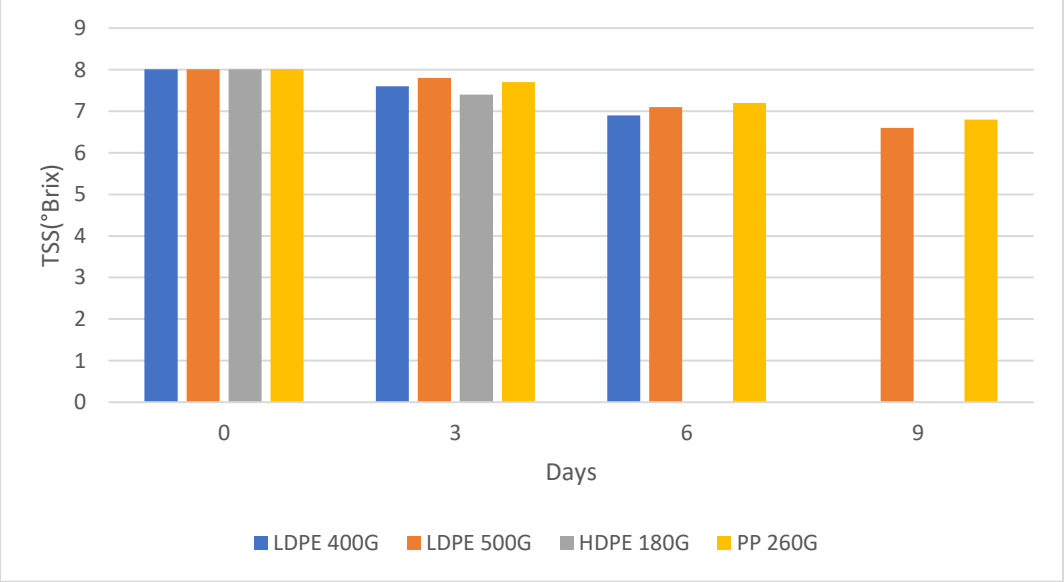


Figure 4.6 Effect of vacuum packaging on TSS content (room temperature)

4.2.4.7 Microbial plate count

The microbial safety of minimally processed food products is very important since these products are consumed raw with no intervening processing steps. The results of the microbial analysis giving the microbial profile in terms of total plate count are presented in Table 4.10. Vacuum packaging was found to be very effective in controlling the microbial growth in packages.

Plate 4.3 Initial microbial load on minimally processed jackfruit seed

Table 4.10 Microbial counts

	Microbial load (cfu/gm)			
Days	**LDPE 400G**	**LDPE 500G**	**HDPE 180G**	**PP 260G**
0	5	5	5	5
3	52	18	80	14
6	58	28	113	25
9	65	35	157	33
12	70	47	TNTC	42
14	TNTC	56	TNTC	54

PP 260G shows maximum shelf life with minimum microbial load. Comparing all the four-packaging material PP 260G and LDPE 500G shows maximum storage performance, while the other two are not preferable for long term storage of jackfruit seed. Figure 4.7 Shows the graphical representation of table 4.10

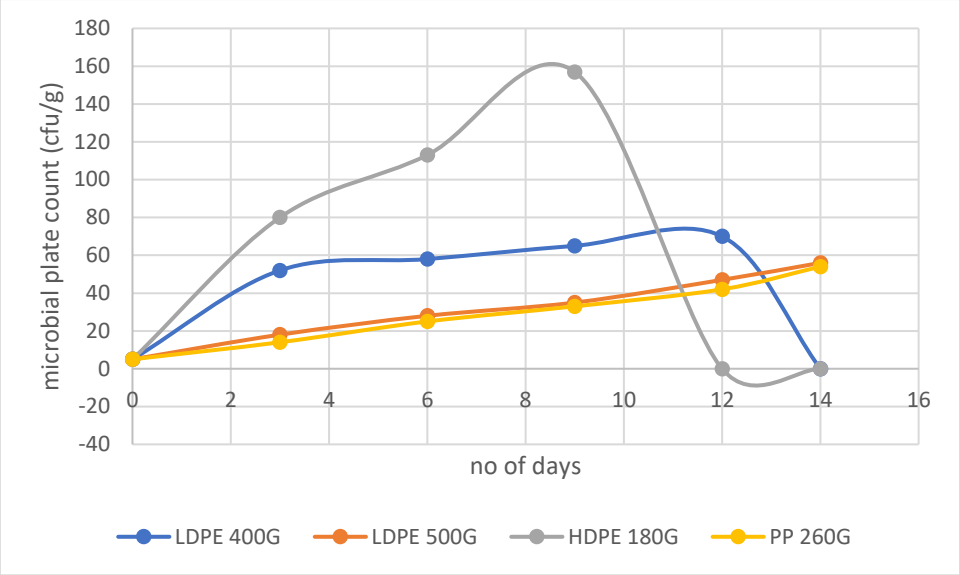


Figure 4.7 microbial growth on packaged product

CHAPTER V

SUMMURY AND CONCLUSION

Jackfruit is a seasonal organic fruit and it is popularly used as vegetable in its tender stage and fruit in ripened stage. This under exploited fruit is considered as heavenly fruit by the ancient people in Kerala because of its nutritive composition. Though it is a highly nutritious commodity, the post-harvest wastage is huge due to its perishable nature.

The most underutilized part of a jackfruit is its seed, which have high nutritional value. Availability of jackfruit seed as a product is very much limited in local markets as well as in foreign markets. Now a days, consumers are preferring mostly minimal processed fresh like products. The objective of our study includes converting jackfruit seed into ready to cook forms along with production of jackfruit seed powder by wet processing. The jackfruit seeds were vacuum packed without addition of preservatives to produce ready to cook jackfruit seed.

It was found that vacuum packaging is an effective method to enhance shelf life up to 2-2.5 weeks when stored under refrigerated condition. Comparatively lower changes were observed in ascorbic acid content, Titrable acidity and, TSS on storing under above mentioned condition. Storage studies were conducted and effect of vacuum packaging on jackfruit seed stored in different packaging materials (LDPE 500 G, LDPE 400 G, PP 260 G, HDPE 180 G) were investigated. LDPE 500 G and PP260 G showed best results out of the four packaging materials. From the results we came to a conclusion that PP 260 G can be used for refrigeration, transportation and for export of jackfruit seeds.

The second objective of our research was to produce jackfruit seed flour by wet processing at different temperature combination for production of the flour and comparison with dry processed powder. Through the studies and results, it was found that the best method to produce jackfruit seed powder commercially is by dry processing method.

Following possible modification could be done in future research;

1. Modified atmospheric packaging of the jackfruit seeds
2. Packaging of seeds using different pre-treatments and preservatives
3. Vacuum packaging of cut seeds after pre-treatments

CHAPTER V

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APPENDIX I

CALCULATION OF OPERATING COST

Initial cost (C)

Average life of vacuum packaging machine(L)=10 years

Cost of the machine =67,000

Working hours per year(H)=1500 hrs

Salvage value(S)=10%of initial cost

A. Fixed cost

1. Depreciation = C-S/L*H
   =67000-6700/10*1500
   =4.02/Hr
2. Interest on investment at 12% =(C+S) *12/(2*H)
   =
   (67000+6700)*12/(2*1500*100)
   =.491/Hr
3. Total fixed cost=depreciation + interest on investment at 12%
   =4.02+.491=4.511/Hr

B. Variable cost

4. Labour wages =62.5/hr
5. Repair and maintenance cost at 10% of cost per annum =67000*10/1500*100
   =4.466/hr
6. Total operating cost = 66.966 +4.511 =71.477
7. Total operating time per packet =20 mnts
8. Total operating cost per packet = 20*71.477/60=23.825
9. Cost of jackfruit seed per packet(500gm) = 18
10. Total cost =18+23.825= 41.825 Rupees

COMMERCIAL UTILIZATION OF JACKFRUIT SEED

By,

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ABSTRACT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology

In

Food Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Processing and Food Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM

KERALA, INDIA

2019

ABSTRACT

Jackfruit is a homestead fruit found predominantly in tropical areas. The fruit is regarded as the state fruit of Kerala primarily owing to its nutritional benefits it possesses. Though the fruit has immense potential of utilization, the main factor which hinders its full utilization is the non-availability of the produce in the off season. Seed of jackfruit is one of the most underutilized part of the produce. In addition, the lack of ready to use form in the market is also an issue. With regard to the issues at hand a study was conducted to make jackfruit seed in ready to use form.

The study investigated on the usage of different packaging materials for the jackfruit seed to preserve the seed in ready to use form. Taking into account of the cost incurred for the packaging and other benefits vacuum packaging was used for the study. Various packing materials as LDPE 500 G, LDPE 400 G, PP 260 G and HDPE 180 G were taken into study for enhancing the shelf life of the jackfruit seed. The study substantiated the use of PP 260 as packing material considering the characteristics of packaging. A comparative evaluation of jackfruit seed powder by dry and wet processing was also performed. The evaluation showed that the characteristic of seed powder had non-significant variation. Taking into account of the drudgery of the process involved, dry process method has appreciable acceptance.