DEVELOPMENT OF AN EXTRUDED PRODUCT FROM RAW JACKFRUIT

by

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(2013-16-105)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN HOME SCIENCE

(Food Science and Nutrition)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF HOME SCIENCE

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2015

DECLARATION

I, hereby declare that this thesis entitled **"DEVELOPMENT OF AN EXTRUDED PRODUCT FROM RAW JACKFRUIT"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Acknowledgement

Cicero, Rome's greatest speaker and a writer of verse and letters had written that "Gratitude is not only the greatest of virtues, but the parent of all others. I therefore chose to place on record, my sincere gratitude to all the following individuals without whom this thesis wouldn't have materialised.

At the foremost my deepest gratitude to my major advisor, Dr. Suma Divakar, Assistant Professor (S.S), Department of Home Science, for her inspiring guidance, timely advice and constant encouragement throughout the course of my study without which this work would not have seen the light of the day. Her unbound motherly affection and understanding helped me to overcome many situations of crisis and recover when my steps faltered. Her advice in my career as well as in my personal life has been priceless.

It is with immense gratitude, I acknowledge Dr. Mary Ukkuru, Professor and Head, Department of Home Science, for her scientific advice, keen interest, constructive criticism during the course of work. My deep appreciation goes to Dr. P.V Nandini, Professor, Department of Home Science for always selflessly chastening me for the successful completion of my thesis.

No words can truly represent my deep sense of gratitude to Dr. Meena Kumari, Professor and Head, Department of Microbiology for her wholehearted help, valuable suggestions, critical scrutiny constant encouragement and suggestions at various stages of the study.

I sincerely express my profound gratitude to Dr. J.T Sheriff, Head of the Department of crop processing technology (CTCRI) for the help and unstinted co-operation rendered in the completion of work.

I account my sincere thanks to Dr. Elsamma Job, Professor, Department of Ag. Economics, for inspiring and motivating me with suggestions regarding work which made me to look at her with awe and respect. I remember with gratitude the co-operation of Mrs. Brigit Joseph, Associate Professor, Department of Agricultural statistics for her help in the completing the statistical analysis of the data.I avail this opportunity to Dr. B. Aparna, Assisstant Professor, Department of Soil Science for her wholehearted help and concern during the analysis work of research.

I cordially offer my sincere thanks to Dr. Prassana Kumari, Dr.C. Nirmala, Dr. Soffi Cheriyan, Dr. Gita, Dr. Rari John and Dr. Anitha of the Department of Home Science, for their immense help and cooperation rendered throughout this *research endeavour. It was my great privilege and pleasure to have the best help and cooperation from Binu chetta and Manju chechi, the staff members of Department of Home Science.*

I express my gracious thanks to Kerala Agricultural University for providing me the KAU fellowship.I deem it my privilege in expressing my obligation to Mrs Leela Ranisaha, Mrs. Gitanjali, Dr. Usha Singh and Dr. Mukul Sinha, Professor, Rajendra Agricultural University for their encouragement. My acknowledgement will be incomplete if I don't mention my gratitude to Balchandran, Rajagopal, Suleman, Leena and Sindhu, hostel staff for their parenting care and wholehearted support to complete this dissertation against all odds.

From the depth of my heart I thank my seniors Krishnendu, Saima, Lakshmi, Nilesh, Aashish and Preetin and express my love and affection to my loving juniors Ambika, Asmita, Anjali, Soumya, Priya, Aswathy, Siji, Dona and Athira for their help and support at the different stages of this study.

I submit oceans of thanks to my dearest friends Megha, Aishwarya, Soumya, Vaishakhi, Aswathy, Anju, Keerti, and Joggy for helping me to stay focused and *overcome the setbacks during my research, and sincere regards to my classmates Neethu, Aparna and Suma for their help.*

Words fail to express the love and appreciation I have for my best friends, Ravi, Abhinav and Chattrapal. Our relationship has only grown fonder and stronger through the perils of life. As the saying goes "When the going gets tough the tough gets going". Thanks for being there for me.

No words in this mortal world can suffice to express my feelings towards my father Hari Krishna Roy, mother Moti devi, Sister Reena and brother Navneet for their unconditional love, blessings and patience.

I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

Above all I bow my head before Almighty for the blessings showered on me during the course of my study and also at all other times when I needed it most for ramifying the paths of thick and thin of my efforts.

Veena Kumari

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LIST OF ABBREVIATIONS AND SYMBOLS USED

Cfu/g	Colony forming unit per gram
Fig	Figure
OVQ	Overall visual quality
HDPE	High density polyethylene
et al.	And others
i.e.	That is
IU	International unit
Rpm	Rotation per minute
RDA	Recommended dietary allowances
T_1	Treatment 1
T_2	Treatment 2
T_3	Treatment 3
T_4	Treatment 4
T_5	Treatment 5
T_6	Treatment 6
T_7	Treatment 7
pH	Potential of hydrogen
HTST	High temperature short time
KMS	Potassium meta bi-sulphite

NS	Not significant
CD	Critical difference
ND	Not detected
g/cm^3	gram /centimeter cube
RF	Refined flour
RJBF	Raw jackfruit bulb flour
RJSF	Raw jackfruit seed flour
g	gram
Kcal	Kilocalories
Mg	Milligram
m	Meter
cm	Centimeter
mm	Millimeter
mL	Milliliter
min	Minutes
hrs	Hours
^0C	Degree Celsius
^0F	Degree Fahrenheit
@	At the rate of
%	Percentage

APPENDIX

INTRODUCTION

1. INTRODUCTION

Food is a physiological necessity; eating food is also a source of pleasure and therefore demands quantity, quality and variety (Ali, 2006). Health whether physical, mental and spiritual is immensely influenced by the quantity and quality of food consumed. As the saying goes, “A man is what he eats”.

Food is mostly procured from agriculture which is a complex, laborious, time consuming, sensitive and capital intensive activity. India produces about 770 million tonnes of raw food commodities of plant and animal origin, which are processed and transformed into edible forms, so to make them palatable, nutritious and storable.

The two major goals of processing technology are the prevention of loss of produce and value addition through preservation and processing. At every stage of processing, value is added to the products. Agricultural commodities with added value in terms of nutritional enrichment or long shelf-life or both, attract higher premium in the market, while contributing to the national goal of achieving nutritional security. It also helps the farmers by way of curtailing losses of perishables. Modern food technology has achieved significant developments in the mass production of nutritious foods like high- energy, high protein and high fibre foods, which suits various physiological requirements.

Today, consumer demand is for much more than just safe and shelf stable food. They demand higher quality food with greater convenience. Moreover, their demand is for food products that are novel, wholesome, nutritious and convenient but still retain their natural characteristics as much as possible. At the same time, food processors look for more energy efficient, cost-effective and high-speed processing technologies.

In the scenario of health and changing life styles, the demand for ready to cook foods like extruded foods has increased considerably. This is mostly due to, change in perceptions, economic considerations, westernization, urbanization, busy time schedules, increased employment of women, increased per capita income, shifting to nuclear families, innovative kitchen applications, media proliferation etc. Indian cuisine and life styles have undergone tremendous changes over the last few decades (Anand, 2011).

Foods made with refined ingredients mostly are energy dense with less fibre and therefore have little to excrete from the digestive system leading to constipation, flatulence, bloating and even colon cancer. Therefore development of functional foods has been necessitated not only with the aim of improving the nutritional status of the general population, but also for preventing degenerative diseases like digestive and cardiac disorders which are associated with the present day's changing life styles and environment. This has geared food manufacturers to explore and formulate new food products (with improved taste, texture and appearance) and also use traditional food products. It is realised that there is ample scope to include locally available raw materials, which would reduce the cost of raw materials.

The development of new products is a strategic area of food industry. Consumers are demanding foods that primarily show two main properties. The first dealing with the traditional nutritional aspects of the food, whereas, as the second feature being added health benefits that are expected from its regular ingestion. These kinds of food products are often called nutraceutical foods.

Among ready to cook foods 'noodles' forms an important part of the urban dietary. But these products are pointed out to be rich in starch, fat and energy but lack fibre. The popularity of noodles particularly in Asian countries is increasing because of its simple preparation, desirable sensory attributes, and long shelf life augmented with product diversity and nutritive value. As the world market is expanding, studies on the development and improvement of the quality of noodles that satisfies the consumer is needed. In a rapidly changing world, with altered food habits and stressful lifestyles, it is more and more recognized that healthy intestinal health is an essential requirement for determining the overall quality of life (Brouns *et al*., 2002).

Various epidemiological studies have shown that the diet lacking in fibre may be the cause of various lifestyle disorders including gastrointestinal and cardiovascular diseases (Kumari and Grewal, 2007).

Wheat flour is the main ingredient used in the manufacturing of noodles, as physical characteristics of wheat flour are suitable for noodle making. In recent years, the demand to use novel sources as substitute for wheat flour has increased. Studies reveal that flours from alternative sources such as banana, tapioca, and cauliflower etc. are being used as a potential refined flour substitutes in noodles for imparting variety and functionality to the product.

Most processed foods are seen to be cereal based, which therefore stand back with regard to their nutritional quality. Use of the abundant supplies of underexploited agriculture produce like jackfruit in countries like India to substitute cereal flours in products like noodles, will not only reduce the excessive dependence on cereal grains, but also improve the imbalance of nutrients through consumption of refined products.

Therefore, keeping in view the above facts and also the market prospects of the composite flour noodles, this study was planned with the objective to develop a raw jackfruit flour based noodles and assess its functional properties and quality characteristics.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature of the present study entitled "Development of an extruded product from raw jackfruit" is presented under the following subheads:-

2.1 Jackfruit, the ethnic underexploited crop

2.2 Nutritional and health benefits of jackfruit

2.3 Scope for value addition in raw jackfruit

2.4 Prospects of extruded products

2.5 Studies on quality improvements of noodles

2.1 JACKFRUIT, THE ETHNIC UNDEREXPLOITED CROP

Jackfruit (*Artocarpus heterophyllus* L.) tree is a popular tree in tropical homegardens and perhaps the most widespread and useful member of the genus, *Artocarpus.* It belongs to the family *Moraceae* and the fruit is a favourite of many, which is mostly due to its characteristic sweetness.

The word *Artocarpus* is derived from the Greek word '*artos*' meaning (bread) and '*carpos*' meaning (fruit) as reported by Bailey (1949). The name "Jackfruit" has its origin from the Protugese word "jaca", which in turn, is derived from the Malayalam term "chaka".

Thus the world's largest fruit is called by a variety of names*, Viz*. 'Kathal', 'Panasa', 'Jaca', 'Nangka', 'Kanoon', 'Mit', 'Pilapalam', 'Halasu' and *Artocarpus heterophyllus*, its scientific name. The common English name jackfruit was first used by the physician and naturalist Garcia De Orta in his book *Coloquios dos simple e drogas da India* in 1953. It is also known as *jacque* or *jacquier* in French and *jaca* in Spanish (Popenoe, 1974).

The tree is evergreen and monoecious. It is a tropical fruit species found in the coastal, high rainfall and humid areas of the world. Jackfruit is a popular fruit ranking next to mango and banana. The fruit is considered as the poor man's food owing to the numerous culinary uses of unripe, ripe and tender immature fruit.

The tree is medium-sized and evergreen, typically reaching 8–25 m (26–82 ft.) in height. It is easily recognized by its fruit, the largest in the fruit family (Goswami *et al*., 2010). It is a high yielding crop which bears fruits all year round with the peak production during the months of June and December (Ong *et al*., 2014).
Jackfruit is widely cultivated in the tropical regions of India, Bangladesh, Nepal, Srilanka, Vietnam, Thailand, Malaysia, Indonesia and Philippines. Jackfruit is also found across Africa, Cameroon, Uganda, Tanzania, and Mauritius as well as throughout Brazil and Caribbean nations such as Jamaica. However, India is considered to be the native land of jackfruit (Priya *et al*., 2014).
Orchards in Malaysia report a yearly production of 37,500 pounds per hectare. Ken and Robert (2011) reported that nearly, 935965 tons of jackfruit comes annually from an area of 9977 hectares at the rate of 93.81 tons per hectare in Philippines while in India had more than 2,52,000 acres in jackfruit production.
It is grown only in certain parts of India and is found to be popular only in the growing regions. The trees are found distributed in the southern states like Kerala, Tamilnadu, Karnataka, Goa, coastal Maharashtra and other states like Assam, Bihar, Tripura, Uttar Pradesh and the foothills of Himalayas (APAARI, 2012).
The tree is also known for its remarkable, durable timber, which ages to an orange or redish-brown colour. The waste from the leaves and fruits provide valuable fodder for cattle, pigs, and goats. Most parts of the tree including the bark, roots, leaves and fruits are attributed with medicinal properties. Wood chips yields a dye which is used to give the famous orange-red colour to the robes of Buddhist priests (Jagadeesh *et al*., 2006).

The tree can provide many environmental services. It is highly wind tolerant and therefore makes a good component in a windbreak or border planting.

When grown in pastures, it can provide fallen fruits for livestock along with giving shade, and long-term timber. In home gardens, the dense jackfruit canopy can provide a visual screen and is considered very ornamental (Shyamalamma *et al*., 2008).

The fruit matures within 6–8 months after flowering. Depending on rainfall, irrigation, and age of tree, jackfruits can produce 20 to 250 fruits per year, sometimes even up to 500 fruits. Harvest indicators include a hollow sound when tapped, change of skin colour, increased odour, and a flattening of spines. The compound or aggregate fruit is green to yellow when ripe, weighing 4.5-50 kg. Fruits are oblong-cylindrical in shape, typically 30-40 cm (12–16 inch) in length but sometimes even up to 90 cm (35inches). The heavy fruit is held together by a central fibrous core. The interior of the fruit consists of large bulbs of yellow banana-flavoured flesh and each bulb encloses a smooth, oval, light- brown seed. There may be 100-150 seeds in a single fruit (Mamtha and Mahesh, 2014).

The heavy fruit is borne primarily on the trunk and the interior part of main branches. Fruits take 90–180 days to reach maturity. In the Northern hemisphere, the main bearing season is the late spring to early fall (March-September). A few fruits mature in winter or early spring (Shyamalamma *et al*., 2008).

This large and interesting fruit is categorized into 2 major types, based on the quality of the pulp. The first type comprises the fibrous, thin, soft and musky ones ranging from sour to very sweet, emitting a strong aroma when ripe. The second type has a thick edible pulp, which is firm and crisp and less odorous. The second type is more accepted among consumers of Kerala. They are referred to as 'Kuzha' and 'Varikkya' respectively (Anon, 2004).

The value of its versatility is enhanced by its availability during the monsoon period when the supply of other vegetables is low. Jackfruit is consumed both as a vegetable in the unripe stage and also as a fruit when ripe (Ong *et al*., 2014). Unripe jackfruit has a meat-like taste when used in curry dishes with spices in the cuisine of Bihar, Jharkhand, Andhra, Eastern-India, Bengal, Odisha and Kerala.

Jackfruit has unique organoleptic qualities with regard to smell and taste and nutritive properties that makes it desirable for commercial success in many countries, especially in the United States of America (Saxena *et al*., 2009).

Although many people prefer jackfruit for its delicious taste, quite a few are unaware of its related health benefits. It is known for its high nutritional and medicinal values. Jackfruit is rich in fibres, calcium, phosphorous, potassium, magnesium, vitamin C and carbohydrate. It has a high sugar content and antioxidant activity and less calories, which is beneficial for health. The concentration of carbohydrate is around 22 per cent, thus indicating its potential for the production of fermented beverages (Amit and Ambarish, 2010)

Jackfruit bulb is usually consumed fresh, as it has a low shelf life, i.e. 2-3 days, after which they will start to rot. Therefore, it is necessary to process the fruit and transform it into different food products to give it an economic value. Improvement of postharvest handling practices to minimize these losses will not only contribute to increasing the income of rural farmers, but would also ensure the availability of superior quality produce to the consumer at reasonable prices (Sharma *et al*., 2013).

Though India is one of the leading producers of fruits, it is unfortunate that most of the fruits do not reach the table of consumers. There is a loss of around 40% of produce per year. The reasons can be attributed to improper postharvest methods, and underutilization of fruits for value added products. Among the fruit crops, jackfruit tree produces abundant fruits every year, even under neglected conditions. In India, the fruit is not utilized properly. When viewed globally this is an excellent example of a food prized in some countries and allowed to go waste in others.

Priya *et al*. (2014), reported that India, as country has neglected this kalpavriksha since a long time. The consumption of jackfruit is disproportionate to the fruit production in the state. The key reasons for this situation are, that 60-70 per cent of the trees produce very soft fleshed fruits, rendering them less preferred for dessert purpose. Moreover the availability of fruits during June –

July coincides with peak monsoons. Harvesting becomes difficult in this condition and water seepage affects the quality of the fruits. This situation can be avoided by handling and processing the jack fruit before monsoon.

Since, harvested fruits are living entities; they continue to perform metabolic functions in the post-harvest state. Quality deterioration of harvested fruits is the result of a combination of physiological, mechanical, microbiological and environmental conditions.

Jackfruit is categorised as a climacteric fruit. Depending on the cultivar, the optimum storage temperature is 13 ± 1^0C, with potential postharvest life of 2-4 weeks. Tropical fruits are not normally stored at temperatures lower than 13^0C. Fruits exposed to temperatures below 13^0C results in chilling injury, shown by dark-brown discolouration of the skin, browning of pulp and development of off-flavour, followed by susceptibility to decay. The storage life is influenced greatly by the initial quality and maturity of the jackfruit (Kader, 2009).

The fruit is very much perishable and cannot be stored for long time because of its inherent compositional and textural characteristics. Every year, a considerable amount of jackfruit, which is specially obtained in the glut season (June-July) goes waste both in quality and quantity due to lack of proper postharvest knowledge during harvesting, transporting and storing (Molla *et al*., 2008).

APAARI (2013) reported that the fruit is very heavy making its transportation difficult. Proper postharvest technology for prolonging shelf life is therefore, necessary. Besides, alternate ways of using jackfruits in season plays significant roles in reducing postharvest losses. Among the various methods, processing is an important one. It not only adds diversified and attractive food items in the dietary menu but also contributes to generation of income and employment (Mondall *et al.,* 2013).

In tropical areas, there are several factors negatively affecting the quality of this produce, resulting in great losses to the fruit. This leads to rapid decay due to microbial agents. In Kerala conditions, high temperature and relative humidity worsens the conditions which leads to the attack of fruit by fungi causing important produce losses (Juan *et al*., 2011).

Jackfruit seeds make up around 10 to 15% of the total fruit weight and have high carbohydrate and protein contents. Mostly the seeds are discarded as waste, except sometimes when they are boiled or roasted for consumption. As the seeds are recalcitrant and germinate immediately after maturity, it is quite tough to store fresh seeds for long time. Due to the lack of awareness on processing and preservation techniques, huge amounts of jackfruit seeds are destroyed every year in. As a result, a large amount of jackfruit seeds remain unused (Ocloo *et al*., 2010).

As fresh seeds cannot keep for long time, seed flour can be an alternative ingredient in some food products. The starch content of the seed increases with maturity. Jackfruit seeds contain great amount of nitrogen. Jackfruit seed flour can be an alternative ingredient to be used in bakery and bread preparations in particular (Hasidah and Aziah, 2003). Jackfruit seed powder has a lot of potential in food, cosmetics, pharmaceuticals, paper, and bio-nanotechnology industries. Its uses in food industry as a thickener and binding agent are noteworthy (Theivasanthi and Alagar, 2011).

The succulent, aromatic, and flavourful jackfruit is eaten fresh or preserved in myriad ways. Recently, more products based on jackfruits have been developed from raw, tender and ripe fruits with their seeds (Anon, 2004). Other than canning, advances in processing technologies too, have brought in more new products. Freeze-dried, vacuum fried and cryogenic freezing and such advanced preservation methods have ushered new jackfruit based products. There is more scope for processing of raw jackfruit into durable and nutritious food products (Mondall *et al.,* 2013).

Jackfruits for export market are usually in whole-fruit forms. The high freight cost of bulk fruits and the fact that only about 40% of the fruits are edible does not make jackfruit cost-effective for local farmers. Hence, new developments in the processing of jackfruit, especially to ensure suitable shelf life for export purposes are very important (Anon, 2008).

Jackfruit is found in abundant quantities but remain underutilised due to its cumbersome handling procedures. Presently it is of less importance than any other fruits. However it is an excellent source of nutrients. It has the scope to be utilised as a source of income for subsistence to many farm families. With the aim of acquiring food security to the community, it has become necessary that proper postharvest measures and value addition is applied to make jackfruit commercially viable.

It is heartening to note that more and more people are realizing the importance of jack fruit. With good awareness campaign and training, jack fruit can contribute in a big way to local food security (Priya *et al*., 2014)

2.2 NUTRITIONAL AND HEALTH BENEFITS OF JACKFRUIT

2.2.1 Nutritional benefits

Fresh fruits contain health promoting constituents, including antioxidants, minerals, vitamins, (such as A, C and E) phytochemicals, (such as folates, glucosinolates, carotenoids, flavonoids and phenolic acids, lycopene, selenium) and dietary fibres along with being relatively low in calories (Murcia, 2009).
Jackfruit is valued for its moderate in calorie content. Mukprasirt and Sajjaanantakul (2004) reported that 100 gram of edible jackfruit bulbs provide 95 calories. The fruit is made of soft, easily digestible flesh (bulbs) with simple sugars like fructose and sucrose that when eaten replenishes energy and revitalizes the body right away (Ko *et al*., 2003).

Saxena *et al*. (2009) reported that, it is a rich source of dietary fibre and vitamins such as ascorbic acid and thiamine. Jackfruit is a good source of pro-vitamin A, though not as good as papaya (Chandrika *et al*., 2005). It contains very good amounts of pyridoxine, niacin, riboflavin, and folic acid (Ejiofor and Owuno, 2013).

Every 100 grams of jackfruit (pulp) contains 84 per cent water, 18g carbohydrates, 1.9g proteins, 0.1g fat, 1.1g fibre, 30 mg calcium, 287 mg potassium, 0.5 mg iron and 50 IU of vitamin A , (Abraham *et al*., 2004) . A portion of jackfruit pulp of 100 g provides 4 mg niacin, when the recommended daily allowances for niacin is 16 mg for males and 14 mg for females (Soobrattee *et al*., 2005). Jackfruit is also rich in nutrients such as sodium, potassium, iron, calcium, zinc, and many other nutrients (Goswami *et al*., 2010). The table given (Table 1.) depicts the nutritional profile of jackfruit (Azad, 2000).

A total of 23 compounds were identified in jackfruit, esters being the major group contributing to its flavour. Jackfruits are known for having a distinct aroma. In a study using five jackfruit cultivars, the main volatile compounds detected were: ethyl isovalerate, 3-methylbutyl acetate, 1-butanol, propyl isovalerate, isobutyl isovalerate, 2-methylbutanol, and butyl isovalerate.

Defaria *et al*. (2009) reported that jackfruit contains many carotenoids, including all-trans-*β*-carotene which is an important antioxidant for human health. The main carotenoids in jackfruit were revealed to be all-translutein (24% to 44%), all-trans-*β*-carotene (24% to 30%), all-transneoxanthin(4% to 19%), 9-cis-neoxanthin (4% to 9%), and 9-cis-violaxanthin (4% to 10%). The carotenoids of *A. heterophyllus* were identified as the alpha carotene, alpha zeacarotene, alpha zeacarotene, and alpha carotene-5,6- epoxide, as well as a dicarboxylic carotenoid and crocetin (Chandrika *et al*., 2005). Some 18 carotenoids were successfully separated, identified, and quantified by HPLC-PDAMS/ MS. Lycopene was also identified, despite the soft colour of the jackfruit pulp (Defaria *et al*., 2009).

A. heterophyllus contains various chemical constituents namely morin, dihydromorin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, artocarpesin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone, and artocarpanone.

Table 1. Nutritional profile of jackfruit

Sl. No	Composition	Young fruit	Ripe fruit	Seed
1.	Water (g)	76.2 to 85.2	72.0 to 94.0	51.0 to 64.5
2.	Protein (g)	2.0 to 2.6	1.2 to 1.9	6.6 to 7.04
3.	Fat (g)	0.1 to 0.6	0.1 to 0.4	0.40 to 0.43
4.	Carbohydrate (g)	9.4 to 11.5	16.0 to 25.4	25.8 to 38.4
5.	Fibre (g)	2.6 to 3.6	1.0 to 1.5	1.0 - 1.5
6.	Total sugars (g)	-	20.6	-
7.	Total minerals	0.9	0.87 – 0.9	0.9 - 1.2
8.	Calcium (mg)	30.0 – 73.2	20.0 – 37.0	50.0
9.	Magnesium (mg)	-	27.0	54.0
10.	Phosphorus (mg)	20.0- 57.2	38.0 – 41.0	38.0 – 97.0
11.	Potassium (mg)	287 - 323	191 - 407	246
12.	Sodium (mg)	3.0 – 35.0	2.0- 41.0	63.2
13.	Iron (mg)	0.4 – 1.9	0.5 – 1.1	1.5
14.	Vitamin A (IU)	30	175-540	10-17
15.	Thiamine (mg)	0.05 – 0.15	0.03 – 0.09	0.25
16.	Riboflavin (mg)	0.05 – 0.2	0.05 – 0.4	0.11 – 0.3
17.	Vitamin C (mg)	12.0 – 14.0	7.0 – 10.0	11.0

Seeds make-up around 10 to 15% of the total fruit weight and have high carbohydrate and protein contents as reported by Vanna *et al*. (2002). Abraham and Jayamuthunagai (2014) reported that jackfruit seeds have high carbohydrate, protein, dietary fibre, vitamins, minerals and phytonutrients. They are rich sources of protein (13.49%), ash (2.47%) and carbohydrate (70.73%).

The calorific value reported was 357.665 kcal/100g. Jackfruit seeds are good sources of starch (22%) and dietary fibre (3.19%) as reported by Hettiarachchi *et al*. (2011). Tulyathan *et al*. (2002) reported that amylose content of jackfruit seed starch was 32 per cent. Barua and Boruah *et al*. (2004) reported that manganese and magnesium elements have also been detected in seed powder.

Soong and Barlow (2004) reported that jackfruit seeds contain phenolic compounds and about 6.03 mg/g of non-reducing sugars. The compounds of jackfruit identified as prebiotics include oligosaccharides and polysaccharides, such as fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), inulin, and xylo-oligosaccharides, which are non-reducing sugars as reported by Nualla *et al*. (2009).

Prebiotics were extracted by cleaning the jackfruit seeds with water then grinding in a blender to size of 1 to 2 mm. The seeds were extracted with 50% ethanol using batch extractor. To concentrate the extract solution, it was filtered by vacuum filter and then evaporated by rotary vacuum evaporator. The evaporated extract of jackfruit seed was crystallized. The crystallizing temperature of prebiotics was found to be 55 to 64^0C (by using differential scanning calorimeter) and the best temperature to obtain the highest percentage of non-reducing sugar was 58^0C. Moreover, percentage of non-reducing sugar increased with increasing the mixing speed and the best mixing speed identified was 100 rpm (Thitipong *et al*., 2010).

2.2.2 Health benefits

Food is no longer considered as a mere energy and essential nutritional supplier; it is now accepted to be a disease preventing and a disease curing agent.

Realising the role that diet plays in the prevention and treatment of many health disorders, in the recent years, there has been an increased interest on the part of consumers, researchers, and food technologists into food products that can help maintain health (Vinuda *et al*., 2010). Epidemiological studies have shown a strong and consistent protective effect of vegetable consumption against the risk of several age- related diseases such as cancer, cardiovascular diseases, cataract and macular degeneration (Turkmen *et al.,* 2005).

Plant products are considered to be the most important components of human diet for imparting a good health. Fruits and vegetables have proved to exert a protective effect. Fruits and vegetables contain a number of compounds known as phytochemicals which have been found to be responsible for such effects and these include carotenoids, alkaloids, vitamins, minerals and polyphenols.

Research shows that phenolic compounds such as flavonoids and phenolic acids exhibit antioxidant properties. The search for natural antioxidants, especially of plant origin, has notably increased in recent years. In view of this, various fruits and vegetables are under investigation for the detection of these bioactive compounds. Not only the fruits, but their seeds also are considered to be containing large number of bioactive components which can have therapeutic uses (Deepika *et al*., 2011). It is now widely accepted that the beneficial effects of fruits and vegetables for the prevention of certain diseases are due to the bioactive compounds they contain, as reported by Galaverna *et al*. (2008).

Although most people love to eat jack fruit for its sumptuous taste, only a few are aware of the benefits it provides to our body. In spite of the fact that it is high in carbohydrates and calories, the health benefits of jack fruits are numerous.
Artocarpus heterophyllus Lam. is an important source of compounds like morin, dihydromorin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, cycloheterophyllin (C30H30O7), artocarpesin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone, betulinic acid, artocarpanone and

heterophylol, which are useful in the conditions like fevers, boils, wounds, skin diseases, convulsions, diuretic conditions, constipation, ophthalmic disorders, snake bites etc.

Due to the many side effects of using some drugs for ulcer there is a need to find new anti ulcerogenic compounds, with potentially less or no side effects. Medicinal plants have always been the main source of new drugs for the treatment of gastric ulcer (Borrelli and Izzo, 2000). One of the plants that have been traditionally used in Indian and Malay folklore medicine to treat gastric ulcer is *A.heterophyllus L.* (Rates, 2001).

Jackfruit is also used in a traditional medicine as an analgesic and immunomodulator. Immunomodulator activity has been scientifically proved whereas analgesic activity is yet to be scientifically proved (Prakash *et al*., 2013).

Jackfruit is reported to possess many medicinal properties. Jackfruit is gluten-free and casein- free, thus offering systemic anti- inflammatory benefits to skin. Studies proved that jackfruit is the best food to slow down ageing process, it also keeps skin moisture level high and protect from skin disorder. The phenolic compounds isolated from jackfruits are reported to exhibit anti-inflammatory effect (Prakash *et al.,* 2009). The prenylflavones present in jackfruits had shown strong antioxidant properties and is expected to act against lipid peroxidation of biological membranes.

Jackfruit has beneficial nutritional parameters including low glycaemic index (GI). This could be due to the collective contributions of dietary fibre and slowly available glucose. The postprandial glycaemic response to raw and ripe jackfruit elicits low glycaemic index (Hettiaratchi *et al*., 2011). The flavanoids present in the extract have been identified to be responsible for the non-toxic hypoglycaemic action (Chandrika *et al*., 2005).

Phytonutrients are natural compounds found in plant- based foods that give plants their rich pigmentation, as well as their distinctive taste and aroma. They are essentially the plant's immune system and offer protection to humans as well (Umesh *et al*., 2010). Jackfruit contains phytonutrients: lignans, isoflavones, and saponins that have health benefits which are wide ranging. These phytonutrients have anticancer, antihypertensive, antiulcer and anti-aging properties.

Jackfruit is a rich source of phytochemicals, including phenolic compounds, which offers opportunities for the development of value-added products, such as nutraceuticals that offer food applications to enhance health benefits (Umesh *et al*., 2010). Phenolic compounds in fruits and vegetables have been suggested to be a major source of bioactive compounds for health benefits.

The functional component of jackfruit helps to reduce various diseases such as blood pressure, heart disease and strokes, and bone loss. It helps to improve muscle and nerve function by reducing homocysteine levels in the blood. Phytoestrogens are naturally occurring polycyclic phenols found in certain plants that may, when ingested and metabolized, have weak estrogenic effects. Two important groups of phytoestrogens are isoflavones and lignans which are present in jackfruit pulp (Wongsa and Zamaluddien, 2005).

Jackfruit could be considered as a functional food because it has valuable compounds in different parts of the fruit that display functional and medicinal effects. The positive effect of a functional food may include the maintenance of health or wellbeing, or a reduction in the risk of suffering a given illness. Functional foods may be obtained by modifying one or more of the ingredients, or by eliminating some of them (Shrikant *et al*., 2012).

Jackfruit contains many carotenoids, including all-trans-β-carotene which is an important antioxidant for human health (Defaria *et al*., 2009). Carotenoids contained in jackfruit can be important for the prevention of several chronic degenerative diseases, such as cancer, inflammation, cardiovascular disease, cataract, age-related macular degeneration (Stahl and Sies, 2005). Consumption of jackfruit which is rich in vitamin-A and carotenes has been found to prevent lung and oral cavity cancers. It also helps to prevent vision related problems such as macular degeneration and night blindness (Swami *et al*., 2014).

Jackfruit is an excellent source of vitamin C, which helps to protect against viral and bacterial infections. It also helps to strengthen the immune system by supporting the function of white blood cells. One cup of jackfruit can supply the body with a very good amount of this powerful antioxidant. The human body does not synthesise vitamin C, so one must eat foods that contain vitamin C to reap its health benefits. It is an antioxidant that protects the body against free radicals, strengthens the immune system, and keeps our gums to healthy (Umesh *et al*., 2010). It is also vital for the production of collagen, a protein that provides skin with its structure and gives it firmness and strength (Babitha *et al*., 2004).
Jagtap *et al*. (2010) reported that jackfruit is an excellent source of vitamin C which increases immunity to protect against common diseases like cough, cold and flu. It provides vitamin C of about 13.7 mg which is 23 per cent of RDA. Consumption of foods rich in vitamin C helps the body develop resistance against infectious agents and scavenge free radicals.

Jackfruit is rich in magnesium, a nutrient which is important in the absorption of calcium and works with calcium to strengthen the bone and prevent bone related disorders such as osteoporosis. Jackfruit also contains iron which helps to prevent anaemia and also helps in proper blood circulation in our body. Jackfruit is loaded with copper, an important mineral, which plays a key role in the thyroid metabolism, especially in hormone production and absorption (Nualla *et al*., 2009).
Potassium contained in jackfruit has been found to be helpful in the lowering blood pressure and thus reducing the risk of heart attacks as well as strokes. It also reverses the effects of sodium that causes a rise in blood pressure which affects the heart and blood vessels (Selvaraj and Pal, 1989). Another heart-friendly property found in the jackfruit is the presence of vitamin B_6, that helps reduce homocysteine levels in the blood thus lowering the risk of heart disease (Shrikant *et al*., 2012)

Jackfruit is rich in dietary fibre, which makes it a good bulk laxative. The fibre content helps to protect the mucous membrane of colon by decreasing exposure time and as well as by binding to cancer-causing chemicals in the colon (Mondall *et al*., 2013). The presence of high fibre content (3.6 g/100 g) in the jackfruit prevents constipation and produces smooth bowel movements. It also offers protection to the mucous membrane of colon by removing carcinogenic chemicals from the large intestine. Rahman *et al*. (2005) stated that jack fruit acts as a laxative and relieves constipation due to high fibre content. It also cleans up the colon thus preventing from colon cancer.

Jackfruit is considered as an energy generating fruit due to the presence of simple sugars like fructose and sucrose which give immediate energy boost. Although jackfruit is an energy rich fruit, it contains no saturated fatty acids and cholesterol, making it a healthy fruit favouring the heart. Jackfruit has a good amount of protein when raw (Eke and Akobundu, 1993).

2.2.3 Benefits of jackfruit seed

Jackfruit seed contains lignans, isoflavones, saponins and many such phytonutrients whose health benefits are wide-ranging like its anticancer, antihypertensive, anti-aging, antioxidant, antiulcer and many more such properties (Omale and Friday, 2010). Lectin, a class of glycoproteins found in jackfruit seed, has been reported to possess antibacterial, antifungal and anti-carcinogenic properties (Chowdhury *et al*., 2012).

Jacalin and artocarpin are the two lectins present in jackfruit seeds. Jacalin, the major protein from seeds, is a tetrameric two – chain lectin combining a heavy chain of 133 amino acid residues with a light beta chain of 20 to 21 amino acids residues. It is highly specific to the O-glycoside of the disaccharide Thomsen- Friedenreich antigen (Gal beta1-3GalNAc), even in its sialylated form. This property has made jacaline suitable for studying various O-linked glycoproteins, particularly human IgA. Jacalin has been seen to inhibit the herpes simplex virus type 2 and has proved to be useful for the evaluation of the immune status of human immune deficiency virus 1 (HIV1) infected patients. It is also used for the isolation of human plasma glycoproteins, investigation into IgA nephropathy, analysis of 0-linked glycoproteins and the detection of tumours (Haq, 2006).

Uniqueness of jacalin of being strongly mitogenic to human CD4+T lymphocytes, has made it a useful tool for the evaluation of the immune status of patients infected with human immunodeficiency virus HIV-1 (Pereira *et al*., 2006). The fat content of the seeds was negligible making it a good constituent of fat free diet (Deepika *et al*., 2011). Therefore, jackfruit seeds could be used in balanced diets as reported by Abraham and Jayamuthunagai, (2014). Jackfruit seeds have been reported to contain high amount of resistant starch (undigestible starch- RS). RS is categorised into four types (RS1-RS4) and jackfruit seeds contain RS1 type of starch. The undigestible starch escapes digestion in the small intestine, passes on to the colon and is reported to act like dietary fibre (Hettiaratchi *et al*., 2011)

Theivasanthi and Alagar (2011) studied the antibacterial effect of nano-sized particles of jackfruit seed against *E.coli* and *B. megaterium* microbes and revealed the efficacy of jackfruit seed nanoparticles. They concluded that the nanoparticles in jackfruit seed can lend antimicrobial effects to hundreds of square meters of host material. Jackfruit seeds may therefore be developed into therapeutic agents capable of treating infectious diseases and preventing food contamination by food borne pathogens.

Jack fruit is an indigenous and underutilized fruit crop with great yield potential and excellent nutritional qualities. However, its intense flavour may be hindering the factors for acceptance by the consumers.

Jagadeesh *et al*. (2006) has reported that, it is possible to alter the flavour and make it acceptable to the consumers through processing and product diversification.

2.3 SCOPE OF VALUE ADDITION OF RAW JACK FRUIT

It is yet to be realised that jack fruit has got great potential for value addition. There is ample scope for value addition in both firm and soft types of jack fruit in all stages of maturity right from immature to well ripened stage. Each product has its own virtues in terms of taste, colour, preference, flavour, texture and keeping quality. Value addition of ripe jackfruit has received more focus among food technologists; therefore this section has sought to focus on value addition of raw jackfruit. With value addition it can be an additional income for farm families and self-help groups, through its marketing and utilisation at the household level.

Shruthy (2005) observed that jackfruit possesses excellent processing qualities with good sensory appeal and hence it is highly suitable for value addition and processing. Krishnaveni *et al*. (2000) opined that the jackfruit is a rich source of phytochemicals, including phenolic compounds, and offers opportunities for the development of value- added products, such as nutraceuticals and such other food applications to enhance health benefits. They also opined that jackfruit in raw forms is utilised for various culinary preparations. The authors further reported that even the raw fruits have delicious taste, excellent flavour, attractive colour and excellent qualities which make it suitable for processing and value addition.

It has been pointed out that jackfruits are highly nutritious, seasonal and also highly susceptible to spoilage. Preservation of fruits by processing has been the research pursuit of many developed and developing countries, and has yielded quite a number of technologies. There have been quite a few research findings worth mentioning on processing of raw jack fruit into durable and nutritious food products (Molla *et al*., 2008).

2.3.1 Jackfruit chips

Chips is a most popular snack item in many fast food outlets. Fried jackfruit chips with slight changes in flavour have become important commercially. Jackfruit chips are one of the popular and easily saleable snack foods in the market. Moisture level is observed to affect shelf life, crispiness and quality of chips.

The processed jackfruit chips standardized by Molla *et al*. (2008) was not affected by any microbial spoilage up to two months of storage of the products, owing to its low moisture content. The maximum level of moisture content observed was 4.49% which was not suitable for microbial growth. The prepared chips could be stored in ambient conditions by storing in metalex foils for two months without loss of organoleptic quality.

The dehydrated chips of jackfruits pre-treated with ascorbic acid recorded the maximum mean score for colour, flavour and texture irrespective of storage period. The organoleptic scores of these dehydrated jackfruit chips for all above attributes declined with the increase in storage period from 0 to 60 days. The dehydrated chips pre-treated with ascorbic acid recorded maximum overall acceptability score of 6.91 after 60 days of storage which clearly indicated its suitability for making good quality chips and also for storage for above 60 days at ambient conditions without much loss of sensory and nutritional qualities of chips (Patil *et al*., 2014).

2.3.2 Green Jackfruit pickle

Pickle is used as a household meal supplement in almost all Indian families irrespective of their socio economic status. Mondall *et al*. (2013) standardized green jackfruit pickle which contained high amounts of vitamin-C (3.4433 mg/100 g) and carotenoids (22.78 mg/100 g). Quality of the pickle remained unchanged even after 12 months of storage.

2.3.4 Raw mature Jackfruit powder

Kumar *et al*. (2012) standardized jackfruit powder by applying hot air oven drying and freeze drying techniques. The unripe starchy fruits were cut into slices, dried in a hot air oven dryer, powdered and packed. The freeze dried jackfruit powder contained higher nutrients than hot air oven dried powder.

The sensory evaluation attributes revealed that the freeze dried samples of jackfruit stored in refrigerator scored equal to fresh powder in all the attributes. Freeze drying was comparatively found to be a better drying method then the hot air oven drying method, giving better rehydration qualities, better colour, flavour, taste, texture and overall acceptability besides, higher nutrient level of vitamin A and vitamin C. The Vitamin 'A' and 'C' content in dried powder (DP) was 150.45 IU and 2.15 mg per/100g and in freeze dried powder (FP), it was 250.68 IU and 5.92mg/100g of respectively.

2.3.5 Tender jackfruit curry

Tender jackfruit has a mild and pleasant flavour and distinct texture. It is rich in vitamins and minerals along with isoflavones, phytonutrients and anti-oxidants. Tender jackfruit curry is exotically delicious and makes for a fantastic vegetarian dish, similar to chicken in consistency, and is even referred to as "vegetable meat" in many parts of Southeast-Asia. Tender jack fruit curry was standardised with a shelf life of 12 months.

Texture Profile Analysis (TPA) of raw tender jack fruit, blanched and retort processed curry was carried out using Universal Testing Machine (UTM) equipped with TPA software. The hardness of the tender jack fruit reduced significantly after retort processing from 39.78 ± 2.81 to 0.95 ± 0.19. Change in the hardness is affected mainly due to the heat induced thermal softening of tissues. The changes in cohesiveness, springiness, gumminess and chewiness were significant in fresh, blanched and retort processed samples. However, the overall texture of retort processed tender jack fruit curry was acceptable (Rickman *et al*., 2007).

2.3.6 Jackfruit papad

Papads are traditional savory preparations whose quality depends much on the base raw material. They are thin wafer like products prepared from a variety of base ingredients. Jack-fruit pappads from SRS 33, SRS 26 and SRS 7 varieties of jackfruit were standardized by Jagadeesh *et al*. (2006).

The jackfruit types SRS-3 and SRS-15 recorded high starch and dry matter in their bulbs and were associated with higher papad yield. Moisture content in papad of different selections varied widely from 6.45 % (5RS- 32) to 14.66% (SRS – 19). Papads made from different selections exhibited wide variations in oil uptake and expansion on frying. The colour and appearance of papad made from some jackfruit types appeared to be excellent even when their reducing sugar content was more than 2% (SRS 7).

In some jackfruit types the colour and appearance score was significantly lower, even when reducing sugar was much lower than 2%. Hence the colour of fried product appeared to depend not merely on the level of reducing sugar but also on other factors (amino acids, moisture content, and temperature) responsible for millard reaction. The Jackfruit selection SRS-33, SRS-26 and SRS-7 yielded papad of high organoleptic acceptability.

A study to explore the potentiality of YJB (young jackfruit bulb) as an extender in a meat product has been reported. The aim of study was to evaluate the effect of (YJP) as an extender on the quality characteristics of restructured chicken meat block (RCMB) prepared with spent hen meat.

Three levels of young jackfruit (peeled and pulped) Viz. 5, 7.5 and 10 per cent were used as extenders, replacing lean meat in the pre standardized formulation. The RCMB formulated without young jackfruit pulp served as control and was compared with blocks extended with different levels of YJP for various physico-chemical and sensory properties. The pH and cooking yield increased significantly ($P<0.05$) with increase in the extender level, with highest value for the block extended with 10% jackfruit pulp. The moisture, ash and moisture protein ratio increased with the increasing level of extender, but protein and fat ratio decreased significantly ($P<0.05$) with increased level. Sensory scores for general appearance, flavour, binding strength, texture, juiciness and overall acceptability showed some decrease with increasing level of extender.

2.3.7 Avial, Koottu and Olath mix

Liji (2014) standardised three ready to cook curries based on raw jackfruit. The dishes were ethnic to Kerala cuisine. They were ‘Avial mix’, ‘Koottu mix’ and ‘olath mix’. Studies on consumer preference of the RTC revealed that Avial mix was preferred the most, although all the mixes were found acceptable.

2.3.8 Pith pickle

Divakar *et al*. (2012) conducted a study to develop shelf-stable jack-fruit pith pickle. The composition of the pickle consisted of jackfruit pith, vinegar, salt, oil, spices and condiments. The ingredients used were optimized with regard to pH, saltiness, taste and flavour. Physico-chemical, microbial and sensory characteristics were studied. The product was found to be acceptable and microbiologically safe under ambient conditions up to 6 months of storage period.

2.4 PROSPECTS OF EXTRUDED PRODUCTS

During the recent years, quite a number of technologies in food processing have emerged and made an impact on the availability and variety of food products. Food extrusion is one of these latest multidimensional food processing techniques. Great possibilities have been offered in the field of food processing by the use of extrusion technology, to modify physicochemical properties of food components. It is one of the new and versatile food processing technologies being adopted on a large scale all over the world.

Extrusion originates from the Latin word, 'Extrude' which means 'press' or 'push out'. Extrusion is an emerging technology having the advantages of low production cost and capability of producing end products in various shapes and sizes to form a variety of food materials. These food materials ensure easy digestibility, hygiene and high product quality, leaving behind no effluents or hazardous materials. With increasing consciousness about healthy eating and changing lifestyles, extruded products, are becoming a standard feature in many households (Riaz *et al.,* 2007).

Extrusion is a process which involves conveying, mixing and compressing of moist materials to form dough that could be extruded in well-defined shapes. The basis of the technology is the screw system confined within a barrel that conveys the dough towards small openings at the end of the barrel called dies.

With the help of shear energy, exerted by the rotating screw, and additional heating of the barrel, the food material is heated to its melting point or plasticizing point. In this changed rheological status, the food is conveyed under high pressure through a die or a series of dies and the product expands to its final shape. This result in very different physical and chemical properties of the extrudates compared to those of the raw materials used (Brncic *et al*., 2006).

Food extrusion has become a very popular and important processing operation in the food industry. It provides great opportunities to create new and exciting products. The main purpose of extrusion is to increase the variety of foods in the diet by producing a range of products with different shapes, textures, colours and flavours from basic ingredients (Riaz, 2012).

Today, food extruders are used to produce pasta, ready to eat cereals, snacks, pet foods, confectionary products, modified starches for soup, baby foods and instant foods, rice and dhal analogues, beverage bases and texturized vegetable proteins (Singh *et al*., 2007). However, practice of this technology, has remained more of an art than a science. Knowledge and database on extrusion cooking is growing fast (Manisha, 2000).

Following are the areas of food industries where extrusion technology can be employed or is being used presently; beverages powders, boiled sweets, breads, bread substitutes, candy sticks, caramel, chewing gum chocolates, cocoa crumps, crisp bread, confectionery, cooked grains, (barley, corn/sorghum, mixed), dairy products, dried food mixes, egg rolls, fabricated potato chips, food additives, frozen confectionery, fudges, texturized soya products, imitation nuts, pasta products (noodles, spaghetti, macaroni), pastry dough, precooked and modified starches, pressed tablets, pretzels protein (textured and gluten), soup and gravy mixes, sugar crust liqueurs, three dimensional confectionery and toffees (Riaz, 2000).

Extrusion technologies have an important role in the food industry as efficient manufacturing process. Supercritical fluid injection, coupled with the continuous twin-screw extrusion cooking process, opens many opportunities for new engineered processing techniques which in turn develop new products and product concepts. This supercritical fluid extrusion technology is a patented process that already has resulted in new developments in cereals, confectioneries, pastas, flavourings, pharmaceuticals, snacks and other products which were earlier left only to imagination (Riaz *et al.,* 2007).

The processing units have evolved from simple conveying devices to become very sophisticated in the last decade. Their main role was developed for conveying and shaping fluid forms of processed raw materials, such as dough and pastes. Today, their processing functions may include conveying, mixing, shearing, separation, heating or cooling, shaping, co-extrusion, venting volatiles and moisture, flavour generation, encapsulation and sterilization. They can be used for processing at relatively low temperature, as for pasta and dough, or at very high temperatures as for flat breads and extruded snacks. The pressures used in extruders to control shaping, to keep water in a superheated liquid state and to increase shearing, has brought in certain screw types, that may vary from around 15 to over 200 atmospheres (Singh *et al*., 2007).

Food extruders can be visualized as devices that can transform a variety of raw ingredients into intermediate and finished products. The cooking temperature can be as high as 180-190^{0}c (355-375^{0}F) during extrusion, but residence time is usually only 20-40 seconds. For this reason, the extrusion cooking process is named as high temperature short time process.

The first extruder was designed to manufacture sausages in the 1870s. Packaged dry pasta and breakfast cereals have been produced by extrusion, since the 1930s and it was first introduced in food and feed processing in the late 1950s (Karwe and Mukund, 2008). Since then, the systems involved have grown in popularity, efficiency and flexibility. Extrusion technology is mostly used for cereal and protein processing in the food industry and is also closely related to pet food and feed sectors. In the last decade, the development of extruders has evolved to yield sophisticated products, new flavours, encapsulations and sterilisations (Caroline *et al.*, 2001).

An extruder is basically a screw pump, which consists of a flighted Archimedes screw that rotates in a tightly fitting stationary barrel. Control of extrusion process is difficult due to strong interaction between mass, energy and momentum transfer, coupled with complex physico-chemical transformations, which govern final product properties.

The primary extrusion process parameters include feed formulation; feed rate, screw speed, barrel temperature and screw die configuration (Mangaraj and Bargale, 2006). The two main factors that influence the characteristics of extruded products are: raw material characteristics and operational conditions of the extruder (Fellows, 2006).

Extrusion has been sparked to a great extent by the perfection of twin screw extruders. This development has redirected and brought under control the tremendous wastage from the shear imparted to the grain formula during extrusion cooking in the single screw extruder. The flexibility in the set-up of the screw elements in a twin screw, along with greater flexibility in screw speed and heat input, have brought the extrusion cooking process under very exacting control (Bordoloi and Ganguly, 2014).

In pellet-to-flakes extrusion, as for cooked breakfast cereals preparation, cereal flours or grits are cooked with ingredients at a moisture level in the range of 22–26%. They are usually processed in twin-screw extruders, the configuration and operating characteristics of which lead to a lower mechanical component of cooking, reinforcing more of the thermal component as opposed to the previous processing conditions (Riaz, 2007).

Maintaining and increasing the nutritional quality of food during food processing is always a potentially important area for research. Deterioration of nutritional quality, owing to high temperature, is a challenging problem in most traditional cooking methods. Extrusion cooking is preferable to other food-processing techniques in terms of the continuous process, with its high productivity and significant nutrient retention and owing to the high temperature and short time required (Guy, 2001).

Food extruders belong to the family of HTST (high temperature short time)-equipments, capable of performing cooking tasks under high pressure. This is advantageous for vulnerable foods and feeds as exposure to high temperatures for only a short time will restrict unwanted denaturation effects. For example components like proteins, amino acids, vitamins, starches and enzymes which are highly sensitive to physical and chemical conditions are not totally destroyed. Physical and technological aspects like heat transfer, mass transfer, momentum transfer, residence time and residence time distribution have a strong impact on the food and feed properties during extrusion-cooking and can drastically influence the final product quality (Leszek and Dick, 2011).

The extrusion process denatures undesirable enzymes, inactivates some antinutritional factors (trypsin inhibitors, haemagglutinins, tannins and phytates), sterilises the finished product; and retains natural colours and flavours of foods (Bhandari *et al*., 2001). The main advantage of extrusion cooking is the destruction of anti-nutritional factors, especially trypsin inhibitors, haemagglutinins, tannins and phytates, all of which inhibit protein digestibility (Alonso *et al*., 2000).
The destruction of trypsin inhibitors increases with extrusion temperature and moisture content. Extrusion causes complete destruction of trypsin inhibitor activity in extruded blends of broken rice and wheat bran, containing up to 20% wheat bran (Singh *et al*., 2000). Lectin (haemagglutinating) activity is relatively heat resistant. However extrusion has been shown to be very effective in reducing or eliminating lectin activity in legume flour. Thus, extrusion cooking is more effective in reducing or eliminating lectin activity as compared with traditional aqueous heat treatment (Alonso *et al*., 2001).

Parallel to the increased applications, interest has grown in the physico-chemical, functional and nutritionally relevant effects of extrusion processing. Prevention or reduction of nutrient destruction, together with improvements in starch or protein digestibility, is clearly of importance in most extrusion applications. Nutritional concern about extrusion cooking reached its highest level, when extrusion was used specifically to produce nutritionally balanced or enriched foods, like weaning foods, dietetic foods, and meat replacers (Plahar *et al.*, 2003).

Thermoplastic extrusion, depending on process conditions and raw material composition, causes swelling and rupture of the starch granule, completely or partially, destroying the organized granule structure, reducing viscosity and releasing amylose and amylopectin. The major difference between extrusion processing and conventional food processing is that, in the former starch gelatinization occurs at much lower moisture content (12-22%).

During thermoplastic extrusion, amylose and amylopectin are partially hydrolysed to maltodextrin, due to the high temperatures and shear inside the extruder. An important consequence of starch degradation is the reduction in expansion (Caroline *et al.*, 2001). The process conditions used in extrusion cooking in high barrel temperatures and low feed moistures are known to favour the maillard reaction. High amylose rice extruded into noodles had lower starch digestibility and reduced glycemic index in human volunteers, which is advantageous.

Extrusion is also defined as a unique tool to introduce the thermal and mechanical energy to food ingredients, forcing the basic components of the ingredients, such as starch and protein, to undergo chemical and physical changes (Riaz, 2007). Studies carried out with corn grits demonstrated that expansion is inversely proportional to the moisture content of the material being extruded (Caroline *et al.*, 2001)

Protein digestibility value of extrudates is higher than nonextruded products. The possible cause might be the denaturation of proteins and inactivation of antinutritional factors that impair digestion. The nutritional value in vegetable protein is usually enhanced by mild extrusion cooking conditions, owing to an increase in digestibility. It is probably a result of protein denaturation and inactivation of enzyme inhibitors present in raw plant foods, which might expose new sites for enzyme attack. All processing variables have different effects on protein digestibility (Caroline *et al*., 2001).

Increase in extrusion temperature (100–140^{0}C) enhances the degree of inactivation of protease inhibitors in wheat flour, and consequently, the protein digestibility values are increased. Extrusion, even at 140^{0}C, does not have any adverse effect on protein digestibility, which might be attributed to the lesser residence time of dough within the extruder. The effect of other process variables, such as length to diameter ratio and screw speed on protein digestibility values appears to be insignificant. Increased screw speed may have increased the protein digestibility of extruded corn-gluten, because the increase in shear forces in the extruder, denatures the proteins more easily, thus facilitating enzyme hydrolysis (Iwe *et al*., 2004).

The enzyme hydrolysis of protein is improved after extrusion cooking as a result of the inactivation of anti-trypsin activity in extruded snacks. The higher susceptibility of protein to pepsin, as compared with trypsin, further suggested the presence of anti-trypsin activity. The improvement in pepsin hydrolysis might be the result of the denaturation of proteins during extrusion cooking, rendering them more susceptible to pepsin activity. This suggests that extrusion considerably improved the nutritive value of proteins (Singh *et al*., 2000).

The available lysine in the extrudates of defatted soya flour and sweet potato flour mixture ranged from 68 to100% (Iwe *et al*., 2004). Increase in screw speed (80 – 140 r.p.m.) and reduction of die diameter (10–6 mm) enhanced lysine retention. Insignificant changes in dietary fibre content were reported in both untreated and twin-screw extruded wheat flour and whole-wheat meal at a temperature range of 161–180^{0}C, 15% feed moisture and 150–200-r.p.m. screw speed. No significant change was found in dietary fibre content when wheat was extruded under milder conditions, but the fibre present became slightly more soluble.

At mild or moderate conditions, extrusion cooking does not significantly change dietary fibre content, but it solubilises some fibre components. At more severe conditions, the dietary fibre content tends to increase, mainly owing to the increases in soluble dietary fibre and enzyme-resistant starch fractions. Extrusion cooking increased the total dietary fibre of barley flours. The total dietary fibre increased in waxy barley which was the result of an increase in soluble dietary fibre. In the case of regular barley flour, the increase in both insoluble dietary fibre and soluble dietary fibre contributed to the increased total dietary fibre content (Vasanthan *et al*., 2002).

Extrusion processing (high temperature) might have reorganised dietary fibre components, changing their chelating properties. Moreover, it must be taken into consideration that complex agents present in foodstuffs, such as phytates may interact with fibre, modifying the mineral availability (Alonso *et al*., 2000).

The extrusion process can prevent free fatty acid release by denaturing hydrolytic enzymes. Lipid oxidation has negative impact on sensory and nutritional qualities of foods and feeds. It probably does not take place during extrusion owing to the very short residence time. However, rancidity is a concern for extruded products during storage. Food with low fat level is favourable for extrusion cooking. The extrusion process minimises lipid oxidation, thus increasing the nutritional and sensory quality of foods and feeds.

Among the lipid-soluble vitamins, vitamins D and K are fairly stable. Vitamins A and E and their related compounds – carotenoids and tocopherols, respectively, are not stable in the presence of oxygen and heat. Thermal degradation appears to be the major factor contributing to beta-carotene losses during extrusion. Higher barrel temperatures (200^{0}C compared with 125^{0}C) reduce all trans-beta-carotene in wheat flour by over 50%.

Ascorbic acid is also sensitive to heat and oxidation. This vitamin decreased in wheat flour when extruded at a higher barrel temperature with fairly low moisture (10%). The retention of vitamins in extrusion cooking decreased with increasing temperature, screw speed and specific energy input. It also decreased with moisture, feed rate and die diameter. Depending on the vitamin

concerned, considerable degradation can occur, especially in products with high sensory appeal (Singh *et al*., 2007).
Extrusion can improve the absorption of minerals by reducing other factors that inhibit absorption. Phytates may form insoluble complexes with minerals and eventually affect mineral absorption adversely. Extrusion hydrolyses phytates to release phosphate molecules. Extrusion of peas and kidney beans resulted in phytate hydrolysis, which explains the higher availability of minerals after processing (high temperature extrusion) (Alonso *et al*., 2001).

Extrusion cooking enhances apparent absorption of most minerals studied in either pea- or kidney bean-based diets. This increased absorption can be explained by the positive effect of extrusion in the reduction of anti-nutritional factors.
A 13–35% reduction in phytate content was observed after extrusion of a wheat bran-starch–gluten mix. Extrusion reduces phytate levels in wheat flour, but not in legumes, at low extrusion temperature. Minerals are heat stable and unlikely to become lost in the steam distillate at the die area. The increase in mineral absorption, observed after extrusion, could be partly attributed to the destruction of polyphenols during heat treatment. Changes in the polyphenol content after thermal treatment might have resulted in the binding of phenolics with other organic materials present (Alonso *et al*., 2001).
Extrusion can improve the absorption of minerals by reducing factors that inhibit absorption, like phytates and condensed tannins. Most conventional extruded products such as snack foods and breakfast cereals are safe to eat because the raw materials are subjected to high temperatures (higher than 130°C) and the water activity of the product is thus lowered and the product is dried to a moisture content of less than five per cent. The extrusion cooking process has been used increasingly because of its higher efficiency in comparison with conventional methods involving batch processing and multi stage operations (Manisha, 2000).
Packaging influences the flavour, colour, texture as well as moisture and

oxygen transfer. Packaging materials can modify the effects of temperature changes and light. Extruded products are normally dried to a very low moisture level (3-10%) and thus become highly hygroscopic products. These products hold the moisture so firmly that number of water molecules that can leave the product to attain equilibrium with headspace is very low and hence relative humidity of the air surrounding the product is very low (Bargale, 2006).

Since the time required for a product to get transported from its place of manufacture to consumer may vary from 3 to 6 months, it is absolutely necessary that a suitable cooling, drying, packaging, handling and transport system is designed and developed for each extruded product. Packaging is an integral part of processing and preservation of extruded foods and can influence many factors. It can influence physical and chemical changes, including migration of chemicals into foods.

Extrusion cooking is used for preparing baby foods. The type of extruders used, the particle size of the rice flour, the moisture content of the rice water mixture, and the extrusion conditions are some of the important factors influencing the properties of extruded rice baby foods. Fortification of ready-to-eat rice with vitamins, minerals, and flavour compounds is now a very common practice. The usual approach is to add the minerals and more heat-stable vitamins such as niacin, riboflavin, and pyridoxine to the basic formula mix, extrude and then spray the more heat-labile vitamins such as vitamin A and thiamine on the product after extrusion before drying (Riaz *et al*., 2007).

Developments in extrusion cooking have led to some biscuit-like products or pieces. When these are broad, flat and light in texture they offer interesting alternatives to plain crackers. Extrusion cooking is attractive to the manufacturer because of the relatively low capital cost of the plant and a great reduction in space required compared with conventional biscuit-making equipment (Camire *et al*., 2000).

Extrusion processes utilizing one or two extruders in a series have been employed to convert vegetable protein source directly into simplified varieties of meat analogues. These meat analogues have remarkable similarity in appearance; texture and mouth feel to meat. Extruders are used to stabilize the rice bran just after milling and also to reduce the FFA of rice bran oil. This stabilized rice bran can be used in human food and animal feed (Chang *et al*., 2001).

Extrusion also permits the utilisation and co-processing of various by-products. It is used for the recycling of industrial and restaurant food wastes. Extruding food materials in an oxygen-free atmosphere at an elevated temperature level is sufficient to sterilize food materials followed by cooling them, and thereafter tumbling and drying them to reduce the materials to particle form (Riaz, 2000).

Extrusion system adds value to inferior raw materials and waste products in food manufacturing, such as processing dark flours or blending in wheat bran for better-quality products. Even in pet foods with very distinct characteristics, specialized processes of extrusion have been included (Eastman *et al*., 2001).

2.4.1 The Advantages of extrusion

Extrusion cooking as reported by Sallia and Phillips (2011) is an efficient process to destroy or inactivate aflatoxins, if special conditions (high shear, high temperature, and adequate pH) are used. The short residence time and high temperature in an extruder reduces the damage to nutritional properties, but still adequately inactivate the enzymes responsible for the development of the undesirable off-flavours.

Alonso *et al*. (2001) observed that extrusion does not significantly affect mineral composition of pea and kidney bean seeds, except for iron. Iron content of the flours increased after processing and this is most likely to be the result of the wear of metallic pieces, mainly the screws of the extruder. Fortification of foods with minerals prior to extrusion poses other problems. There, iron forms complexes with phenolic compounds that are dark in colour and affects the appearance of foods adversely. Extrusion cooking increases the amount of iron available for absorption, almost in all cases.

The future of extrusion cooking would appear to lie in its ability to produce novel foods, with a large variety of shapes, flavour, colours and appearance. Flavour is a positive attribute of an extruded food because much of the flavour, or more specifically the aroma producing compounds, are normally lost to the atmosphere as the extrudate leaves the die. The process or technique has the versality and ability to consistently produce a given product in continuity at a given set of pre- determined specifications. It destroys fat splitting enzymes, prevents rancidity and thus extends the shelf life of products considerably. Microorganisms present in food materials are destroyed due to high temperature.

It can be effectively utilized to develop functional and designer foods by using several locally available under-utilized foods materials. However, it leads to increased package cost as expanded food products have low bulk density (Srivastava, 2006).

There are many advantages of extrusion processing over other conventional cooking processes as observed by Riaz (2012), it is a continuous and flexible process because on line process adjustments can be made to achieve desired product characteristics. In addition, the same extruder can be used to manufacture different types of products. The process has no effluents and is also energy efficient. It can be used to process relatively dry, highly viscous materials as well as moist or wet materials.

Riaz (2000) has summarized the advantages of extrusion cooking over conventional processes such as baking, autoclaving etc. which is briefly listed below:

- Rapid high energy transfer into mass with H.T.S.T advantages
- High capacity with smaller investment and less space taken
- High energy efficiency because less drying is required (low moisture cooking)
- Continuous and automated operation and less manpower requirement
- Precise control of residence time, temperature and uniformity of cooking
- No effluents released

2.5 STUDIES ON QUALITY IMPROVEMENT OF NOODLES

Noodles are widely consumed throughout the world and their global consumption is second only to bread. This is because noodles are convenient, easy to cook, low cost and have a relatively long shelf-life (Owen, 2001). It has been an increasingly popular food commodity worldwide, with annual production of 101,420 million packs in 2012, with a steady increase of 3% per annum since 2010 (World Instant Noodle Association, 2013).

Researchers have tried to use various composite flours with wheat flour as the base for noodle making which includes sweet potato flour (Reungmaneepaitoon *et al*., 2008), garbanzo bean flour (Lee and Zuzanna*,*1998), soy flour (Lateef *et al*., 2004), cassava (Perez and Perez, 2009) and millets (Vijaykumar *et al*., 2009). Noodle products are staple foods in many parts of Asia. Asian noodles made from wheat may be divided into two general classes based on the ingredients used: white salted noodles (WSN) made from flour, sodium chloride and water, and yellow alkaline noodles (YAN) made from flour, alkaline salts (such as sodium and potassium carbonate) and water (Asenstorfer *et al*., 2006). The type of salt, properties of the flour and the manufacturing processes leads to a wide array of noodle types (Martin *et al*., 2008).

Flour of hard wheat (*Triticum aestivum* L.) is the main primary ingredient. Wheat flour which is usually used to make instant noodles is not only low in fibre and protein contents, but also poor in the essential amino acid, lysine. Other flours may be mixed with wheat flour to make specific types of instant noodles. For example; buckwheat flour is added at 10-40% of wheat flour for the production of buckwheat noodles or soba.

The popular noodles include instant Chinese noodles, instant Japanese noodles, and instant European style noodles, which vary in the basic ingredients used to make the noodles (Fu, 2008).

Chinese-style yellow alkaline noodles (YAN) and Japanese-style white salted noodles (WSN) were prepared from a standard brand of hard red winter wheat flour and also from composite flours containing wheat flour and 25% sweet potato flour (SPF). The composite flours showed two distinct gelatinization endotherms corresponding to the two kinds of starch present. The gelatinization enthalpies of the composite flours were generally slightly lower than all-wheat flour, except for CL-1489-89, which had minimal amylase activity. Rapid Visco-Analyser (RVA) amylographs of composite flours were significantly different under slightly acidic conditions (pH 5.7-6.0) but not under alkaline conditions (pH- 10), primarily due to differences in SPF amylase activity. Correspondingly, YAN was found to be more firm and had lower cooking loss than WSN. Wheat - sweet potato composite flours with the addition of ascorbic acid tended to increase noodle firmness. However, a higher degree of browning after 24 hrs of storage at 40^0C was observed in noodles containing ascorbic acid (Collado and Harold, 1996).

Dried noodles are usually eaten after being cooked or soaked in boiling water for 3-5 min while precooked noodles can be reheated, or eaten straight from the packet (Fu, 2008). Semolina (durum wheat flour) is the main ingredient for making Asian noodles. Three parts of flour are usually mixed with one part salt or alkaline salt solution to form crumbly dough from which white salted noodles are made (Wu *et al.,* 1998).

Kulkarni *et al*. (2012) developed nutrient rich noodles by the addition of optimized proportions of wheat and malted ragi flour. Combinations of wheat and malted ragi flour (90:10, 80:20, 70:30, 60:40 and 50:50) and other ingredients like vegetable oil, corn flour, wheat gluten, GMS and guar gum were optimized by varying the proportions to obtain better quality noodles. Iodized salt, baking powder and water were kept constant for all formulations. Results revealed that among all the formulations tried, noodle samples prepared from 70:30 flour combinations had the same sensory score as that of control and higher values of protein, fibre and minerals (i.e. calcium, iron and phosphorous) than the control sample.

Sinha and Masih (2014) conducted a study on incorporation of beetroot pomace powder and pulse powder of different fractions in noodles and its qualities were analyzed. Different levels of rice flour, pulse powder and beetroot pomace powder were added in the ratio of 100:00:00, 85:7.5:7.5, 80:10:10, 75:12.5:12.5 and 70:15:15 for the development of beetroot incorporated noodles. As quantity of beetroot pomace powder increased, fibre content increased. Colour darkened as proportion of beetroot pomace increased. There was an increase in protein with increase in content of pulse powder. Phosphorus, Iron and fat contents increased with increased proportion of beetroot pomace powder. Noodles developed with addition of beetroot powder had desirable organoleptic properties as indicated by the taste panel studies in comparison to control sample. Based on sensory analysis, noodles with 75:12.5:12.5 rice flour, beetroot powder and pulse powder (T_3) respectively were found to be more acceptable than other levels and were also found to be optimum for incorporation. Protein, fat, crude fibre, phosphorus, iron levels decreased during storage.

The instant fried noodles with 40 per cent sweet potato flour of different cultivars increased total dietary fibre to more than 10% of the recommended daily intake (RDI). The instant fried noodles with added purple-fleshed sweet potato flour had the highest antioxidant activities, which ranged from 8.27 ± 0.66 to 17.81 ± 0.42 mg vitamin C equivalent (VCE)/100 g, as compared to wheat noodles (3.61 ± 0.07 mg). The total phenolic content was in the range of 38.29 ± 0.81 to 55.58 ± 1.27 mg of gallic acid equivalent (GAE) per 100 g noodles, which was similar to wheat noodles (32.09 ± 0.31 mg). The tensile force and breaking distance of instant fried noodles containing uncooked sweet potato flour of each cultivar was significantly greater than that for noodles containing cooked sweet potato flour ($p \leq 0.05$). The tensile force and breaking distance of instant fried noodles containing 20% uncooked purple-fleshed sweet potato flour were not significantly different from wheat noodles ($p \geq 0.05$). The sensory acceptability of instant fried noodles made with 20% sweet potato flour from each cultivar had the highest overall sensory scores as standardised by Reungmaneepaitoon (2009).

Jayasena *et al.* (2008) observed that lupin flour improved the nutritional value of the product by increasing protein by 42% and dietary fibre by 200%.

Lupin flour can be incorporated up to 20% in instant noodles to improve the nutrient value without affecting the sensory properties.

The effect of wheat flour substitution with unripe banana flour was investigated in terms of the physicochemical, textural, cooking and sensory qualities of dried noodles. Five samples of dried noodles were prepared by substituting wheat with 10, 20, 30, 40, and 50% banana flour and only 100% wheat flour for control. The results indicated that as the amount of banana flour increased, the stickiness of the noodles decreased and the appearance became darker. The optimum formula consisted of 20.45% banana flour, 47.72% wheat flour, 20.45% water, 2.04% salt, 1.02% sodium carbonate, 6.82% egg powder, 0.14% polyphosphate and 1.36% propylene glycol. Banana flour was used to replace 30% of the total wheat flour in the formula. Uncooked dried noodles were composed of 13.7% protein, 0.12% fat and 4.8% dietary fibre (including 2.8% resistant starch). The optimal cooking time and cooking loss were 14.5 min and 11.15%, respectively. The tensile strength and breaking length of cooked noodles were 16.4 g and 67.2 mm, respectively. The results of consumer evaluation showed that the overall sensory score of uncooked and cooked dried noodles were at the moderate levels. Thus it was proved that unripe banana flour is a potential source of fibre when substituted for wheat flour in dried noodle products. The incorporation of 30% unripe banana flour in the noodle ingredients significantly increased their total dietary fibre and resistant starch content, as standardised by Ritthiruangdej *et al.* (2011).

Finger millet was blended in various proportions (30-50%) with refined wheat flour and used for the preparation of noodles. The control composed of only refined wheat flour. The 30% finger millet incorporated noodles was selected as the best on the basis of sensory evaluation. Nutrient composition of the noodles showed that 50% finger millet incorporated noodles contained the highest amount of crude fat (1.15%), total ash (1.40%), crude fibre (1.28%), carbohydrate (78.54%), physiological energy (351.36 kcal), insoluble dietary fibre (5.45%), soluble dietary fibre (3.71%), iron (5.58%) and calcium (88.39%), respectively. However, control comprising of refined wheat flour noodles contained highest amount of starch (63.02%), amylose (8.72%) and amylopectin (54.29%). The glycemic index of 30% finger millet incorporated noodles (selected by sensory evaluation) was observed to have significantly lower values (45.13) than control noodles (62.59). It was found that finer millet flour incorporated noodles were found to be nutritious and showed hypoglycaemic effect (Shukla and Srivastava, 2014).

Addition of 10% modified wheat starch or waxy maize decreased surface firmness of cooked noodles. Incorporation of starch to the hard wheat flour improved the cutting stress and surface reconstitution and surface firmness of cooked noodles. At 0.5% level, lecithin increased the strength of cooked noodles, whereas nonpolar lipids and glycolipids reduced the strength of the noodles. Sodium stearoyl-2-lactylate and monoglycerides increased breaking stress of dry noodles. Thus it was observed that gluten from the hard wheat flour gave improved surface firmness to cooked noodles as standardised by Rho *et al*. (1989).

The noodles made with extruded maize flour, and wheat straw supplements obtained the highest total sensory score. Cooking losses of these samples were below 10%. The sample with lecithin had the lowest cooking loss; however it was not acceptable for the panel members. Supplementation with extruded maize, maize and defatted soy flours, and wheat straw could be used to produce noodles without eggs, with reduced cholesterol content, enriched with dietary fibre and possessing a lower glycemic index (Hardi *et al*., 2007).

In another study mechanical characteristics of noodles made from buckwheat flour-water dough were analysed. In characteristics concerning tensile and breaking strength along with texture, buckwheat noodles were shown to have unique mechanical characteristics: relatively high tensile strength, with low extensibility, high rupture energy and relatively high textural values including hardness and chewiness. Polyacrylamide gel electrophoresis showed some changes in the protein components of buckwheat noodles after cooking (Ikeda and Asami, 2000).

Banana peel (BP) noodles prepared by partial substitution of wheat flour with green cavendish banana peel flour were characterized for physicochemical properties and *in-vitro* starch hydrolysis. Banana peel noodles had lower L* (darker) and b* values (less yellow) than the control noodles. The tensile strength of BP noodles was similar to control but their elasticity was higher. Following *in-vitro* starch hydrolysis studies, it was found that the glycaemic index of Banana peel noodles was lower than control noodles. Thus this study proved that partial substitution of banana peel into noodles may be useful for controlling starch hydrolysis of yellow noodles (Ramli *et al*., 2009).

Breadfruit starch (BS) isolated from matured breadfruit was used to produce noodles in combination with hard red wheat flour (WF) at a ratio of 100% WF:0% BS, 80% WF:20% BS, 60% WF:40% BS, 40% WF:60% BS, 20% WF:80% BS. The protein, fat, ash, crude fibre and moisture contents of the Breadfruit starch-Wheat flour (BS-WF) noodles prepared from the above blends ranged from 0.65 to 10.88%, 0.35 to 3.15%, 1.28 to 2.25%, 1.18 to 1.45% and 4.65 to 5.45%, respectively. The contents of protein, fat, ash and crude fibre increased as the percentage breadfruit starch decreased. Noodles produced from blends of 20% breadfruit starch and 80% wheat flour showed superior proximate, culinary and sensory attributes (Akanbi *et al*., 2011).

In another study, the physical attributes (pH and colour), cooking yield, textural and mechanical properties (firmness, tensile and texture profiles analyses) and structural breakdown properties (multiple extrusion cells with added artificial saliva) of five yellow alkaline noodle (YAN) formulations were studied. Samples used were noodles with (a) typical formulation (control), (b) soy protein isolate (SPI), (c) soy protein isolate plus microbial transglutaminase enzyme (SPI/MTGase), (d) green banana pulp flour (GBPu) and (e) green banana peel flour (GBPe). Compared to other noodles SPI/MTGase noodle showed significantly ($P < 0.05$) higher values in terms of textural, mechanical and breakdown properties. Incorporating SPI, banana pulp and peel flours into the noodles had imposed some differences on most of the mechanical and textural parameters from the control YAN. However, these noodles could not be clearly distinguished in term of structural breakdown properties, (Foo *et al*., 2011)

Nura *et al*. (2011) recorded that rice flour with the smallest particle size had the highest water absorption index, peak viscosity, hot paste viscosity, final or cold paste viscosity and gel hardness, but the lowest gelatinization temperature. Laksa noodles produced from rice flour with the smallest particle size had the best textural properties.

Roasted wheat flour was incorporated with cauliflower leaf powder containing wide range of nutrients for enrichment of noodles. The alterations in chemical constituents (moisture, protein, fat, ash and fibre) of noodles were examined by adding cauliflower leaf powder to the noodle formulation at the levels of 0, 10, 15 and 20 per cent on flour weight basis. The results indicated that samples of cauliflower leaf powder added noodles, of all addition levels, contained more protein, fibre and ash as compared to control sample. The result obtained in this study suggests that acceptable noodles in terms of physico-chemical and sensory properties could be produced by incorporating cauliflower leaf powder into roasted wheat flour up to the level of 10 per cent on flour weight basis. Thus, cauliflower leaf powder could be successfully used to enrich noodles, giving alternative utilization opportunities to producers and be a healthy choice option to the consumers (Wani *et al*., 2011)

Three types of gluten-free noodles were made using the flour of breadfruit, konjac, and blend of pumpkin and tapioca. Due to different characteristics of the three raw materials, preparations were carried out in three different methods in three separate experiments. Breadfruit and pumpkin noodles were made by using texturing agents: fermented cassava flour and tapioca flour, respectively, while konjac noodle did not need any texturing agent. Results showed that samples of breadfruit noodle had hardness ranging from 2520 to 3890 g and had a preference score of 5.60 out of 9. Water ratio in the pre gelatinized flour and proportion of dry breadfruit flour in the noodle dough affected the hardness of breadfruit noodle, while interaction of the two factors influenced hardness, adhesiveness and cooking time of breadfruit noodles. Cooking loss was not affected by preparation method. Cooking time of breadfruit noodle ranged from 3.11 to 4.77 min, and cooking loss ranged from 12.45 to 17.04%. Texture of Konjac noodles were affected by the preparation method. Konjac noodles had a hardness of 3094 to 5204 g and adhesiveness of -406 to -920 g. Sensory evaluation of konjac noodles was influenced by the preparation method, and the highest score for overall preference was 6.6 out of 9. Pumpkin noodle had a hardness ranging from 2237 to 4954 g, and adhesiveness of -158.05 to -351.41 g, cooking time ranging from 2.30 to 5.0 min, and cooking loss was observed to be 11.20 to 27.38%. The highest preference score was 6.0 given to the noodles containing 54% pumpkin flour (Purwandari *et al*., 2014).

Vijaykumar *et al*. (2009) presents the influence of millet flour blending on physical, functional, nutritional, cooking and organoleptic characteristics of noodles prepared from composite flour of millet flour, whole wheat flour and soy flour. Fibre and amylose/ amylopectin ratio increased significantly, with increase in level of millet flour blend incorporation. Cooking time of developed noodles from composite flour (15-18) was significantly higher than cooking time of branded noodles (9.3 min). Mean of overall organoleptic scores of developed noodles from composite flour was in the range of highly acceptable criteria (20-25), 20% level of millet flour incorporation was found to be most acceptable. Mean glycaemic index and load of developed noodles was significantly lower than branded noodles.

Blends of taro flour at 20%, 30%, 40%, 50% and 60% levels with remaining equal proportions of rice and pigeon pea flour were prepared for the production of noodles. Taro flour was significantly different from other flours due to its highest ash, crude fibre, lower fat and protein content and exhibited lowest L*, ΔE , foaming capacity (FC) and highest WSI (water solubility index), WAC (water absorption capacity) and OAC (oil absorption capacity), as compared to rice and pigeon pea flour($P < 0.05$). Increased concentration of taro flour in the blends resulted in shifting of the blends towards the positive score of the first principal component (PC1). Evaluation of anti-nutritional factors of noodles revealed that as the percentage of taro flour in the noodles increased, there was a reduction in phytic acid content. The noodles containing 50% taro, 25% rice and 25% pigeonpea flour obtained the highest scores for colour, taste, firmness and overall acceptability (Kaushal and Sharma, 2012).

Instant noodles from wheat flour and high iron brown rice flour were developed. Three varieties of rice flour, Suphan buri 90 (SB), Homnin 313 (HW) and Homnin 1000 (HP), containing amylose content of 30.40, 19.10 and 15.74% (w/w) and iron content of 1.24, 2.04 and 2.22 (mg/100 g) respectively, were used to replace wheat flour for instant fried noodle production. To determine the physicochemical properties and acceptability of the instant fried noodles, different percentages (30, 40, and 50%) (w/w) of each rice flour sample were used. The instant fried noodles were fortified with ferrous sulphate at levels of 0, 32, and 64% iron of RDI per serving. Increasing amount of iron content in the mixtures decreased the L* value, b* value and increased a* value for the colour of the instant fried noodle with brown rice flour. The texture characteristics of the noodles with 30, 40, and 50% replacement with each variety of brown rice flour were significantly different from those of wheat noodle. Tensile force of the noodles decreased from 11.57±1.30 g to 6.38±1.45 g (SB), 8.36±0.96 g to 5.71±0.57 g (HP) and 10.09±1.20 g to 5.46±1.31 g (HW), as the rice flour content increased from 30 to 50%. The sensory acceptability of the noodles made from each variety of 30% brown rice, flour fortified with 32% iron of RDI had higher preference scores for elasticity, firmness, colour and overall acceptability, than those with 64% iron of RDI. The acceptability scores (frequency percentage) of the noodle with HP and HW were 88 and 84% respectively. Shelf life studies revealed that the developed products were acceptable up to 4 months. These products were claimed to be iron rich noodles (Reungmaneepaitoon *et al*., 2008).

Composite flour noodles were developed using blends of refined wheat flour with malted cowpea flour, with replacement level of 10 and 20%. The results of the proximate composition showed that malting of cowpea considerably increased the protein content of the cowpea flour. Increasing levels of malted cowpea flour in the blends resulted in increased protein content and water absorption capacity. Malted cowpea flour blends showed higher values for setback and pasting temperature (at 10% substitution level). Blending of malted cowpea flour with wheat flour had significant effects on the cooking and textural properties of noodles. Composite flour noodles revealed less cooking time, less percentage solid loss, low hardness, adhesiveness and cohesiveness. The reduced swelling capacity of the flour blends resulted in lower value of cohesiveness. Presence of ingredients other than wheat flour could have caused discontinuity in the gluten network resulting in the faster moisture penetration and hence less optimum cooking time of noodles. Thus noodles with improved nutritional and acceptable cooking and textural quality attributes could be successfully developed using composite flours based upon refined wheat flour and malted cow pea flours as reported by Yadav *et al*. (2013).

Sabbatini (2014) studied the effect of hydrocolloids in the formulation of a premixture for gluten-free noodles using base ingredients like corn starch, cassava starch and rice flour. As regards machineability, guar gum showed the best performance, giving the dough an easy form without stickiness. Regarding texture, guar gum again showed the best quality, thus giving cooked noodles the typical characteristic of *al dente* consistency. These noodles resembled those made with wheat flour to a great extent.

Kaur *et al.* (2005) studied the effects of glycerolmonoestearate (GMS) on the physicochemical, rheological and textural properties of noodles made with corn starch and potato starch. Noodles added with GMS showed longer cooking time and lower weight of the cooked noodles. Texture of cooked noodles was slightly softer, though with a higher cohesiveness than the control ones.

To investigate the effects of starch characteristics on the quality of noodle making, white salted noodles (WSN) from reconstituted flours, in which the wheat starch was substituted by different cereal starches, including waxy and non-waxy rice starches, waxy wheat starch and waxy corn starch, were prepared. The rheological properties of raw WSN were mainly influenced by the size of starch granules, whereas, the small starch granules, such as that for rice starches, exhibited high amounts of water absorption during dough preparation and a dense packing of starch granules inside a thin gluten-strand network. The rheological properties of cooked WSN were mainly dominated by the amylose content and the fine structure of the amylopectin, which resulted in the differences in water absorption and cooking time required for cooked WSN (Huang and Lai, 2010).

Inglett *et al*. (2005) conducted a study with the objective to introduce an oat hydrocolloidal fibre composition, called Nutrim-5 into rice flour noodles. The rheological properties of the noodle flour composites indicated that Nutrim-5 contributed binding qualities to the composites. Nutrim-5 appeared to contribute functionality to the rice flour, allowing for larger quantities to be used in the making of Asian noodles. The noodles were prepared in 20 kg batches by mixing blends of wheat flour, rice flour, and Nutrim-5 with alkali, salt solution, and egg. After mixing and kneading into smooth sheets, the noodles were cut, curled, and deep fat-fried. By using 10'%, Nutrim-5 in the formulation, it was possible to satisfactorily make noodles using 50 % rice flour. The cooking loss and tensile strength were measured and found to be satisfactory for this amount of rice flour in the noodles. A trained sensory panel also indicated that these noodles did not reveal any difference in taste

Plantain noodles were shown to contain moisture (8.20%), fat (1.72%), crude fibre (1.62%), carbohydrate (88.20%), protein (3.60%), energy (345 kJ/g) and pH of 5.8. Mean cooking time for PN_3 (Plantain flour with 3.5 xantham gum) was 7.62 minutes, while that of PN_2 (Plantain flour with 2.5xantham gum) was 7.10 min, PN_1 (Plantain flour with 1.5 xantham gum) was cooked in 5.10 min and PNO (Plantain flour without xantham gum) in 4.5 min, but the branded commercial noodles were cooked in 8.21 and 8.29 min. Percentage cooking losses for the noodles were 6.60, 7.60, 8.40, 10.40, 6.52 and 6.39 for PN_3, PN_2,

PN_1, PN0, BN_1 (branded noodles 1) and BN_2 (branded noodles 2) respectively. Rate of water absorption for PN_3, PN_2, PN_1, PN_0, BN_1 and BN_2 was 124.20, 115.25, 113.50, 105.50, 112.58, 111.30 respectively. There was significant difference ($p<0.05$) in the colour, starchy mouth coating, stickiness, firmness and smoothness of the cooked samples of noodles. In colour, both branded noodles 1 and 2 were found to have light yellow colour, while noodles produced from plantain flour with or without xanthan gum (PN_O) had the least colour grey (1.2). In terms of value of smoothness, the range was 1.5- 4.2 where, in PN_3 was found to be very smooth. The range of values for firmness was 2.2-4.1 and PN_3 was adjudged to be very firm among the noodle samples from plantain flour. The range of values for stickiness was (1.4-4.3), and PN_3 was found not to be as sticky as other noodle samples produced from plantain flour. The range of values for starchy mouth feel was (1.6-4.2) and PN_3 was found to have the least starch mouth feel. The result showed that there was no significant difference ($p>0.05$) in all the sensory attributes (appearance, flavour, taste, texture and colour) of noodles produced from plantain flours, but significant difference ($p<0.05$) existed between the plantain noodle samples and the commercial branded noodles. The range of mean scores for taste was (1.0 4.7), flavour (1.5-4.6), texture (2.0-4.4), colour (1.2-4.2) and acceptability (2.0-4.6). It was therefore concluded that plantain noodles using 3.5% of xantham gum produced the best product when other products like wheat and soya bean were incorporated (Ojure and Quadri, 2012).

Mensah (2011) conducted a study to phosphorylate starch from a legume which was used as flour binder for noodles preparation. Four different factors namely; reaction time, Sodium hexametaphosphate % (SHMP) and starch solids were varied at 130^0C and optimized to obtain 1.6 h, 0.163 % SHMP and 33 g starch solids for the preparation of phosphorylated starch. The modified starch gave optimized responses with a degree of substitution of 0.0042 and specific volume of 1.48 cm3/ g. An optimum binder to the flour in the ratio of 1.41 g to 19.95 g gave the flour gelation concentration of 0.246 g per ml. When pasted it showed a peak viscosity of 177 BU with relatively slight breakdown of 26 BU and increased viscosity during cooling at setback of 172 BU. This observation suggested that modified starch could be utilised as a potential component for visco elastic food products. Three sample noodles; alkaline, udon and control were prepared from the composite flour. From the sensory evaluation studies, the alkaline noodles was found to be the most preferred sample that gave the best sensory characteristic scores for aroma, texture, colour, mouth feel and after taste, being, 3.59, 5.74, 7.55, 9.88 and 8.57 respectively.

The utilization of Bambara groundnut flour in the food industry especially when composited with the starch binder has been recommended for the preparation of noodles. In another study, noodles made with extruded maize (E), maize flour (M) and wheat straw supplements (WS) obtained the highest total sensory scores. These samples exhibited the highest scores for the sensory parameter- external appearance, due to a desirable yellow colour.

The increasing consumption of noodles has led to concerted efforts to explore the feasibility of using instant noodles as a vehicle for micronutrient fortification. While several technological and implementation challenges remain, this food appears to have the potential to be an effective food vehicle for micronutrient fortification.

Umesh *et al*. (2010) has rightly proved on that since jackfruit is a rich source of phytochemicals, nutrients, antioxidants, including phenolic compounds, it offers opportunities for the development of value-added products such as noodles which will have commercial value along with health enhancing properties.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled, "Development of an extruded product from raw jackfruit" was aimed at developing a value added extruded product from the bulbs and seeds of raw jackfruit. The developed product Viz. noodles was studied in depth for its physico-chemical, cooking, nutritional and organoleptic and shelf life qualities. The methodology of the present study is presented under the following heads:-

3.1 Selection and collection of jackfruit

3.2 Processing of flour

3.3 Quality analysis of flours

3.4 Extrusion of noodles

3.5 Standardization of cooking procedures

3.6 Quality analysis of noodles

3.7 Storage stability of noodles

3.8 Selection of the best combination

3.1 SELECTION AND COLLECTION OF JACKFRUIT

Artocarpus heterophyllus Lam., commonly called jackfruit, is a medium-sized evergreen tree that bears high yields of the largest known edible fruit. However, this fruit has been exploited only to a less extent, due to the wide variation in fruit quality.

Jackfruit variety "*Koozha*" was selected for the study owing to its abundant availability and lower utilisation. Raw mature jackfruits were harvested from the trees grown in the Instructional farm, College of Agriculture, Vellayani and also from the adjacent home yards, for the study purpose.

Product quality is one of the prime factors for ensuring consistent marketing of jackfruit products. However there is no precise measurement, clear definitions or standard units to identify product quality objectively, as quality is always associated with the degree of acceptance by the consumers (Sim *et al*., 2003).

The fruits chosen were in the fully mature stage, (90-110 days after fruit set) with acceptable appearance for the raw stage of consumption. External visible maturity indices such as distance between spines per unit area and colour of spines (green) were ensured before harvest. Weights of the fruits were recorded. The other ingredients namely refined flour, vegetable oil and iodised salt were purchased from the super market.

3.2 PROCESSING OF FLOUR

Dried jackfruit chips and flour have a longer shelf life than the fresh fruits. One of the most pressing problems associated with jackfruit is its seasonal availability and its handling and storage difficulties. The problems of availability, bulkiness and perishability can best be solved, if more of the harvested fruits are processed into chips, and flour. Processed forms are less bulky and less delicate to handle and can be stored with less storage losses than the fresh fruit.

3.2.1 Preliminary processing

Vegetables are subjected to several preliminary operations after harvesting and before processing. As a result of peeling, cutting, blanching and drying, the produce will change from a state of perishability, with a shelf life, as short as 1-3 days to a relatively stable state with a shelf life of several weeks or months. To get flour of jackfruit bulb and seed, fruits were subjected to several preliminary processing methods like washing, peeling, cutting, separating of bulbs and seeds, blanching and boiling.

3.2.1.1 *Cleaning and recording weight*

Freshly harvested jackfruits were washed under clean running water and cut into large slices. The bulbs and seeds were separated out manually from

Jackfruit

Jackfruit bulb

Jackfruit seed

Plate 1. Whole jackfruit, bulb and seed

fruits. The fresh weight of whole jackfruit, bulbs and seeds were recorded in order to determine the final yield of the processed product after dehydration.

3.2.1.2 ***Standardization of dimension of slices for pre-treatment***

Selection of appropriate dimension of slices of the vegetables to be dried is very important, as thicker slices will dry at a slower rate or may not dry fully and it may subsequently deteriorate after packing than thinner pieces. And in the case of very thin pieces, there is a tendency for raw materials to stick to the drying trays and will also be difficult to remove.

So the optimum dimension of the jackfruit bulb and seeds were selected by the overall visual quality (OVQ) scores of the dried slices. OVQ scores are given using a 9 point scale where, 9 refers to excellent appearance, 7 to good, 5 to fair (limit of marketability), 3 to fair useable but not saleable and 1 to unusable (Yuan *et al*., 2010), by a panel comprising of 10 members. The variations in dimension of jackfruit bulbs and seeds, which were evaluated, are given in Table 2.

Table 2. Variation in dimension of bulbs and seeds

Sl. No.	Bulb	Dimension (cm)	Seed	Dimension (cm)
1.	T_1	1.5 x 1	T_1	0.5 x 0.5
2.	T_2	2 x 1	T_2	1 x 1
3.	T_3	2.5 x 1	T_3	1.5 x 1
4.	T_4	3.5 x 1	T_4	2 x 2

3.2.1.3 ***Standardization of blanching time of raw jackfruit bulb***

Blanching is a unit operation prior to freezing, canning or drying in which fruits or vegetables are heated for the purpose of inactivating enzymes; modifying texture; killing microorganisms; preserving colour, flavour , and nutritional value and removing trapped air (Corcuera *et al*., 2004).

Blanching is a mild heat treatment, (usually accomplished at temperatures below 212^{0}F for less than 2 to 3 min) applied to foods that are to be subsequently canned, frozen, or dried. The purpose behind this operation is to eliminate or reduce the activity of enzymes in the foods that catalyse changes in flavour, texture, or colour. Other benefits include removal of air from the food tissues to reduce oxidation, softening of the plant tissues to facilitate packing into packages, and inactivation of anti-nutritional properties.

Steam and cold water were the media used here for blanching. The best identified dimension of jackfruit bulb was subjected to blanching. The optimum blanching time was identified by analysing the scores of overall visual quality (OVQ) as rated by the sensory panel after blanching and drying. The different periods of time studied are depicted in Table 3.

3.2.1.4 *Standardization of boiling time of seeds*

The jackfruit seeds were cleaned manually and the white arils (seed coat) were peeled off manually. The spermoderm layer was removed by rubbing the seeds between the hand and washing thoroughly under running water. It was then subjected to thermal treatment to inactivate anti-nutritional factors present in the seeds. Seeds were pressure cooked for various durations of time, cooled and dehydrated. The optimum boiling time was selected from the scores given by the sensory panel.

3.2.1.5 *Standardization of pre- treatment media*

Pre-treatment of fruits and vegetables for storage is an important step in preserving food products. It helps to retain the natural colour of the food product, along with inactivating enzymes and killing microorganisms that can cause food spoilage. Torreggiani (1993) reported that pre-treatment with chemicals (SO_2) or blanching prior to drying of fruits and vegetables effected the prevention of discolouration.

Table 3. Variations in blanching/boiling time of raw material

Sl. No.	Treatments	Blanching time of bulb (min. sec)	Boiling time of seed (min. sec)
1.	T_1	1.00	2.00
2.	T_2	1.30	5.00
3.	T_3	2.00	10.00
4.	T_4	2.30	15.00
5.	T_5	3.00	20.00
6.	T_6	3.30	25.00

The pre-treatment media giving the best products with respect to appearance and colour was identified. The various treatments applied to the blanched slices of jackfruit bulb are given in the Table 4. Five hundred grams of blanched slices were immersed in one litre water with the respective additives. The best of these variations were again identified by analysing the scores of OVQ after the treated materials were drawn out, dried and then rated by the sensory panel.

3.2.1.6. ***Standardization of immersion time***

Immersion of vegetables in alkaline or acid solution prior to drying of vegetables prevents discolouration (Sunkja and Raghavan, 2004). The blanched bulbs were immersed in the selected media. The most suitable immersion time in the selected media for retaining maximum sensory qualities was identified on the basis of scores obtained in the scale for OVQ. Table 5. presents the various time periods chosen for the immersion.

Table 4. Composition of various immersion media

Sl. No.	Treatments	Particulars of immersion media
1.	T_1	Salt (0.5%)
2.	T_2	KMS (0.2%)
3.	T_3	Citric acid (0.2%)
4.	T_4	Salt (0.5%) + KMS (0.2%)
5.	T_5	Salt (0.5%) + Citric acid (0.2%)
6.	T_6	KMS (0.2%) + Citric acid (0.2%)

Table 5. Variations in immersion time of bulbs

Sl. No	Treatments	Time (min. sec)
1.	T_1	5.00
2.	T_2	7.00
3.	T_3	10.00
4.	T_4	12.00
5.	T_5	15.00

3.2.1.7. ***Dehydration of the pre-treated raw material***

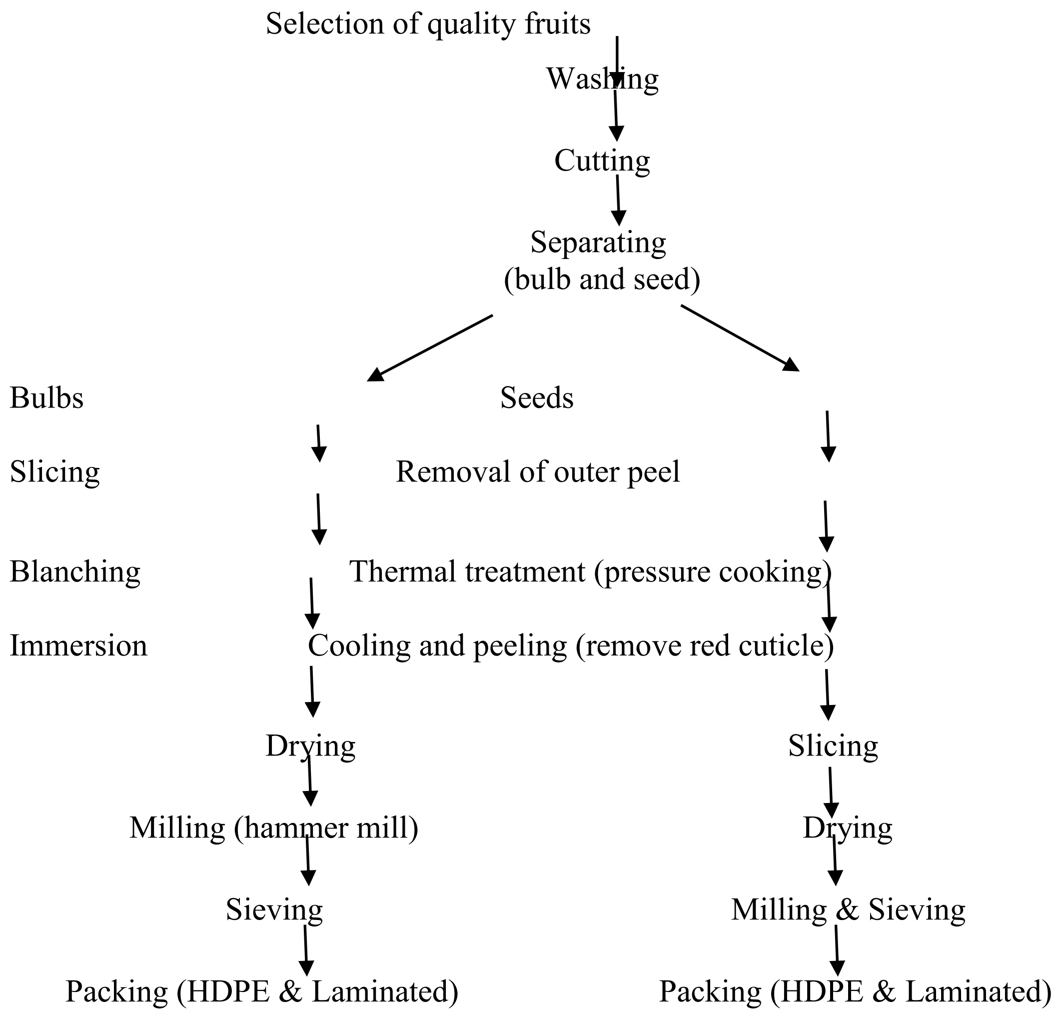
Drying is intended to halt or slow the growth of microorganisms and rate of chemical reactions. The removal of water provides food processors excellent opportunities to reduce the product's volume and weight, extend shelf life, and convert liquid to powdery products, such as instant coffee or a vegetable soup base mix. Vegetables contain enough moisture to permit the activity of native enzymes and microorganisms for spoilage.

Dehydration has been a means to reduce moisture content by mechanical means. The bulbs and seeds were drained and dried in a cabinet drier at 60°C. The pre-treated bulbs and seeds were dehydrated in cabinet dryer till crisp and breaking stage.

3.2.1.8 Milling of flour

Dried jackfruit bulbs and seeds were milled into fine flours separately-RJBF and RJSF. The flours were sieved through a 0.05 mm sieve and packed in high density polyethylene (HDPE) and laminated cover for further analysis.

Figure - 1   Flow diagram for preparation of raw jackfruit flour (RJF) flour



Jackfruit seed and bulb flour

Flour packed in HDPE cover

Jackfruit flour in laminated cover

Moistened Flour

Plate 2. Jackfruit bulb and seed flour

3.3 QUALITY ANALYSIS OF FLOURS

The flours prepared from the raw jackfruit bulbs and seeds were analysed for physical, chemical, nutritional and shelf life qualities.

3.3.1. Physical, chemical and nutritional qualities of flours

The physical qualities like bulk density, chemical qualities like moisture and fibre and nutritional qualities like calorie, protein, carbohydrate, and total minerals were analysed by standard techniques. The details of the analysis are presented in Table. 6

Table. 6 Analysis of physical chemical and nutritional constituents of RJF

Constituents	Method adopted
Bulk density (g/cm^3)	Okaka and Potter (1979)
Fibre (g)	AOAC (2005)
Moisture (%)	AOAC (2005)
Carbohydrate (g)	AOAC (2005)
Protein (g)	AOAC (2005)
Calories (kcal)	AOAC (2005)
Total minerals (mg)	AOAC (2005)

3.3.2 Shelf life qualities of raw jackfruit bulb and seed flour

Assessment of shelf life quality is important since it determines the suitability of a particular ingredient for product development. Shelf life is the recommendation of time that the products can be stored, during which the defined quality of a specified proportion of the goods remains acceptable under expected conditions of distribution, storage and display (Azanha and Faria, 2005).

The flour prepared from raw jackfruit bulbs and seeds were stored in high density polyethylene (HDPE) and laminated packages for a period of three months. Thakur *et al*. (1995) reported that chemical and sensory qualities are influenced by storage conditions. The shelf- life qualities were assessed with respect to changes in moisture, insect infestation and microbial count.

3.3.2.1 ***Moisture***

Moisture provides a measure of the water content of the jackfruit bulb flour and seed flour and its total solid content. It is also an index of storage stability of the flour. Moisture content of the dehydrated food material is an important factor which affects the stability of the food. So it is necessary to control the moisture to a level where microorganisms may not be able to grow and spoil the product.
Moisture content of flours generally depends upon the duration of the drying process (Ocloo *et al*., 2010). The lower the moisture content of flour, better its shelf stability and hence the quality.

Five grams of the sample was weighed into previously weighted moisture cups and dried in an oven at 100^0C till a constant weight was attained. Moisture content of the flour stored in HDPE and laminated packages were analysed at monthly intervals for 3 months in a similar way.

$$\text{Moisture \%} = \frac{\text{Initial weight (g) - Final weight (g)}}{\text{Initial sample weight (g)}}$$

3.3.2.2 ***Insect infestation***

Insects are pests that reduce the quantity and quality of food and forage by feeding on fibre during production and storage. They damage food commodities during harvesting, processing, marketing, storage or use and also transmit disease organisms to man or plants and animals (Ogedegbe and Edoreh, 2014). Insects are responsible for the quality deterioration of flours by contamination with their droppings and hair. During the storage period, insect infestation was observed at monthly intervals through sieving and visual observation.

3.3.2.3 *Microbial profile*

The fresh as well stored flour samples were assessed for the presence of various microorganisms Viz. bacteria, fungi, and coliforms at monthly intervals up to three months. The flours were stored in ambient conditions for three months. The microbial evaluation was done initially and at 30 days intervals up to 3 months. The growth of bacteria, fungi and coliforms were observed using Nutrient agar (NA), Potato dextrose agar with rose bengal (PDARB) and Eosin methylene blue (EMB) respectively.

The evaluation was done by serial dilution of samples followed by pour plating technique suggested by Johnson and Curl (1973). The serial dilution of the samples followed by pour plating was employed to estimate the population of viable micro-organisms in the developed flour.

3.4 EXTRUSION OF NOODLES

The major food ingredients in addition to refined flour selected for the development of extruded products were raw jack fruit bulb and seed flour. The method used for preparation of these flours is presented in Fig 1. Purwandri *et al*. (2014) standardised noodles from breadfruit, konjac and pumpkin flour in the form of as a gluten free noodles.

3.4.1 Formulation of noodles

The current trend is to develop composite flour based food products with enhanced nutritional as well as other quality traits, thus adding variety to the food basket (Baljeet *et al*., 2014). Shittu *et al*. (2007) reported that composite flours used were either binary or tertiary mixtures of flours from food crops with or without wheat flour. Refined flour, raw jackfruit bulb and seed flour were combined in different proportions to prepare composite flour for the noodles. The different combinations of composite flour are presented in Table 7.

Maida is the refined wheat flour which contains the protein gluten, which acts as a binder along with providing strength. Maida gives volume to the composite flour and lacks a strong flavour or taste. Such qualities are essential as an ingredient in extruded products. Hence, maida formed one of the major ingredients of the formulation.

Table 7. Combinations of composite flour (100g)

Sl. No	Treatments	Refined flour (maida)	Jackfruit bulb flour (JFBF)	Jackfruit seed flour (JFSF)
1.	T_1	40	30	30
2.	T_2	50	25	25
3.	T_3	50	30	20
4.	T_4	50	40	10
5.	T_5	50	10	40
6.	T_6	50	20	30

3.4.2 Setting up the extruder

For extruding the composite flour into noodles, water was added to in 3 phases and kept for refrigeration so as to maintain moisture at 33 per cent. The flour was kept in the Brabender single screw food extruder and the temperatures set at the different zones were: Zone 1: 60^{o}C; Zone 2: 70^{o}C ; Zone 3: 80^{o}C and die zone 135^{0}C . The other parameters set before the extrusion was:

Screw speed - 40 min-1

Dosing screw speed - 15 min-1

Speed of feeder - 16 rpm,

Extrusion of noodles

Plate 3. Noodles in oven

Screw - 40 rpm

Size of the die – 2 mm x 4 strands.

Figure 2. Flow chart for extrusion of noodles

Composite Flour (bulb, seed, and refined flour)

↓

Mixing

↓

Conditioning

↓

Freezing (overnight)

↓

Mixing

↓

Tempering

↓

Feeding

↓

Sheeting (strands of 2mm thick)

↓

Cutting in required sizes

↓

Drying (60^{o}C for 8 hours)

↓

Packing of dry noodles

The extruder starts functioning with the mixing activity, which is affected by the viscosity of the flours, when mixing is complete, sheets were extruded. The sheets were cut into strips. The noodle strips were dried in the cabinet dryer at 60^{0}C for 8 hrs. and sealed in HDPE and laminated pouches and kept for further analysis.

3.5. STANDARDIZATION OF COOKING PROCEDURE

The cooking procedure was standardised by assessing the time needed for thoroughly cooking of noodles. For this the noodles were cooked in equal quantity of boiling water and weight of the cooked noodles was recorded.

Dry noodles

Cooked noodles

Noodles in HDPE and Laminated cover

Plate 4. Packed noodles

3.5.1. Cooking time

Cooking quality of noodles was analysed according to Ojure and Quadri's method (2012) on unripe banana noodles. Ten grams of noodles were cooked in 300 ml of boiling deionised water in a covered beaker. Cooking time was determined by the removal of a piece of noodles every 2 minutes and pressing the noodles between 2 pieces of glass slides. Optimum cooking was achieved when the centre of the noodles became transparent or when the noodles were fully hydrated. Cooking was stopped by rinsing briefly in deionised cold water.

3.5.2. Cooked weight

Cooked weight of a noodles were analysed according to Omeire *et al*. method (2015) on cassava noodles. They defined cooking weight as the weight gain of the noodles during the cooking which indicated the amount of water that was absorbed and was therefore an index for the swelling ability of the noodles. Each treatment was cooked according to the determined cooking time and then the cooking weight was calculated and given in percentage.

3.6. QUALITY ANALYSIS OF NOODLES

Quality is the ultimate criteria for the desirability of any food product. It has been variously defined as those characteristics of food that are acceptable to consumers which include standard external factors such as appearance, texture and flavour and internal standards such as physical, chemical and microbial attributes. Quality comprises the totality of characteristics of an entity that bears on its ability to satisfy the implied needs of consumer (Peri, 2006). The quality of noodles was assessed in terms of cooking, physical, chemical, nutritional and sensory attributes.

3.6.1 Cooking characteristics

Besides changes in sensory quality, cooking also leads to changes in physical and chemical properties of food. Some of the changes that were ascertained were, cooking loss and water absorption.

3.6.1.1 *Cooking loss*

The quantity of a dried material which was leached out in the cooking water of cooked noodles is its cooking loss (Yadav and Gupta, 2015). Cooking loss of a noodles was analysed according to Ojure and Quadri method (2012) on unripe banana noodles. Ten grams of noodles were cooked in 300 ml of distilled water in a 500 ml beaker until the central opaque core in the noodles strand disappeared. Cooking loss (%) was measured by transferring the cooked water to a pre-weighed beaker and evaporating the water in a conventional oven overnight at 100^0c, then reweighing the beaker with left over solids. Cooking quality analysis was performed in triplicate.

$$\text{Cooking Loss (\%)} = \frac{\text{Dried residue in cooking water}}{\text{Weight of noodles before cooking}} \times 100$$

3.6.1.2. *Water absorption*

Water absorption of noodles was analysed according to Ojure and Quadri's method (2015) on unripe banana noodles. Water absorption (%) is the difference in weight of cooked noodles and uncooked noodles, expressed as the percentage of the weight of uncooked noodles. Cooked noodles were rinsed with water and drained for 30 sec, then weighted to determine the gain in weight. This analysis indicates the amount of water absorbed by the noodles during cooking process. It was calculated by using the formula given below:

$$\text{Water absorption (\%)} - \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$$

3.6.2. Physical characteristics

There are certain physical characteristics specific to extruded products. Analysis to check for these specifications will ensure and confirm the quality of the products. Physical characteristics like extrusion behaviour, firmness, shape, uniformity of strands, tensile strength, packaging quality, bulk density, true density, swelling index, yield ratio, processing loss and colour of product were ascertained.

3.6.2.1. *Extrusion behaviour*

This characteristic was analysed for wet noodles (before drying). The extrusion behaviour of the developed product was ascertained with respect to residence time, uniformity of strands and appearance during extrusion. Residence time depends on the rheological property (viscosity) of the flour. In residence, time maximum quantity (gram) of noodles through the die within minimum time (min) is considered as the best extrusion behaviour.

Uniformity in flow of strands and external appearance during extrusion was rated by technical experts using score card (Karoline, 2004).

The quality of dry noodles was assessed for firmness, shape, uniformity of strands, tensile strength and packaging quality (suitability) subjectively. A five point score card was used for this (Appendix1).

3.6.2.2 *Bulk density*

Bulk density is an indicator of drying retention and accuracy of weighing. It is the ratio of the weight of the sample to the weight of equal volume of water. It is used as an index for comparing the volume of different foods. Bulk density depends upon the particle size of the samples. This measure is important for determining packaging requirements, material handling and various other applications in wet processing.

Fifty grams of the sample were put into 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g cm-^{3}) was calculated as weight of sample (g) divided by volume of sample after tapping (cm^{3}) (Okaka and Potter, 1979).

$$\text{Bulk density} = \frac{\text{Weight of the sample}}{\text{Weight of equal volume of water}}$$

3.6.2.3. *True density*

True density means mass per unit volume of grains which does not include pore spaces between granules (Tapash and Bhaskara, 2006). For this a single noodle was taken and its length and diameter were measured by scale and screw gauge to calculate its volume ($\prod r^2h$). True density is given by the formula below:

$$\text{True Density (g/ml)} - \frac{\text{Weight of sample}}{\text{Volume of sample}}$$

(Tapash and Bhaskara, 2006)

3.6.2.4. *Swelling index*

Swelling power is a measure of hydration capacity, because its determination is a measure of swollen starch granules and occluded water. Quality of food is often connected with retention of water in the swollen starch granules (Ocloo e*t al.,* 2010). The swelling index (SI) of noodles was determined according to the method described by Chen *et al.* (2002). A 10 g sample of noodles was cooked for an optimum cooking time, weighted and dried at 105°C for 16 hrs. Measurements were repeated three times. The swelling index value was expressed as below:

$$\text{Swelling Index} - \frac{W_2 - W_1}{W_1}$$

Where,

W_1- Weight of cooked noodles

W_2- Weight of noodles after drying

3.6.2.5. Yield ratio (noodles)

Ratio of actual yield to theoretical yield expressed using percentage is referred as yield ratio. Yield ratio of the developed products were analysed using the formula.

$$\text{Yield ratio} - \frac{\text{Final weight of the product}}{\text{Weight of the raw ingredients}}$$

(Krishnaja, 2014)

3.6.2.6. *Processing loss*

Processing loss is an economic characteristic to understand the actual edible entity produced from the raw material after the wastage is accounted. Processing loss was computed using the formula

$$\text{Processing loss} = \frac{\text{AP weight} - \text{EP weight}}{\text{AP weight}}$$

(Karoline, 2004)

Where,

AP weight – weight as purchased

EP weight – edible portion weight

3.6.2.7. *Colour*

Colour is a key quality trait because of the 'visual impact' at the point of sale (Mares and Campbell, 2001). Asenstorfer *et al*. (2006) reported that in order to achieve bright yellow colour, noodle manufacturers often add pigments such as tartrazine, sunset yellow and beta-carotene because there is insufficient natural pigmentation to meet customer expectations however, today's customers prefer natural flour noodles.

Colour analysis was carried out on noodles using a Minolta spectrophotometer (Japan). The noodle samples after drying at 50°C for 2 hours were powdered using a blender and filled in a petridish of size 60 mm (i.d) and height 17 mm. The primary colour coordinates 'L', 'a', 'b' values were measured by Minolta spectrophotometer and by granular material cover. From the above primary parameters, the total colour difference and the whiteness index of the powered samples were measured using standard equation as follows.

Total colour difference - $\sqrt{} (L^0 - L)^2 + (a^0 - a)^2 + (b^0 - b^0)^2$

Whiteness index - $\sqrt{}100 - (100 - L)^2 + a^2 + b^2$

Where,

L = degree of lightness

a = degree of redness

b = degree of yellowness

L^0 = lightness value of the reference plate - 99.34

a^0 = redness value of the reference plate - - 0.03

b^0 = yellowness value of the reference plate - - 0.01

3.6.3. Chemical composition

Since chemical constituents have a definite role in food properties, determination of chemical components in the developed noodles is crucial. Thus the major chemical components such as moisture and fibre were analysed.

3.6.4. Nutritional composition

Nutritional quality of food appears to be the major concern for consumers all over the world. Proximate composition of the developed products were analysed using the standard procedures depicted in Table 6.

3.6.5 Sensory qualities of noodles

Sensory evaluation plays an important role in the acceptability of a new product. Sensory evaluation is defined as a scientific discipline used to evoke measure, analyse and interpret those responses to products that are perceived by the sense of sight, smell, touch, taste and hearing (Stone and Sidel, 2002). Samples were presented to a panel of 10 trained judges selected from the Department of Home Science. Sensory characteristics like appearance, colour, texture, taste and overall acceptability of the noodles were assessed by a panel of judges using a five point scale (Appendix 2).

3.6.6. Economic viability

To know the economic viability, cost of the product was calculated. Cost of the developed products were worked out based on input cost i.e. cost of different ingredients used for the preparation of the product, cost of packaging materials and output cost (10 per cent of the cost of products were added as overhead charges for fuel and labour, to the total input cost added).

3.7. STORAGE STABILITY OF NOODLES

Just as microorganisms can grow during storage, other changes too may occur in the composition of the food. This deterioration may make the food unacceptable to the consumer. Due to such cases the changes in the food during storage may make it unsafe due to the nature of the compounds formed. Shelf-life studies can provide important information to product developers enabling them to ensure that the consumer will see a high quality product for a significant period of time after production. Food products that do not spoil under ordinary unrefrigerated temperature and humidity conditions are called shelf stable products.

To observe the keeping quality, the noodles were stored separately in heat sealed HDPE and laminated pouches at ambient conditions. Fifty grams of noodles from all treatments were stored separately in 36 HDPE and 36 laminated pouches. One pouche for each treatment was to be picked randomly every month. The values were analysed in triplicates. The 6 randomly picked packets were used for analysis of sensory attributes every month. Moisture and microbial profile were conducted for 3 months.

3.7.1. Sensory stability

Sensory evaluation is a scientific discipline that applies the principle of experimental design and statistical analysis by using of human senses Viz. sight, smell, taste, touch and hearing for the purpose of evaluating consumer products (IFT, 2005). This discipline requires a panel of human assessors, on whom the products are tested and responses made by them are recorded. When food is assessed by human sensory organs, the evaluation is said to be sensory analysis (Simi, 2002).

Sensory qualities like appearance, colour, texture, taste and overall acceptability was assessed at each month interval for 3 months by using 5 point score card. . Sensory evaluation of the freshly prepared noodles was carried out in mid-morning time with the help of 10 trained panel members from the department of Home Science. This was conducted to test for changes in quality during storage.

3.7.2. Moisture

Moisture content of the products was assessed at monthly intervals as mentioned in 3.3.2.1 .

3.7.3. Microbial profile

Processed foods which are stored and consumed after a period of storage require certain microbial criteria to be employed to ensure their quality and safety. According to Shankaran (2000), several factors such as quality of raw material, storage temperature, storage containers, processing methods and the environment in which it is processed will affect the microbiological quality of processed foods. Since processed foods provide ample scope for contamination with spoilage from pathogenic microorganisms, the microbial quality was assessed.

The stored product samples were assessed for the presence of various microorganism Viz. bacteria, fungi, and coliforms at monthly intervals up to three months. The serial dilution of the samples followed by pour plating was employed to estimate the population of viable microorganisms in developed products.

3.8. SELECTION OF THE BEST COMBINATION

The best treatment was selected by ranking the scores of various characteristics. Among the physical characteristics appearance, uniformity of strands, colour of raw material, and sensory quality of cooked noodles were assessed. The scores of appearance and uniformity of raw strands were ranked. Highest score was given the rank of 1st and lowest score was ranked 6th. Colour of cooked noodles was the next parameter considered. The score of the sensory panel were evaluated and ranks recorded. The highest score got 1st rank and the lowest score got the 6th rank. Similarly over all acceptability was also ranked. Less cooking time was selected as criteria for identifying the best treatment from the consumer point of view. For chemical constituents high fibre content was considered for selection from the health point of view. Treatments were ranked based on the fibre content. One of the vital considerations in food selection was calorie and protein content. The treatments were again ranked from 1 to 6 based on low calorie and high protein content. Last but not the least the treatments were ranked with respect to safety from microbial attack during storage for 3 months.

3.9. STATISTICAL ANALYSIS

In order to obtain suitable interpretation, the generated data was subjected to statistical analysis like one way analyses of variance (ANOVA) at 0.05% significance level and Student's't' test to calculate significant differences in the treatment means. Graphical interpretation of analysed data is also presented. The data generated during the study were compiled analysed statistically and presented under results and discussion.

RESULTS

. RESULTS

The results of the present study entitled "Development of an extruded product from raw jackfruit" are detailed in this chapter under the following headings:

4.1 Selection and collection of jackfruit

4.2 Processing of flour

4.3 Quality analysis of flours

4.4 Extrusion of noodles

4.5 Standardization of cooking procedures

4.6 Quality analysis of noodles

4.7 Storage stability of noodles

4.8 Selection of the best combination

4.1 SELECTION AND COLLECTION OF JACKFRUIT

Jackfruit is a tropical crop which has immense scope for processing. There are two cultivars of jackfruits that are predominant in Kerala. *Varikka* has a slightly hard inner flesh when ripe, while the inner flesh of ripe '*Koozha*' fruit is very soft and almost dissolving. Thus, underutilised cultivar '*Koozha'* was selected for the study.

Jackfruit is an aggregate fruit with numerous fruitlets, each containing one seed. A single seed is enclosed in a white aril encircling a thin brown spermoderm, which covers the fleshy white cotyledon.

The process of separating the fruitlets from the centre core is quite unpleasant, since the fruit is full of gummy latex that sticks to the hands and knife. The difficulty in accessing the flesh makes it very unpopular for use.

Fruits were collected after 90- 110 days of fruit set. It was more or less cylindrical in shape. Fruits had slight green colour. The outer surface of jackfruit was covered with spines which were also light green in colour. On an average a single fruit had a weight of more than 10 kg. The fruits did not have any strong smell. Tree to tree variation was observed with respect to physical characteristics like size of bulb and seed, colour etc.

4.2. EXTRACTION OF FLOUR

Flour is the base material for preparation of extruded product. The trend of substitution of local raw materials for wheat flour is increasing due to the growing market for confectionaries (Aziah and Komathi, 2009). Thus, several developing countries have encouraged the initiation of programmes to evaluate the feasibility of incorporating locally available flours as a substitute for wheat flour (Abdelghafor *et al*., 2011). Jackfruit bulb and seed flour were prepared processed after preliminary processing and drying.

4.2.1 Preliminary processing

To extract the jackfruit bulb and seed flour, bulbs and seeds were subjected to several preliminary processing methods. Preliminary processing helps to preserve quality, appearance and acceptability of products by suppressing oxidative changes and microbial contamination during processing, storage and consumption.

4.2.1.1 *Cleaning and recording weight*

Fruits were cleaned after harvesting under running water. It was then cleaned with distilled water. As jackfruit is big in size it was cut into big pieces, bulbs and seeds were then separated out. Weight of the whole jackfruit, bulb and seed were taken separately. From Table 8. it can be seen that on an average the yield of wet weight of bulb ranged from 40.63 to 57.23 while yield of dry weight of bulb ranged from 21.80 - 36,40. On computing the average weight of wet seed, it ranged from 23.39 to 30.17 and dry weight of seed ranged between 42.07-47.41.

Table 8 - Yield of bulb and seed from jackfruit

Sl. No	Whole weight of jackfruit (kg)	Wet weight of bulb (kg. g)	Dry weight of bulb (kg. g)	Wet weight of seed (kg. g)	Dry weight of seed (kg. g)
1.	10. 275	4.175 (40.63)	1.52 (36.40)	3.100 (30.17)	1.470 (47.41)
2.	13. 550	6.650 (49.07)	1.450 (21.80)	3.345 (24.68)	1.500 (44.84)
3.	15.465	7.200 (46.57)	1.825 (25.34)	4.160 (26.89)	1.920 (46.15)
4.	19.220	9.870 (50.98)	2.233 (22.62)	5.300 (27.57)	2.230 (42.07)
5.	20.00	11.447 (57.23)	2.500 (21.83)	4.679 (23.39)	2.100 (44.88)

(Figures in parenthesis denotes yield percentage)

4.2.1.2. ***Standardization of dimension of slices***

Dimension of slices was varied keeping in mind that water loss increases with increase in the surface area of fruit pieces. It was assured that all of the pieces are about same size, so that they would dry at the same rate (James and Kuipers, 2003). The mean value of scores allotted by the panel members for overall visual quality was worked out. Over all visual quality scores for the different treatments revealed that T_3 i e bulb slices of 2.5 x 1 cm was found to be most the accepted dimension with a score 8.20. The next higher score was obtained by T_4 for the slices which had a dimension of were 3 x 1 cm (7.65). Other two treatments T_2 and T_1 scored 7.15 and 6.90 respectively, which was less than the first two treatments but were on par with each other.

In case of width of seeds, the highest OVQ score 8.65 was recorded for T_3 (1.5 x 1 cm) sized slices. This was followed by T_4 and T_2 with the score of 7.65 and 7.40 respectively which were on par with each other. Treatment T_1 with the width of 0.5 x 0.5 cm sized slices were found to be inferior in terms of OVQ score (6.30), compared to the rest of the treatments.

Table 9. OVQ scores of dimension of bulbs and seeds

Sl. No	Treatments	Bulb (cm)	OVQ of bulb (Score)	Seed (cm)	OVQ of seed (Score)
1.	T_1	1.5 x 1	6.90	0.5 x 0.5	6.30
2.	T_2	2 x 1	7.25	1 x 1	7.40
3.	T_3	2.5 x 1	8.20	1.5 x 1	8.65
4.	T_4	3 x 1	7.65	2 x 2	7.65
	CD (0.05)		1.394		1.207

(Results are expressed as mean values of ten replicates)

4.2.1.3. ***Standardization of blanching time***

Blanching of vegetables is one of the most important preservation techniques in the food industry, to extend the shelf-life of foods. It generally involves heating or steaming of food for a pre- determined time to eliminate pathogenic microorganisms which endanger public health, as well as those organisms and enzymes that deteriorate the food during storage.

Kendall *et al.* (2005) reported that heat treatment expands the tissue of vegetables, so that the slices will dry faster. Moreover it helps to protect vitamins and retain colour and also reduces the time needed to refresh before cooking. It also helps to slow or stop the enzymatic activities that can cause undesirable changes in colour, flavour and texture during storage.

The scores of OVQ of blanched jackfruit slices were analysed with various time duration Viz. 1 min, 1.30 min, 2 min, 2.30 min, 3 min, 3.30 min. Among the six different treatments of blanching the highest OVQ score (8.67) was obtained by T_1 treatment. This was followed by T_2 (7.81) and T_3 (7.72) which were on par with each other. Other treatments T_4 (5.49), T_5 (2.95) and T_6 (1.52) obtained lower scores compared to other treatments. And this difference was found to be statistically significant as depicted in Table 10.

4.2.1.4. ***Standardization of boiling time of seed***

Powerful trypsin inhibitory activity was reported in jackfruit seeds and it was shown that the activity could be destroyed by boiling the aqueous solution of seed at 100^{o}c for 30 min (Bhat and Pattabiraman, 1989). Boiling helps to remove the brown layer or spermoderm and also helps in easy cutting of seeds. This also prohibits the activity of trypsin inhibitors.

Table 10. indicates the OVQ scores of seeds after different duration of heat treatments. The data reveals that the highest score (7.86) was obtained by T_5 being 20 min. Treatment T_4 scored the next highest score (6.82) being 15 min. This was followed by T_6 with 25 min (5.85). The treatments T_3 (4.92) and T_2 (4.17) were on par. T_1 scored the least among all the treatments with a score of 3.20, being 5 min. The differences in values among treatments were found to be statistically significant too.

4.2.1.5. ***Standardization of pre- treatment media***

In order to prevent browning of bulbs and also to preserve the colour of developed product, pre- treatment media comprising of salt (0.5%), potassium meta-bisulphite (KMS-0.2%), citric acid (0.2%), and their combinations were used.

On analysing the OVQ scores for the 6 different treatments, the treatment T_2 with KMS (0.2%) was observed to have the highest score (7.70), followed by

T_4 (7.49), T_6 (7.45) and T_5 (7.22). Treatment T_3 with citric acid (0.2%) and T_1 with salt (0.5%) obtained the lowest scores. Hence, T_2 was selected from among the 6 treatments as the best pre-treatment media for jackfruit slices as shown in Table 11.

Table 10. OVQ scores of blanching and boiling time of bulb and seed

Sl. No.	Treatments	Blanching time of bulb (min. sec)	OVQ score of bulb	Boiling time of seed (min. sec)	OVQ score of seed
1.	T_1	1.00	8.67	5.00	3.20
2.	T_2	1.30	7.81	7.00	4.17
3.	T_3	2.00	7.72	10.00	4.92
4.	T_4	2.30	5.49	15.00	6.82
5.	T_5	3.00	2.95	20.00	7.86
6.	T_6	3.30	1.52	25.00	5.85
	CD (0.05)		1.463		1.756

(Results are expressed as mean values of ten replicates)

4.2.1.6. ***Standardization of immersion time***

The immersion time of jackfruit slices in pre- treated media were evaluated for different time durations such as 5 min, 7 min, 10 min, 12 min and 15 min. Treatment T_3 (10 min) gave the highest score (8.22) for OVQ among all the treatments. The next highest score was obtained by T_2 (5.89) followed by T_4 (5.65) and T_1 (5.42). These three treatments T_2, T_4 and T_1 were found to be on par. The treatment T_5 scored the least (4.65) among all five treatments. The differences in values were significant too as shown in Table 12.

Table 11. OVQ scores of immersion media of jackfruit bulb

Sl. No.	Treatments	Particulars of immersion media	OVQ score
1.	T_1	Salt (0.5%)	6.15
2.	T_2	KMS (0.2%)	7.70
3.	T_3	Citric acid (0.2%)	6.42
4.	T_4	Salt (0.5%) + KMS (0.2%)	7.49
5.	T_5	Salt (0.5%) + Citric acid (0.2%)	7.22
6.	T_6	KMS (0.2 %) + Citric acid (0.2%)	7.45
	CD (0.05)		NS

(Results are expressed as mean values of ten replicates) (NS- not significant)

Table 12. OVQ scores of immersion time of jackfruit bulb

Sl. No.	Treatments	Time (min. sec)	OVQ score
1.	T_1	5.00	5.42
2.	T_2	7.00	5.89
3.	T_3	10.00	8.22
4.	T_4	12.00	5.65
5.	T_5	15.00	4.65
	CD (0.05)		0.736

(Results are expressed as mean values of ten replicates)

4.2.1.7. *Dehydration of the pre-treated raw material*

Drying is basically used for decreasing moisture content and preventing enzymatic and microbial activity, thus consequently preserving the product for extended shelf life. Pre-treated bulbs and seeds were kept separately for drying at 60^0c. Drying helps to reduce the moisture content and prepare materials for dry grinding. When JF bulb took 14 hrs to dry seeds needed 24 hrs at the same temperature for reaching the breaking stage.

4.2.1.8. *Milling of flour*

Dehydrated bulbs and seeds were milled separately into flour and sieved. The mesh size for sieving of both the flours was 0.05 mm. Residue, leftover after sieving was removed to get uniform fine powder. There was a loss of about 0.5 per cent in weight of product on processing of flour.

Conventionally in extruded products, refined flour is used as a major ingredient. In the present study a significant portion of refined flour used for the development of the extruded product was replaced with jackfruit bulb (JFB) and seed flour (JFSF). Thus, JFB and JFS flours were processed from the *Koozha* varieties and the quality of flours were assessed.

4.3. QUALITY ANALYSIS OF FLOUR

The flour prepared from dehydrated bulbs and seeds were analysed for various characteristics like physical, chemical, nutritional and shelf-life qualities.

4.3.1. Physical, chemical and nutritional qualities of flour

The physical qualities like bulk density, chemical qualities such as crude fibre and moisture and nutritional qualities like carbohydrate, protein, energy, total minerals were analysed and the results are presented in Table 13.

Analysis of bulk density of flour revealed that bulb flour had higher bulk density (0.96g/cm^3) compared to seed flour (0.92g/cm^3). Though there was a slight difference in the bulk density of both type of flour, it was not statistically significant as shown in Table 13. from the t value.

Crude fibre was observed to be higher (4.06 g) in bulb flour than seed flour (3.13g). Moisture analysis of flour revealed that seed flour had the higher value (7.97 per cent) for moisture than bulb flour. Bulb flour contained 7.23 per cent of moisture. Carbohydrate content was found to be higher (81.46 g) in seed flour in comparison to bulb flour (74.12 g). Significant difference in protein content could be observed in seed flour (10.48g) and bulb flour (1.53g). Seed flour had higher value for energy (353.87 kcal /100g) than bulb flour (329 kcal /100g).

Table 13. Physical, chemical and nutritional content of jackfruit flour

Sl. No.	Physical/chemical/ nutritional characteristics	Bulb flour (100g)	Seed flour (100g)	t value
1.	Bulk density (g/cm3)	0.96	0.92	3.15
2.	Fibre (g)	4.06	3.13	74.56**
3.	Moisture (%)	7.23	7.97	99.72**
4.	Carbohydrate (g)	74.12	81.46	217**
5.	Protein (g)	1.53	10.48	13420**
6.	Energy (kcal)	329.88	353.87	2169**
7.	Calcium (mg)	30	308.56	476.95**
8.	Potassium (mg)	328.11	1478. 37	1792.28**
9.	Sodium (mg)	35.06	60.63	1025**
10.	Magnesium (mg)	0.13	338.04	10806**

(Results are expressed as mean values of three replicates)

In case of minerals too, seed flour had shown higher values than bulb flour. Potassium content was higher on dry weight basis in seed flour (1478.37

mg) than bulb flour which had 328.11mg/100. Magnesium was also found to be higher in seed flour 338.04 mg than bulb flour (0.13 mg). Sodium (60.63mg) and calcium (308.56 mg) was found to be higher in seed flour compared to bulb flour which showed 35.06 mg of sodium and 30 mg of calcium respectively.

4.3.2. Shelf-life qualities of flour

Shelf life of flours mainly depends upon the changes in moisture content, insect infestation and microbial quality.

4.3.2.1. ***Assessment of moisture in stored flour***

Moisture content of bulb and seed flours which were stored in two different packaging materials i e. HDPE and laminated were analysed at monthly intervals up to three months. Both the flours had different moisture levels.

Moisture analysis in stored flour showed that seed flour had higher moisture level than bulb flour. The initial moisture levels of bulb and seed flour were found to be 7.23 and 7.97 per cent respectively. HDPE covers revealed a moisture increase of 0.75 per cent for bulb flour and 0.77 per cent for seed flour. The samples kept in laminated covers exhibited an increase in moisture content by 0.89 per cent and 0.99 per cent for bulb flour and seed flour respectively. Samples stored in HDPE packages exhibited comparatively low moisture values than those in laminated cover.

The data further reveals that seed flour had higher moisture content. The rate of increase in moisture was also higher in seed flour. The per cent increase of moisture was less in bulb flour in both type of packaging i.e. HDPE (0.75) and laminated (0.89).

4.3.2.2. ***Assessment of insect infestation in stored flour***

Insect infestation in stored flour was assessed periodically. It was observed that there was no insect infestation in the stored flour irrespective of type and packaging material during the three months of storage period.

Table 14. Moisture analysis of flour during storage (%)

Sl. No.	Treatments	Initial		1st month		2nd month		3rd month		Increase (%)	
		HDPE	**Laminated**	**HDPE**	**Laminated**	**HDPE**	**Laminated**	**HDPE**	**Laminated**	**HDPE**	**Laminated**
1.	Bulb	7.23	7.23	7.44	7.55	7.64	7.88	7.99	8.13	0.75	0.89
2.	Seed	7.97	7.97	7.99	8.12	8.34	8.65	8.75	8.97	0.77	0.99
CD (0.05)		0.14		0.23		0.56		0.74			

(Results are expressed as mean values of three replicates)

4.3.2.3. *Assessment of microbial quality of jackfruit flour*

Jackfruits (bulb and seed) were subjected to adequate heat treatment like blanching and boiling during processing for ensuring the absence of pathogenic microorganisms and as far as possible through preventing their multiplication by pre-treatments. The details of microbial analysis are presented in Table 15.

The data revealed that there was no bacterial and fungal attack in both flours initially as well in the first and second month. After 3 months, bacterial and fungal contaminations were observed in bulb and seed flour, but it was below permissible levels. There was no presence of coliforms observed in fresh as well as stored samples.

Table 15. Microbial profile of Flour

	Bulb			Seed		
Treatments	**Bacteria cfu/g x10^6**	**Fungi cfu/g x10^2**	**Coliforms cfu/gx10^6**	**Bacteria cfu/gx10^6**	**Fungi cfu/g x10^2**	**Coliforms cfu/gx10^6**
Initial	-	-	-	-	-	-
1^{st} month	-	-	-	-	-	-
2^{nd} month	-	-	-	-	-	-
3^{rd} month	1.0	1.5	-	1.5	2.0	-

(Results are expressed as mean values of two replicates)

4.4. EXTRUSION OF NOODLES

Noodle is a universally accepted staple food which is made with refined flour (maida). Various scientific evidences reveal that incorporation of fruits, vegetables, tubers, seeds, egg, pulses and grain into wheat flour evolves healthy and nutritious noodles. The nutritional quality of noodles can be improved by replacing the refined flour with fruits and vegetables flours. Yadav and Gupta (2015) reported that incorporation of apple pomace powder raised the dietary fibre and polyphenol content in noodles and also showed enhanced antioxidant activity.

4.4.1. Formulation of noodles

The raw ingredients selected for any food product plays an important role in determining the quality of the product. Mixing the ingredients selected in different combinations will decide the nutritional quality and extrusion behaviour. Composite flour is a mixture of wheat flour and flour from different sources/crop (Noorfarahzilah *et al*., 2014).

Refined flour, jackfruit bulb flour and seed flour were the basic materials used for the development of noodles. The different combinations attempted for the formulation of the products are presented in Table 7. In each formulation, the quantity of both JFB and JFS flour varied, while the amount of refined flour remained constant in all treatments, except one. In treatment T_1 the proportion of refined flour was 40 per cent while in all other treatment it formed 50 per cent. In treatment T_1 and T_2 Jackfruit bulb and seed flour were in equal proportion. In T_3 and T_4 proportion of Jackfruit bulb flour were higher, while in T_5 and T_6 jackfruit seed flour were higher in proportion. The extruded noodles were allowed for cabinet drying for 6 hours at 60^0C in order to improve and retain the texture of noodles. Dried noodles were packed in HDPE and laminated pouches for further investigations.

4.5. STANDARDIZATION OF COOKING PROCEDURE

Time, labour and fuel saving factors of any food product play a decisive role in conditioning its popularity among consumers. Cooking quality of the developed products was ascertained through measuring the cooking time and cooked weight and data pertaining to these factors are presented in Table 16.

4.5.1. Cooking time

Cooking time is the time taken for the white core to disappear when the noodle strand is boiled in water (Chen *et al*., 2002). Products which need less energy to cook have great demand, hence cooking time of the developed products were determined. Statistical interpretation of the table showed that there was significant difference in cooking time among the developed noodles. Cooking time of the different treatments ranged from 8.26 min to 9.36 min.

The result further revealed that among developed noodles T_6 took the least time (8.26 min.) for cooking. The second treatment which took less time for cooking was T_3 (8.38 min) and it was seen to be par with T_6 (8.26 min). More time was taken for cooking T_4 (9.36 min). However T_7 (market noodles) was observed to take even lesser time (7.16 min) for cooking.

4.5.2 Cooked weight

Cooked weight is an indicator of the extent of absorption of moisture by a food after complete cooking. It is determined by assessing the increase in weight of raw material (10g) after complete cooking. Cooked weight of noodles was calculated as the percentage increase of weight of raw to its cooked weight and the data revealed that highest increase of weight (140.62) was obtained for T_4 after optimum cooking. The next highest score (130.53 per cent) was obtained by T_1. On comparison control was seen to have the lowest increase in weight (90.87 percent) which was lowest among all treatments. Table 16. indicated that all the treatments were significantly different too.

4.6. QUALITY ANALYSIS AND STORAGE STABILITY OF NOODLES

Quality is a very important parameter for judging the acceptance of any food product (Sharma, 2006). Noodles developed from the composite flours were assessed for cooking, physical, chemical, nutritional, and sensory and shelf-life qualities to determine the best combination.

Table 16. Cooking time and cooked weight of noodles

Sl. No.	Treatments	Cooking time (min)	Cooked weight (g)
1.	T_1	8.54	23.52 (130.52)
2.	T_2	8.43	21.49 (110.49)
3.	T_3	8.38	22.64 (120,64)
4.	T_4	9.36	24.62 (140.62)
5.	T_5	8.55	20.53 (100.53)
6.	T_6	8.26	20.45 (100.45)
7.	T_7 (control)	7.16	19.87 (90.87)
	CD (0.05)	0.189	0.396

(Results are expressed as mean values of three replicates and numbers in parenthesis denote percentage)

4.6.1. Cooking characteristics

Cooking characteristics of noodles were assessed with respect to cooking loss and water absorption index.

4.6.1.1 *Cooking loss*

The quantity of solids going into water during cooking of noodles is a determinant of quality of noodles. Cooking loss of developed noodles were analysed and the results showed that the cooking loss per cent for T_4 was the least (9.13 per cent) among all treatments. It was immediately followed by T_1 with a percentage loss of 13.05 per cent. T_2 had shown highest cooking loss (15.37). Cooking loss of T_7 (control) was higher compared to all treatments (16.20 per cent).

4.6.1.2. *Water absorption*

When the water absorption capacity of noodles were analysed, it was found that the highest water absorption was observed for T_4 (140.62 %) followed by T_1 (130.52 %), T_3 (120.64 %), and T_2 (110.49). The other two treatments T_5 and T_6 were seen to be on par with the score of 100.53 and 100.45 per cent respectively. The lowest water absorption 90.87 per cent was recorded by control (T_7). All other treatments were seen to have higher water absorption than control.

Table 17. Cooking characteristics of noodles

Sl. No.	Treatments	Cooking loss (%)	Water absorption (%)
1.	T_1	13.05	130.52
2.	T_2	15.37	110.49
3.	T_3	14.57	120.64
4.	T_4	9.13	140.62
5.	T_5	15.06	100.53
6.	T_6	14.05	100.45
7.	T_7 (control)	16.20	90.87
	CD (0.05)	0.044	0.01

(Results are expressed as mean values of three replicates)

4.6.2. Physical characteristics

The physical characteristics are important criteria for product acceptance. The physical characteristics which may decide the acceptance of extruded products are extrusion behaviour, firmness, shape, uniformity, tensile strength and packaging quality (suitability), bulk density, true density; swelling index, yield ratio, processing loss, and colour of the noodles. The score of all physical characteristics assessed are presented in Table 18 to 23.

4.6.2.1 Extrusion behaviour

Extrusion behaviour usually depends on the raw ingredients of extruded product. It was observed by, residence time of raw material, uniformity of strands and external appearance during extrusion. The last 2 parameters of extrusion behaviour of the treatments were assessed by a panel of ten technical experts using a standardised pre-tested score card. The variation in extrusion behaviour of the combinations were statistically analysed and the results obtained are presented in presented in Table 18.

Regarding residence time, the data revealed that treatment T_6 took minimum time for extrusion (31. 05 min). The next higher residence time taken by T_1 (35.16 min) and T_5 (36.98 min) for extrusion. It was immediately followed by T_3 for 40.55 min and T_4 for 43.50 min. T_2 took highest residence time (45.11 min) among all the treatments. Table 18 indicates that there were significant differences in residence time.

Results of uniformity of strands showed that treatment T_3 obtained the highest score (4.89) which was immediately followed by T_6 with the score of 4.76. Treatment T_4 and T_5 were observed to be on par with the scores of 4.66 and 4.50 respectively. T_3 and T_1 scored the lowest values among all (4.35 and 4.10 respectively).

External appearance during extrusion was evaluated and data revealed that there was no significant difference in appearance during extrusion. The value of sensory scores ranged from 4.04 to 4.66. The highest score was obtained by T_5 (4.66) and it was immediately followed by T_6 with the score of 4.53.

Firmness, shape, uniformity of strands, tensile strength and packaging quality (suitability) were assessed for dry noodles by a panel of ten technical experts using a standardised score card.

Firmness determines how the material will withstand packaging and handling. With respect to firmness, the scores ranged from 4.23 to 4.50. It was found to be higher in T_3 (4.50) which were on par with T_6 (4.48). Other treatments T_4, T_5, T_2 and T_1 scored 4.42, 4.37, 4.35 and 4.23 respectively. The score for shape of developed noodles was highest for T_6 (4.68) followed by T_3 (4.64), T_5 (4.52), T_4 (4.49) and T_1 (4.13) and respectively. The lowest score was obtained by T_2 (3.86).

Table 18. Extrusion behaviour of different combination

Sl. No.	Treatments	Residence time (min/300g)	Uniformity of strands	External appearance
1.	T_1	35.16	4.40	4.20
2.	T_2	45.11	4.35	4.23
3.	T_3	40.55	4.89	4.15
4.	T_4	43.50	4.66	4.04
5.	T_5	36.98	4.50	4.66
6.	T_6	31.05	4.76	4.53
	CD (0.05)	1.272	0.355	0.501

(Results are expressed as mean values of two and ten replicates)

The score for uniformity of strands ranged from 4.06 - 4.75. The highest score was obtained by T_3 (4.75). The second highest score was obtained by T_6 (4.67). The other two treatments T_4 and T_5 scored 4.53 and 4.44 respectively. T_2 and T_1 scored less and the values were 4.26 and 4.06 respectively.

Regarding tensile strength, scores ranged from 4.21 – 4.65. The highest score was obtained by T_4 (4.65) and it was seen to be on par with T_3 (4.58) and T_6 (4.56) respectively. The lowest score was obtained by T_2 (4.21). The table further revealed that there was no significant difference in packaging quality i.e. suitability for packaging among treatments and all the treatments were found to be on par.

Table 19. Physical characteristics of extruded products

Sl. No.	Treatments	Firmness	Shape	Uniformity of strands	Tensile strength	Packaging quality (suitability)
1.	T_1	4.23	4.13	4.06	4.25	4.57
2.	T_2	4.35	3.86	4.26	4.21	4.59
3.	T_3	4.50	4.64	4.75	4.58	4.52
4.	T_4	4.42	4.49	4.53	4.65	4.58
5.	T_5	4.37	4.52	4.44	4.47	4.53
6.	T_6	4.48	4.68	4.67	4.56	4.50
	CD (0.05)	0.294	0.222	0.381	0.327	NS

(Results are expressed as mean scores of ten replicates)

4.6.2.2. ***Bulk density***

Bulk density is one of the most common and simple measurements in food analysis, which can be used for the analysis of solid foods. The volumes of different food products can be compared with this parameter. Here the treatments exhibited variations in bulk density and the data is presented in Table 20. Bulk density of six different combinations and control revealed that among the 7 treatments bulk density was higher in T_3 (0.91) followed by T_2 (0.90) and T_1 (0.86) and all these treatments were seen to be on par. The lowest bulk density was seen for control samples (0.68) among all treatments.

4.6.2.3. ***True density***

True density is the density of the solid material excluding the volume of any open and closed pores. Depending on the molecular arrangement of the materials, the true density can equal the theoretical density of the material and therefore be indicative of how close the material is to a crystalline state or the proportion of a binary mixture. True density of noodles in Table 20. revealed that there was no significant difference among treatments as well with control.

4.6.2.4. *Swelling index*

Swelling index of noodles is an indicator of the water absorbed by the starch and protein during cooking, which is utilized for the gelatinization of starch and hydration of proteins. During cooking of noodles, starch absorbs water and swells and the granular structure collapses leading to the leaching of amylose.

Swelling index of developed noodles was highest for T_4 with a score 1.46 which was followed by 1.35 for T_1. Swelling index of control was lower than the experimental samples. Though there was slight difference in the treatments, it was not statistically significant.

Table 20. Physical characteristics of noodles

Sl. No	Treatments	Bulk density (g/cm^3)	True density (g/ml)	Swelling index (g)
1.	T_1	0.86	0.01	1.35
2.	T_2	0.90	0.01	1.14
3.	T_3	0.91	0.02	1.26
4.	T_4	0.89	0.04	1.46
5.	T_5	0.85	0.01	1.05
6.	T_6	0.78	0.01	1.12
7.	T_7 (Control)	0.68	0.01	1.00
	CD (0.05)	0.040	NS	0.007

(Results are expressed as mean values of three replicates)

(NS- not significant)

4.6.2.5. ***Yield ratio (noodles)***

Drying removes moisture, as a result the product shrinks and decreases in size and weight, thus requiring less space for storage. Many times foods lose volume or weight as they are processed. Yield of dried products are directly related to how much water is in the original product.

The yield for the noodles from flour was calculated using the formula as described in methodology 3.6.2.5. Yield ratio of the different combinations were analysed and the results are presented in Table 21. Yield ratio of different treatments ranged from 0.86 – 0.94 per cent. Results further reveal that T_6 having RF: RJBF: RJSF in the ratio of 50:20: 30 had the highest value (0.97). The lowest value was obtained by T_1 (0.86).

Table 21. Yield ratio of noodles

Sl. No.	Treatments	Weight of flour (g)	Weight of noodles (g)	Yield ratio
1.	T_1	300	268.00	0.86
2.	T_2	300	265.72	0.88
3.	T_3	300	287.90	0.89
4.	T_4	300	289.68	0.92
5.	T_5	300	274.28	0.94
6.	T_6	300	279.59	0.97

(Results are expressed as mean values of two replicates)

4.6.2.6. ***Processing loss (jackfruit)***

Processing loss occurs in fruits and vegetables due to removal of inedible portion and moisture loss. Processing loss of jackfruit bulb and seed after dehydration was computed and is presented in Table 22. It can be seen that the loss ranged from 66.45 to 73.98 per cent.

Table 22. Processing loss of jackfruit

Sl. No	Whole weight of jackfruit (kg)	Wet weight (bulb + seed) (kg)	Dry weight (bulb + seed) (kg)	Processing loss (%)
1.	10. 275	5.31	1.58	70.24
2.	13. 550	7.88	2.05	73.98
3.	15.465	7.63	2.32	69.54
4.	19.220	9.45	4.04	57.22
5.	20.00	9.19	3.08	66.45

4.6.2.7. ***Colour analysis***

Colour is a major factor affecting the appeal of a product. Natural colours of food products magnetize consumers these days. It is one of the prime criteria for evaluating a product. Colour of developed noodles from composite flour depends on the colour of raw ingredients and their ratio of combination. The noodles after drying were found to be different shades of cream colour.

Table 23 indicate that lightness (L value) of T_3 was highest (80.07). It was followed for T_6, T_2 and T_5 treatments with value of 77.43, 77.23 and 76.73 respectively. These three treatments were on par with each other. Treatment T_1 (75.47) and T_4 (75.44) were also on par with each other. Value for redness (a value) was highest (3.07) for T_1 and was immediately followed by T_2, T_5 and T_4 (2.68, 2.64 and 2.59 respectively). The other two treatments T_3 and T_6 were seen to be on par (2.12 and 2.23 respectively).

Yellowness of the samples (b value) were analysed and observed that 'b' value was highest in T_1 (23.27) followed by T_4 and T_6 with the score of 22.89 and 22.04 respectively. This was immediately followed by T_2 with a score of 21.78. The remaining two treatments T_3 and T_5 were found to be on par (19.95 and 19.43 respectively).

As shown in Table 23, it was revealed that the scores of total colour differences were highest in T_1 treatment (33.53) and it was on par with T_4 (33.22). The other three treatments showed values that were on par T_2 (31.25), T6 (31.16) and T_5 (29.94). Treatment T_3 scored the lowest value 27.55 among all treatments.

Whiteness index of the combinations was calculated from 'L', 'a' and 'b' values. It was analysed that T_3 had highest whiteness index (71.71). It was followed by T_5, T_2 and T_6 with score of 69.57, 68.37, and 68.25. These 3 treatments were seen to be on par. The other 2 treatments showed values that were on par with the scores of 66.30 and 66.20 for T_4 and T_1 combination. There was significant difference in the data.

Table 23. Colour value of noodles

Sl. No	Treatments	Lightness (+)/ darkness (-)	Redness (+)/ greenness (-)	Yellowness (+)/ Blueness (-)	Total colour difference	Whiteness index
1.	T_1	75.44	3.07	23.27	33.53	66.20
2.	T_2	77.23	2.68	21.78	31.25	68.37
3.	T_3	80.07	2.12	19.95	27.55	71.71
4.	T_4	75.42	2.59	22.89	33.22	66.30
5.	T_5	76.73	2.64	19.43	29.94	69.57
6.	T_6	77.43	2.23	22.04	31.16	68.25
7.	T_7 (control)	93.50	1.02	15.05	20.59	85.36
	CD (0.05)	0.922	0.283	1.290	1.452	1.483

(Results are expressed as mean values of three replicates)

4.6.3. Chemical composition of noodles

Chemical compositions of developed noodles were assessed with respect to moisture and fibre content and it was compared with control (commercial noodles).

4.6.3.1. *Moisture*

Moisture content of the food material is an important factor as it affects the physical and chemical aspects of food which relates to the freshness and stability of food. Moisture content of developed noodles ranged from 6.40 to 6.45 per cent. When moisture content was analysed it was found that all the treatments had significantly higher moisture value than control (5.79 per cent). Though all the samples showed almost similar moisture content, the value was highest in T_5 (6.47) which was found to be on par with all the other treatments. The lowest moisture content was observed in T_4 (6.40) and T_1 (6.40). The results of moisture content are shown in Table 24.

4.6.3.2. Fibre

Plant foods, have indigestible complex molecules, namely fibre which contribute to the bulk of intestinal contacts thus serving the digestive tract. It is indigestible portion of food derived from plants. The total fibre content of the developed noodles is depicted in the Table 24. Fibre content of the mixes ranged from 5.07 to 5.42g. The maximum fibre content was noted for T_4 (5.42) and least fibre was recorded for T_7 (control- 0.03g). The ANOVA results revealed that there was no significant difference between the fibre content of the developed noodles.

4.6.4. Nutrient composition of noodles

In recent years, there have been significant changes in the preference of consumers for foods that are healthier, have higher nutritional quality and are more exotic. Traditional foods satisfied these parameters adequately. New food products should thus be developed based on these principles. Individual food manufacturers must respond rapidly to these changes in order to remain competitive within the food industry.

4.6.4.1. ***Proximate composition***

Protein, carbohydrate, energy and minerals are referred to as proximate principles. Man needs a wide range of nutrients to perform various functions in the body and to lead a healthy life. The nutrients analysed were energy, protein, carbohydrate and minerals. These nutrients are chemical substances which are present in the food that we eat daily. Most food contains almost all the nutrients in various proportions, some foods being rich in certain nutrients.

Energy is essential for growth, maintenance, activity and rest (Sheng *et al.*, 2010). When the energy value of the treatments were computed, it was found that energy value was found to be higher in T_5 (380.86 kcal) and lower in T_2 (291.60). Energy value of T_7 (control) obtained the second highest score (372.00). All other treatments T_6 (366.93 kcal), T_3 (357.30 kcal), T_4 (350.86 kcal) and T_1 (336.33 kcal) were less than T_7 (control). Table also revealed that the differences in energy values of treatments and control were statistically significant.

Intake of **carbohydrate** from vegetables, fruits, whole grains, legumes and dairy products is advisable over intake from other carbohydrate sources especially those that contain added fats, sugar or sodium (Alison *et al.*, 2014). Table 24. gives the carbohydrate content of different treatments of developed noodles. The statistical analysis of data revealed that there was a significant difference between carbohydrate content of the developed noodles. The maximum carbohydrate content was noted for T_5 (70.91g) but this was only next to T_7 (control) which had carbohydrate content (81.50g). This was followed by T_6 with the score of 63.54. The lowest score was obtained by T_3 (56.11)

Protein is one of the most important nutrients required by the body to carry out a wide range of functions, essential for the maintenance of life (Gopalan *et al.*, 2009). The protein content of the developed noodles is depicted in Table 24. Protein content ranged from 10.12 – 13.49g. The protein content was found to be higher for T_5 (13.49) and lower protein content was noted for T_3 (10.12). Treatment T_5, T_6, and T_2 had higher protein content (13.49g, 12.92g and 12.03g respectively) than control (11.50g). The data further revealed that other 3 treatments T_4, T_1 and T_3 had lower protein content (10.64g, 10.61g and 10.12g respectively) than control.

Total minerals are a measure of the total amount of minerals present within a food, and it is also a measure of the amount of specific inorganic components present within a food. The total mineral content of the developed noodles are depicted in Table 24.

Calcium is essential for all living organisms especially for the cell physiology. As a major material used in mineralization of bone, teeth and shells, calcium is the most abundant macro mineral by mass in most animals. The calcium content of the developed noodles is depicted in Table 24. Results emphasize that there was significant differences in calcium content in selected treatments of noodles. The maximum calcium content was noted for T_5 (146.94 mg) followed by T_6 (113.11mg), T_1 (110.63 mg), T_2 (96.13 mg) and T_3 (79.30 mg). The minimum calcium content was recorded for T_4 (45.36 mg).

Potassium is an essential macro-mineral in human nutrition; it is the major cation inside animal cells. It is important for maintaining the fluid and electrolyte balance in the body. Potassium is also important in conducting muscle contraction and in the sending of nerve impulses in animals through cation potential. Potassium content of different treatments is depicted in Table 24. It was seen to be highest for T_5 (787.33 mg) followed by T_6 (606.53 mg). It was followed by T_1 (593.40mg) and T_2 (516.54 mg). The minimum potassium content was recorded for T_4 (245.36 mg).

Magnesium is highly required for cellular metabolism, essential for the intracellular enzyme activities, metabolism of carbohydrate and as structural components of DNA and RNA. The magnesium content of the developed noodles is recorded in Table 24. From the table it is noted that there was significant difference in the magnesium content of the developed noodles. Its level ranged from 60.49 – 162.24 mg. Mg content was found to be high in T_5 (162.24 mg) and it was followed by T_6 (128.29mg) and T_1 (122.50 mg). The lowest magnesium content was found in T_4 (60.49 mg).

Sodium plays a very significant role in maintaining intracellular fluid and electrolyte balance. The result elucidated that T_5 had the highest sodium content (42.73). The second highest content was found in T_6 (33.23 mg) and T_1 (32.31 mg). The lowest sodium content was observed for T_4 (14.38 mg) as represented in the Table 24. From the table it clear that T_5 revealed higher values for total mineral where as it was lowest in T_4. Minerals content was not displayed in T_7 (commercial noodles).

4.6.5. Sensory qualities of noodles

Sensory parameters such as appearance, colour, flavour, taste and overall acceptability of any food product depends to a great extent on oxidation of fats and oils in the food due to the formation of peroxides aldehyde and ketones (Gupta, 2005). Numerical scoring is generally used to evaluate particular characteristics of one or more samples indicating the rating as excellent, very good, good, fair and poor (Manay and Swamy, 2000). All six treatments were cooked and evaluated by 10 panel members and compared with control (commercial noodles).

4.6.5.1. *Appearance*

Appearance is the criteria for the desirability of any food product. The results are presented in the Table 25. It can be noticed from the data that T_5 scored the highest (4.59) among all six treatment for appearance, though T_7 (commercial noodles) scored higher (5.00) than T_5. Treatment T_5 was immediately followed by T_6 with a score of 4.42. T_2 T_1 and T_3 scored 3.87, 3.79 and 3.71 respectively. The lowest score was obtained by T_4 (2.98).

Table 24. Nutritional and chemical composition of food (100g)

Treatments	Energy (kcal)	CHO (g)	Protein (g)	Total minerals (mg)				Fibre (g)	Moisture (%)
				Ca	K	Mg	Na		
T_1	336.33	57.04	10.61	110.63	593.40	122.50	32.31	5.07	6.40
T_2	291.60	59.41	12.03	96.13	516.54	111.70	28.44	4.96	6.45
T_3	357.30	56.11	10.12	79.30	426.13	94.35	23.67	5.26	6.41
T_4	350.86	48.89	10.64	45.36	245.36	60.49	14.38	5.42	6.40
T_5	380.93	70.91	13.49	146.94	787.33	162.24	42.73	4.57	6.47
T_6	366.93	63.54	12.92	113.11	606.53	128.29	33.23	4.77	6.45
T_7 (control)	372.00	81.50	11.50	*	*	*	*	0.03	5.79
CD (0.05)	1.460	0.886	0.302	0.279	0.497	0.958	0.470	0.061	0.108

(Results are expressed as mean values of three replicates) (*- not displayed)

4.6.5.2. *Colour*

Colour is one of the important visual attributes that has been used to judge the overall quality of foods for a very long time. If the colour is unattractive, a potential consumer may not be impressed by any other attribute. The first impression of food is usually visual and a major part of willingness to accept a food depends on its appearance. The cooked samples were seen to have a cream colour and a transparent appearance.

The data in Table 25. further reveals that there was a significant difference in the mean rank values obtained for colour. The highest rank was obtained by control (5.00) in comparison with the other six treatments. The second highest score obtained by T_5 and it was followed by T_6 with the score of 4.77 and 4.74 respectively. The other three treatments T_1, T_2 and T_3 scored less compared to above three treatments (3.89, 3.72 and 3.55 respectively). The lowest score was obtained by T_4 (3.37).

4.6.5.3. *Texture*

Texture constitutes a physical property of food stuffs apprehended by the eye, skin and muscle senses located in the mouth. The samples varied from very soft to rubbery texture. Score for texture of developed noodles was high in T_5 and T_6 with the score of 4.89 and 4.75 respectively and they were on par. The next highest score was observed in T_3 (4.54) and T_4 (4.21). Highest score was obtained for control (4.91) with respect to texture assessment. The statistical interpretation proves that there was significant difference among the noodles regarding texture. Least score for texture was shown in T_1 (3.65) followed by T_2 (3.73).

4.6.5.4. *Taste*

Taste is the major attribute which determines the acceptability of a food. The developed noodles had a bland and nutty taste. Sensory scores of freshly prepared noodles were assessed and the results revealed that taste of the developed noodles was appreciably high in all the treatments as shown in Table

25. All the treatments had scored higher values, though the highest scores was observed in T_6 (4.93) and T_5 (4.87) among developed treatments. Commercial noodles had higher values among all the treatments (4.96)

4.6.5.5. *Overall acceptability*

Overall acceptability comprises appearance, colour, texture and taste of developed products. The data in Table 25 revealed that overall acceptability was higher for T_5 (4.78). The next higher score was obtained by T_6 and T_3 with the score of 4.71 and 4.14 respectively. All the treatments had lower values than control (4.96).

Table 25. Scores of sensory evaluation

Sl. No.	Treatments	Appearance	Colour	Texture	Taste	Overall acceptability
1.	T_1	3.79	3.89	3.65	4.45	3.92
2.	T_2	3.87	3.72	3.73	4.29	3.90
3.	T_3	3.71	3.55	4.54	4.78	4.14
4.	T_4	2.98	3.37	4.21	4.71	3.81
5.	T_5	4.59	4.77	4.89	4.87	4.78
6.	T_6	4.42	4.74	4.75	4.93	4.71
7.	T_7 (control)	5.00	5.00	4.91	4.96	4.96
	CD (0.05)	0.516	0.474	0.408	0.035	0.533

(Results are expressed as mean values of ten replicates)

4.6.6. Cost analysis of noodles

The cost of the developed proportion of noodles was calculated by taking into account of the expenses incurred in raw material, adjuncts, packaging expenses, and labour charges. Cost analysis of the selected six proportions of noodles was computed taking into consideration of the market price of the ingredients used and cost involved in processing. Cost of 1400 g of noodles was found to be Rs /108.00 which was three times lower than control.

Table 26. Cost analysis of product

Items	**Quantity**	**Unit price**	**Cost (Rs)**
Jackfruit	10 kg	Rs 6/kg	60.00
Refined flour	750g	Rs 40/kg	30.00
Overhead charges	@ 20%		18.00
Total			108.00/1400g
Price of market noodles	1400g		Rs/. 327.00

4.7. STORAGE STABILITY OF NOODLES

The shelf life of a food is the time period within which the food is safe to consume and or has an acceptable quality to consumers. Shelf stability of a product depends upon many factors like raw materials used in the products and chemical composition of the product. During storage episodes, chemical and physical changes along with microbial growth may be observed in perishable food items.

The rate of spoilage during storage period is directly proportional to the perishability of the food. Shelf life studies can provide important information to product developers, enabling them to ensure that the consumers will receive high quality products for a significant period of time after production. Shelf-life study of noodles was conducted for three consecutive months. At intervals of 1 month or 30 days randomly selected samples of noodles were analysed for the sensory quality, microbial growth and moisture content.

4.7.1. Sensory quality of stored noodles

Sensory analysis of a food product during storage period is important as far as food manufacturers are concerned. Sensory appeal is the key standard for a new food product in the market. The interpretation of chemical and physical measurements is often easier and more meaningful when combined with sensory data (Table 27 to Table 31). The samples were taken at random from either HDPE/ laminated at periodic intervals for 3 months and cooked. The results are presented in Table 26.

4.7.1.1. *Appearance of stored noodles*

Many individual factors contribute to the total perception of the appearance of a food product. This total perception is built up from all the visual sensations experienced when a product is viewed on the shelf or as it is being prepared or when it is presented on the plate, and all three situations are extremely important to the consumer and hence to the processor (Hutchings, 1977). Statistical analysis showed that there was decrease in scores for appearance during storage, though the product was acceptable to judges.

Table 27. Evaluation of appearance of noodles during storage

Sl. No	Treatments	Initial	1st month	2nd month	3rd month	CD (0.05)
1.	T_1	3.79	3.74	3.64	3.53	0.063
2.	T_2	3.87	3.80	3.79	3.72	0.052
3.	T_3	3.71	3.68	3.49	3.26	0.071
4.	T_4	2.98	2.94	2.80	2.16	0.074
5.	T_5	4.59	4.43	4.42	4.21	0.067
6.	T_6	4.42	4.37	4.28	4.13	0.064

(Results are expressed as mean scores of sensory panel)

4.7.1.2. Colour of stored noodles

Colour has always had an important implication on the minds of people as far as food is concerned. Cuisines prepared in attractive colours have immensely lured men folk in all the quarters of the world. It is therefore very necessary to preserve the natural or maintain the characteristic colour of a food product while it is manufactured or stored for future use. The statistical analysis shows that there was significant change in score of colour of noodles during storage periods and the colour scores were found to decrease after each month in all six developed treatments. This however did not make the product unappealing.

Table 28. Evaluation of colour of noodles during storage

Sl. No.	Treatments	Initial	1st month	2nd month	3rd month	CD (0.05)
1.	T_1	3.89	3.86	3.83	3.78	0.094
2.	T_2	3.72	3.61	3.66	3.60	0.098
3.	T_3	3.55	3.49	3.50	3.19	0.135
4.	T_4	3.37	3.35	3.32	3.05	0.129
5.	T_5	4.77	4.75	4.71	4.68	0.076
6.	T_6	4.74	4.71	4.64	4.66	0.054

(Results are expressed as mean scores of sensory panel)

4.7.1.3 *Texture of stored noodles*

As far as noodles are concerned, texture plays a noteworthy role. It is the property of food which is associated with the sense of feel or touch experienced by fingers or the mouth. Although one may feel the texture while handling, the texture is indicated best by the sensations caused by contact with hard and soft parts in the mouth. It was observed that there was significant change in texture scores during the storage period. It was rightly pointed out that though the fresh texture decreased, it was still marketable.

The results further revealed that a considerable difference was not found in stored noodles but it consistently decreased during storage period. The panel however did not point out any unacceptable rating.

Table 29. Evaluation of texture of noodles during storage

Sl. No	Treatments	Initial	1st month	2nd month	3rd month	CD (0.05)
1.	T_1	3.65	3.62	3.50	3.38	0.064
2.	T_2	3.73	3.62	3.38	3.23	0.093
3.	T_3	4.54	4.41	4.21	4.09	0.057
4.	T_4	4.21	4.10	3.97	3.81	0.049
5.	T_5	4.89	4.64	4.45	4.05	1.325
6.	T_6	4.75	4.70	4.55	4.27	0.529

(Values are expressed as mean scores of sensory panel)

4.7.1.4. *Taste of stored noodles*

One of the most important aspects of any food product is its taste which gives an identity to consumers. Though decreasing trends in values were observed for taste of noodles during storage period, it was not declared as unacceptable by the panel.

4.7.1.5. *Overall acceptability*

Overall acceptability comprises appearance, colour, texture and taste of developed products. Significant difference and decreasing trends were observed for values on overall acceptability of noodles during storage period, but it was declared as acceptable by the panel in all the above parameters.

Table 30. Evaluation of taste of noodles during storage

Sl. No	Treatments	Initial	1st month	2nd month	3rd month	CD (0.05)
1.	T_1	4.45	4.41	4.39	4.35	0.045
2.	T_2	4.29	4.22	4.13	4.00	0.069
3.	T_3	4.78	4.71	4.60	4.52	0.054
4.	T_4	4.71	4.62	4.55	4.48	0.043
5.	T_5	4.87	4.72	4.67	4.59	0.096
6.	T_6	4.93	4.85	4.78	4.69	0.085

(Values are expressed as mean scores of sensory panel)

Table 31. Evaluation of overall acceptability during storage

Sl. No	Treatments	Initial	1st month	2nd month	3rd month	CD (0.05)
1.	T_1	3.94	3.90	3.84	3.76	0.049
2.	T_2	3.90	3.81	3.74	3.63	0.064
3.	T_3	4.14	4.07	3.95	3.76	0.059
4.	T_4	3.81	3.75	3.66	3.37	0.048
5.	T_5	4.78	4.63	4.56	4.38	0.095
6.	T_6	4.71	4.65	4.562	4.43	0.084

(Results are expressed as mean of scores of sensory panel)

4.7.2. Moisture

. The initial moisture levels of noodles were 6.40, 6.45, 6.41, 6.40, 6.47, and 6.45 for T_1, T_2, T_3, T_4, T_5, and T_6 treatments. After the three months of storage the value of moisture were increased for T_1 (7.13, 7.24), T_2 (7.22, 7.31), T_3 (7.22, 7.43) T_4 (7.24, 7.29), T_5 (7.35, 7.46) and T_6 were (7.31, 7.39) in HDPE

Table 32. Moisture content during storage period

Treatments	**Initial**		**1st month**		**2nd month**		**3rd month**		**Increase (%)**	
	HDPE	Laminated	HDPE	Laminated	HDPE	Laminated	HDPE	laminated	HDPE	Laminated
T_1	6.40	6.40	6.54	6.71	6.76	6.96	7.13	7.24	0.73	0.84
T_2	6.45	6.45	6.65	6.77	6.92	6.98	7.22	7.31	0.77	0.86
T_3	6.41	6.41	6.64	6.73	6.92	6.97	7.22	7.43	0.81	1.02
T_4	6.40	6.40	6.52	6.73	6.72	6.98	7.24	7.29	0.84	0.89
T_5	6.47	6.47	6.68	6.77	6.85	6.92	7.35	7.46	0.88	0.99
T_6	6.45	6.45	6.62	6.68	6.83	6.91	7.31	7.39	0.86	0.94
CD (0.05)	0.013		0.019		0.021		0.024			

(Results are expressed as mean values of scores of sensory panel) and laminated covers respectively. Moisture analysis of the products showed that product packed in HDPE covers showed less moisture content in all the treatments. The result of the study is presented in Table 32.

4.7.3. Microbial study of stored noodles

Microbial population in processed foods is an important factor, which determines the quality and safety of the product. Microbial contamination of the extruded product developed in the study was ascertained to determine the keeping quality of the products. When foods are processed, there are chances of contamination through various means including conditions of storage of the products. These microbes multiply and cause spoilage of the products. Hence assessment of microbial population of the noodles is an essential step in the development of new products.

Table 33. Microbial profile - Fungal colonies cfu/g($x10^{2)}$

Sl. No	Treatments	Initial	1st month	2nd month	3rd month
1.	T_1	ND	ND	ND	ND
2.	T_2	ND	ND	1.5	3.0
3.	T_3	ND	ND	ND	ND
4.	T_4	ND	ND	ND	ND
5.	T_5	ND	ND	ND	ND
6.	T_6	ND	ND	ND	ND

(Results are expressed as mean values of two replicates) Nil

It is evident from the Table 33. that during the three months of storage period, no bacterial colonies were found to appear in the developed products. But fungal colonies were observed in T_2 in the second (1.5×10^3) and third (3.0×10^3) months. Even though fungi were detected, it was present only in negligible levels within the permissible limits. No pathogenic organisms could be detected in the different treatments.

4.8 SELECTION OF THE BEST COMBINATION

The six treatments were rated with respect to 9 parameters with respect to appearance, uniformity of strands, overall acceptability and sensory quality during storage. Other factors necessary for consumer acceptance like low cooking time, colour (whiteness index), fibre, calorie, high protein, and safety from microbial attack were also considered to select the best combination.

Table 34. Selection of the best combination

Sl. No	Parameters	T_1	T_2	T_3	T_4	T_5	T_6
1.	Appearance	6	5	1	3	4	2
2.	Uniformity of strands	4	3	5	6	1	2
3.	Overall acceptability	4	5	3	6	1	2
4.	Less cooking time	4	3	2	6	5	1
5.	Colour (whiteness index)	6	2	3	5	1	4
6.	High Fibre	3	4	2	1	6	5
7.	Low Calorie	2	1	4	3	6	5
8.	High protein	5	3	6	4	1	2
9.	Safety from microbial attack	1	1	1	1	1	1
Total Score		35	27	27	35	26	24
Rank		4	3	3	4	2	1

Based on factors like uniformity of strands, overall acceptability, colour (whiteness index), high protein, and safety from microbial attack T_5 was found to get the highest rating. With respect to less cooking time T_6 got the 1st position and 2nd in appearance, uniformity of strands, overall acceptability and protein content. With respect to fibre T_4 ranked the highest but it lagged behind in all other parameters. So treatment T_5 followed by and T_6 was selected as best combinations with RF: RJBF: RJSF in the ratio of 50:10:40 and 50:20:30 respectively.

On analysing the sensory quality, all the treatments were acceptable. The nutrition profiles of each treatment were also found to be acceptable. But on a closer analysis, T_5 and T_6 fare better with respect to consumer appeal.

DISCUSSION

5. DISCUSSION

The results of the present investigation entitled "Development of an extruded product from raw jackfruit" is discussed below, under the following heads:

5.1 Selection and Collection of jackfruit

5.2 Processing of flour

5.3 Quality analysis of flours

5.4 Extrusion of noodles

5.5 Standardization of cooking procedures

5.6 Quality analysis of noodles

5.7 Storage stability of noodles

5.8 Selection of the best combination

5.1 SELECTION AND COLLECTION OF JACKFRUIT

Fruits are important part of human diet. They are commercially important and nutritionally indispensable food commodities (Prasanna *et al*., 2007). Man has assigned these commodities in his diet to provide variety, taste, interest, aesthetic appeal and to meet certain nutritional requirements

They play a vital role in human nutrition, by supplying the necessary growth factors essential for maintaining normal health. Fruits along with vegetables are termed as 'protective foods' (Singh and Sharma, 2007). They are rich sources of vitamins (A, B complex and C) and minerals (calcium, iron and phosphorus) that help to keep human health in good state.

Though there is a tremendous increase in fruit production, it is estimated that about 25-40 % of the fruits produced are lost due to spoilage at various post-harvest stages (Kader, 2013). India, in spite of being one of the largest producers of fruits, exports only less than 1 per cent of its total fruit production (Peter *et al*., 2006).

The high postharvest losses demand an instant need to process them so as to maintain supply of fruits and vegetables to the burgeoning population. This demand can only be fulfilled by either using the technology to prevent the deterioration of fruits after harvest or to introduce underutilized fruits for their commercial utilization. Underutilized fruits have a vital role in imparting nutritional security to people. The father of green revolution, Swaminathan has also rightly stated that "Fruits and vegetables are the food of the future" (Peter *et al*., 2006).

Wide range of underutilized fruits are grown in India, but full potential of these fruits are not exploited, which leads to limited scope for marketing of the processed goods outside the region. It is observed that, traditional processing methods are adopted in processing. Besides the seasonal availability of fruits, non -suitable methods of storage and lack of information regarding the nutritional value limits the use of these underutilized fruits (Peter *et al*., 2006).

Jackfruit is one such under exploited fruit, which is a member of the Moraceae family, which is grown sporadically in India as well as in other parts of the tropics mostly as a backyard tree. Among the fruits grown in Kerala, jackfruit tops the list in terms of production and is highly popular (Ukkuru and Shruti, 2005). The fruit is highly nutritious and contains nutrients such as protein, calcium, phosphorus, iron, beta-carotene, thiamine etc. and is considered as a poorman's food (Haq, 2006).

Raw jackfruit is being utilized to a lesser extent only as a vegetable, mainly owing to its cumbersome preparation procedures. Their full potential has not been exploited and utilized. Such under and un-utilized fruits are needed to be evaluated for their nutritive value and potential uses, including processing to convenience foods.

The selection of raw materials is a vital consideration for the quality of processed products. Airani (2007) reported that the cultivar *Koozha*, which is being wasted, could be utilized and processed to develop various value added convenient food products.

Therefore, in the present investigation, jackfruit cv *Koozha* in the raw mature state was selected to be utilised. They were harvested from the trees grown in the Instructional farm, College of Agriculture, Vellayani and also from the adjacent home yards, for the study purpose.

5.2 PROCESSING OF FLOUR

In food industry, fruit and vegetable flours are formulated in order to promote its use in commercial products, as they represent a rich source of dietary fibre, with insoluble dietary fibre (IDF) and soluble dietary fibre ratio (SDF). This imparts added nutritional value to the products. In fruits, the ratio between IDF and SDF fractions is more balanced compared to cereals (Ajila and Rao, 2013).

Green banana flour, especially unpeeled, was found to be the important ingredient when the aim was increase the non-digestible fraction in food and could have positive effects on health as reported by Bezerra *et al*. (2013).

Flour was prepared from the bulb and seed and stored in packages. Processing of jackfruit into flour improves the shelf-life of jackfruit and reduces its bulkiness and perishability.

5.2.1. Preliminary processing

Preliminary processing helps to reduce unnecessary parts of the fruits like leaves, stalk, pith, peel and seed. It also helps to provide optimum width by cutting, inactivating enzymes by scalding and immersing in suitable media for preservation of colour and appearance. Jackfruits underwent several preliminary processing like cutting, blanching and immersing so as to enhance the quality of final product.

5.2.1.1 *Cleaning and recording weight*

As jackfruit was obtained directly from farm, it was cleaned to remove external impurities which had adhered during carrying or transportation. The Food and Drug Administration state that all fruits and vegetables, including those that are organically grown, could benefit from a thorough washing to reduce soil, surface microbes and some pesticides. Usually jackfruits are big in size; so they were cut to separate out their bulbs and seeds. Weight of both bulbs and seeds were recorded to get the final yield of the product. Recording weight of raw material is an important parameter for assessing yield of products. The present findings portrays that the weight of rind, perigones and outer covering ranged from 41.85 – 54.01 per cent. This finding is in line with the findings of Ejifor *et al*. (2006), who reported that jack fruits consisted of 29% pulp, 12% seeds and 54% rind.

5.2.1.2 *Standardization of width of slices*

Separated bulbs and seeds were sliced into varying widths. The width of 2.5 x 1cm and 1.5 x 1cm respectively were identified as the most suitable dimension on analysis of OVQ. Shape, size and thickness of the chips influences how fast it dries; diffusion and the rate of drying are fastest in small chips. When chips are thick the outer layer easily compresses, thereby preventing the free air movement through the mass (FIIR, 2005).

Abano and Samamoah (2011) reported that the rate of drying time depends on temperature of the drying air and thickness of the slices. If the slices are thinner it will dry faster as compared to thicker slices. Oghenechavwuko *et al*. (2013) reported that cassava tubers were cut into chips of 2.0 cm thickness for faster dehydration. Islam *et al*. (2012) reported that thickness was found to affect the drying time, as thickness of the sample increased, the drying time to achieve a desirable moisture ratio also increased.

The best dimension 1.5 x 1cm of jackfruit seeds were identified as the optimum dimension, because it scored the highest score for OVQ. Rengsutthi and

Charoenrein (2011) reported that jackfruit seeds were sliced (2 mm thickness) and tray dried at 45^0 C until the moisture content was less than 13 g/100 g for obtaining seed starch. Mozumder *et al*. (2012) reported that tomatoes were cut into slices with thickness of 5 mm for optimum drying.

5.2.1.3 *Standardization of blanching time of raw jackfruit bulb*

Fruits are usually hot blanched, or blanched only under mild (low temperature) conditions prior to freezing because blanching produces desirable texture changes. Before drying, fruits and vegetables are sometimes blanched. After blanching, they are quickly chilled by spraying with cold water, or by conveying them to a flush of cold water that often serves to transport them to the next part of the process.

Blanching vegetables to inactivate endogenous enzymes is a critical step prior to processing. However, the severity of the process should be limited in order to maintain colour, texture, flavour, and nutritional quality. These blanching conditions permit a decrease in the activity of catalase and peroxidase to a level below 5% of the initial value. The total absence of peroxidase activity indicates over blanching and there is a substantial body of evidence suggesting that the quality of products frozen after blanching is superior if a certain level of peroxidase activity remains at the end of the blanching process (Kmiecik *et al*., 2008).

Blanching is one of the most widely used pre- treatments in the drying of vegetables because of the resultant inactivation of enzymes, changes in tissue structure and short drying time (Latapi and Barrett, 2006). Blanching times varies with altitude (higher altitudes require longer blanching times), the type and texture of the vegetable, the amount of vegetable, and the thickness of the pieces. The sliced jackfruits were subjected to water blanching for 1 min, 1.30 min, 2 min, 2.30 min, 3 min and 3.30 min. One minute blanching was found to give best OVQ score. Liji (2014) blanched raw jackfruit for 8.45 min to get better products.

Higher blanching time and higher temperature affects the antioxidant contents (vitamin C) which is mainly derived from the vegetables. Therefore blanching time of 1 min is recommended for blanching of vegetables (Olayinka *et al*., 2012). Water blanching requires longer processing time which results in increased leaching of minerals and nutrients such as vitamins, and also produces effluents with large biological oxygen demand (BOD). Steam blanching is usually used for cut and small products which require less time than water blanching because heat transfer coefficient of condensing steam is greater than that of hot water. Steam blanching is more energy-efficient and produces lower BOD and hydraulic loads than water blanching. In addition, nutrient leaching is reduced compared to water blanching (Corcuera *et al*., 2004)

5.2.1.4 *Standardization of boiling time of seeds*

Boiling helps to remove the brown layer and helps in easy cutting of seeds. Jackfruit seeds were subjected to heat treatment for 2min, 5 min, 10 min, 15 min, and 20 min. Boiling time 20 min scored the highest OVQ scores.

Powerful trypsin inhibitory activity was reported in jackfruit seeds and it was seen that the activity could be destroyed by boiling the aqueous solution of seed at 100^0C for 30 minutes (Bhat and Pattabiraman, 1989). Ejiofor *et al*. (2014) too had boiled jackfruit seeds for various durations of time to get the flour, to know the effect of processing methods on the functional and compositional properties of flour.

5.2.1.5 *Standardization of immersion media for the bulbs*

Pre-treating light-coloured fruits before drying is important for the quality and safety of the final product. Soaking the sliced fruit in an acidic solution preserves the colour and texture of the dried fruits and increases the destruction of potentially harmful bacteria during drying (Robinson, 2012)

The sliced jackfruit was pre-treated with salt (0.5%), KMS (0.2%), citric acid (0.2 %) in different combinations. The treatment conducted with KMS (0.2 %) for 10 min was found to give a product with better appearance and acceptability. According to Rahman *et al*. (2012) jackfruit bulbs treated with 0.1 % KMS before osmotic dehydration gave the most acceptable product.

Ioannou and Ghoul (2013) reported that appropriate chemical pre-treatments can be adopted to preserve colour and inactivate enzymatic action. Different pretreatment methods have been developed for fruit drying, among which are immersing in lemon juice/salt solution/ honey dip/ ascorbic acid, sulphuring; osmotic pre-treatment and blanching (Karim, 2005).

According to the study conducted by Lee and Lim (2011) on pre-treated pumpkin and non-pre-treated pumpkin, it was revealed that, the pre-treated pumpkin had better retention of aroma, colour and nutrients whereas the non-pre-treated pumpkin were of inferior in quality. If no pre pre-treatment is done, the fruits will continue to darken after they are dried (Liji, 2014).

5.2.1.6 *Standardization of immersion time*

The blanched jackfruit slices were immersed in selected pre- treatment media for 5 min, 7 min, 10 min, 12 min and 15 min. Immersion time of 10 min was found to be optimum for giving a better product. In the preparation of jackfruit candy, jackfruit bulbs were cut into 1x 0.5 cm sized pieces, blanched in hot water for 4 min and immersed in 2% calcium lactate and 0.1% KMS solution for 2 min. It was inferred higher immersion time increased the strength of the product (Zuniga *et al*., 2004). Liji (2014) immersed jackfruit in KMS (0.2%) that obtained the best OVQ scores amongst other treatments.

5.2.1.7 *Dehydration of the pre-treated raw material*

Drying is the most common way to preserve agricultural produce especially the surplus ones. It is one of the most cost-effective ways of preserving foods, which involves removal of water by application of heat. It is well known that the product quality is greatly affected by drying methods and drying process. Dried foods can be stored for long periods without deterioration. The principle reasons for this is that the micro-organisms which cause food spoilage and decay are unable to grow and multiply in the absence of sufficient water and most enzymes which promote undesired changes in the chemical composition of the food cannot function without water. The JF bulbs attained breaking stage after drying for 14 hrs at 60^0C, whereas seeds attained this stage after drying for 24 hrs at 60^0C in cabinet dryer.

Drying air temperatures between 50^o and 60^oC appear to be feasible for drying large number of medicinal plants (Rocha *et al*., 2011). Satwase (2013) concluded that the cabinet tray drying method was the best method of dehydration of drumstick leaves. There was better retention of nutrients like protein, carbohydrates, crude fibre, minerals; as compared to the oven, shade and sun drying methods.

Dehydration of leafy vegetables reduced wastage, labour and storage space. Dehydrated leafy vegetables are simple to use and have longer shelf life than fresh vegetables. Dehydrated amaranthus had higher nutrient composition especially protein and it could be stored for a period of six months (Rajeswari *et al*., 2013).

5.2.1.8 ***Milling of flour***

Medicinal plants like *M. charantia* and *C. esculenta* were dried in hot air oven, then powdered, sieved by passing through 60 mesh sieve and stored in air tight container (Gayathri, 2014).

Here dehydrated bulbs and seeds were milled separately in the flour mill and sieved. The mesh size for sieving of both the flours was the same i.e. 0.5 mm. The left over residue was removed to get uniform flour. Both type of flours were packed in HDPE and laminated packages for further study.

Odoemelam (2005) reported that JF seeds were sliced and dried at 60 °C for 24 hrs. They were milled using flour mill and passed through a 250 µm sieve and packed in polyethylene bags and kept in refrigerator (~ 4 °C). In another study jackfruit seeds were dried at 60^o C for 24 hrs and then milled to pass through a 0.5 mm sieve as reported by Ocloo *et al*. (2010).

Jackfruit seed after cutting into slices of 2 mm thickness were blanched at

$70^{o}C$ with 0.5% KMS for 10 min. Pre-treated slices were dried in cabinet dryer at $60^{0}C$ for 24 hrs, followed by grinding into powder of particle size of 0.2 mm using a grinder. The powder was sieved and packed in high density polyethylene bags for further study (Hosein *et al*., 2012).

Butool and Butool (2013) sliced JF seed into thin chips and dried at 50- 60^{o} C to constant moisture. The dried chips were powdered in a flour mill and passed through 60 mm mesh sieve. They were packed in polyethylene pouches and stored in a refrigerator.

5.3 QUALITY ANALYSIS OF FLOUR

The quality is the combination of the attributes that determine the degree of acceptability of the food product. Quality of flours were analysed in terms of physical, chemical and nutritional characteristics.

5.3.1. Physical, chemical and nutritional qualities of flour

In the present study, quality assessment of JF bulb and seed flour was carried out by analysing physical, chemical and nutritional qualities. Bulk density is a measure of heaviness of a flour sample. It is affected by the particle size of the samples. It is important for determining packaging requirements, material handling and for various other applications in wet processing in the food industry (Ocloo *et al*., 2010). Odoemelam (2005) also reported a bulk density value of raw flour from jackfruit seeds to be about 0.61g/ml. Ocloo *et al*. (2010) obtained the bulk density of jackfruit seed flour to be 0.80 g/cm3.

In present study bulk density was found to be higher and it was higher in bulb flour (0.96 g/cm^3) than seed flour (0.92g/cm^3). This may be due to variations in particle size of the products because bulk density is generally affected by the particle size and the true density of the flour. The value obtained is higher than 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 as well (Ocloo *et al*., 2010).

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. In this study moisture content of flour was high and among both types of JF flour, seed flour showed the higher moisture value (7.93 %) than bulb flour (7.23%).

Abraham and Jayamuthunagai (2014) reported that the moisture content of the seed flour was 7.758%. The lower the moisture contents of flour, the better its shelf stability and the quality. Moisture content of flour generally depends on the duration of the drying process. Ocloo *et al*. (2010) reported that the moisture content of the jackfruit seed flour was 6.09 %. Munishamanna (2012) reported that jackfruit bulb flour had a moisture content of 5.2%. Mahmood (2004) reported that moisture content of wheat and maize varieties depended largely on the genetic makeup and is also influenced by the agronomic and climatic conditions.

In the present study crude fibre content of bulb flour was higher (4.06g) than seed flour which had fibre content of 3.13g. Ocloo *et al*. (2010) reported that JF seed flour had 3.19 g fibre whereas Munishamanna (2012) reported that JF bulb flour had 1.8g fibre in 100g. This difference may be due to varietal difference.

In this context, carbohydrate content was found to be higher (81.46g) in seed flour as compared to bulb flour (74.13g). Abraham and Jayamuthunagai (2014) had reported that JF seed flour had a carbohydrate content of 70.73g whereas Ocloo *et al*. (2010) reported that JF seed flour had a carbohydrate content of 79.34%. This variation may be due to variety or cultural factors.

In present context, protein content was found to be higher in seed flour (10.48g) than bulb flour (1.53g). Ocloo *et al.* (2010) reported that protein content of JFS flour is 13.50g, whereas Abraham and Jayamuthunagai (2014) reported that protein content of JFS flour has 13.49g. Munishamanna (2012) reported that JF bulb flour had a protein content of 1.05g. This may be due to the fact that fruits and vegetables are not as concentrated in nutrients as seeds with respect to macro nutrients.

In this study seed flour was observed to have an energy value of 353 kcal whereas, bulb flour had 329 kcal. Ocloo *et al*. (2010) reported the calorie value of seed flour to be 382 kcal/100g. Abraham and Jayamuthunagai (2014) reported that the calorific value of seed was 358 kcal/100g.

The study revealed that JFB flour contained potassium (328.11mg), magnesium (0.13mg), sodium, (35.06) and calcium (30 mg). Seed flour was observed to contain potassium (1478.37), magnesium (338.04), sodium (60.63) and calcium (308.56 mg). The jackfruit seed flour was observed to contain an appreciable value of calcium (3087 mg/kg), potassium (1478 mg/kg), sodium (60.66 mg/kg) as reported by Ocloo *et al*. (2010). Abraham and Jayamuthunagai (2014) reported that seeds were rich in potassium (6466 ppm), magnesium (4582 ppm) and sodium (8906 ppm).

5.3.2 Shelf life qualities of flour

Shelf-life studies can provide important information to product developers, which will enable them to ensure that the consumers will have a high quality product for a significant period of time after production. The storage conditions after milling and packaging are very important for the quality of the flour since they affect the shelf life and safety of the consumer.

Kumar (2001) suggested that there are many ways in which quality and nutrients can be lost. They may not necessarily result in the product being harmful but can mean that it is no longer of an acceptable standard. Shelf life study is an objective, methodical means to determine how long a food product can reasonably stay safe without any appreciable change in quality. Hence in the present investigation, moisture, insect infestation and microbial growth were examined periodically up to a periods of three months.

5.3.2.1 *Moisture*

Moisture is one of the important parameters which determine the shelf life quality of food product. Low moisture is highly important for longer storage period. Moisture content of the flour is very important for shelf life, lower the flour moisture, the better its storage stability (Shankar, 2003).

In present findings, there was increase in moisture content in all the samples during storage. The moisture content should be below 9% as per Indian standards (IS: 7836 AND 7837 1975). The moisture content of freshly prepared bulb flour was 7. 23 per cent, which gradually increased up to 7.99 (HDPE) and 8.13 per cent (laminated) in final (3^{rd}) month of storage. Similarly, seed flour had an initial moisture content of 7.97 per cent which increased up to 8.75 per cent (HDPE) and 8.97 per cent (laminated) in 3^{rd} month.

Packaging material also has an influence on moisture content of food product. Packaging materials had an effect on the moisture level of roasted cashew nuts during the storage as reported by Oladapo *et al*. (2014).

The selection of the right films for package involves the consideration of vapour transmission rate, and gases transmission characters. In the present study HDPE and laminated packages were used for study. Even though both the packaging materials revealed less increase in moisture content, their difference was considerable. It was found that increase of moisture per cent was less in HDPE packages in bulb (0.75 per cent) and seed (0.77 per cent) flour. The moisture content of bulb flour which was packed in HDPE packages had increased from 7.23 to 7.99 per cent and in laminated pouches it increased from 7.23 to 8.13 per cent. Similarly seed flour which was packed in HDPE had revealed an increase in moisture content from 7.97 to 8.75 per cent and 7.97 to 8.97 per cent in laminated pouch. The variation in the percentage may be due to different water vapour transmission rate of packaging material.

Murugkar and Jha (2011) studied influence of storage and packaging conditions on the quality of soy flour from sprouted soybean and reported that flours can be kept in Al foil laminated packages for 60 days (ambient) and 45 days (accelerated). They further reported that the variation in moisture contents of these products is directly related to the water vapour transmission rate of the packaging materials. The laminated packages were most effective and least moisture could migrate through them. This was mainly due to the fact that alluminium foil is considered to have a very low water vapour transmission rate (WVTR) under humid condition (80% RH).

In another study by Goyal and Kumar (2012), it was reported that the highest moisture content of potato flour was (5.78 %) observed in LDPE poly packs and the lowest moisture content (4.8%) was observed in HDPE packed flour stored at room temperature. The author also reported that highest moisture content of potato observed was 4.78 % in LDPE poly pack, and the lowest moisture content observed was 4.32% for the flour packed in laminated pouches. There was significant effect of packaging material and storage period and combined effect of packaging material and storage period on moisture content. It was observed that in laminate and HDPE poly packs; there was minimum change in moisture content during the storage period up to 45 days, increase in moisture content was high after 60 days however the change in moisture content was minimum. The best results were observed for HDPE and laminate packaging materials.

Moisture content is affected significantly by storage, treatments, packaging and their interactions. It is also affected by hygroscopic properties of flour as reported by Rahman *et al*. (2005).

5.3.2.2 *Insect Infestation*

Insects that live on stored grains and their products depend upon the moisture supply. Moisture is an important factor in controlling grain infestation. The assessment of the incidence of insect pest in the stored flours revealed that there was no insect infestation in the HDPE and laminated covers. Generally, moisture content below 9% restricts infestation. In this study also moisture content was less in both type of flours and this might have restricted the growth of insects. Insects have preference for moist flour materials and increased moisture level aggravated infestation.

Ogedegbe and Edoreh (2014) reported that food products that were left undisturbed on the shelves for long periods were particularly susceptible to infestation. The main factors which contributed to infestation were attributed to residual populations from old stock, unclean storage containers, unhygienic condition of the warehouse with high moisture content, mix-up of bags of flours in stores and markets, lack of knowledge of the insect pests and alternate hosts.

5.3.2.3 ***Microbial profile***

Although flour is generally regarded as a safe product due to its low water activity, a variety of pathogenic and non-pathogenic microorganisms contaminate the flour during processing (Berghofer *et al*., 2003). Pathogens that contaminate flour can survive for extended periods and produce toxins, even though their growth is retarded under low moisture conditions. There are different threats on food quality due to microbial infestation. Spoilage causing organisms cause off odour and off taste and lead to economic loss (Rao, 2003). Spoilage by microorganisms is the primary cause of the end of shelf life of products hence reducing initial microbial populations is a strategy to extend shelf life (Zagory, 2003).

In the present investigation it is evident that during the three months of storage period, growth of bacteria and fungi was observed only during third month. It may be due to increase in moisture content, characteristics of packaging material and storage conditions. Total plate count of fungi (1.5 $x10^2$ and 2.0 $x10^2$) was more in both types of flour, which may be due to the ability of fungi to grow in low moisture and high carbohydrate content. Total microbial count was found to be more in seed flour. The reason for this phenomenon could be that seed flour contains more protein and fat and so chances of proteolytic and lipolytic organisms to grow on them is more. Higher lipolytic and proteolytic activities are related to higher moisture content, which further leads to loss in nutrients (protein and fat) and production of more free fatty acids resulting in inferior sensory characteristics.

Even though bacteria and fungi were detected, it was present only in permissible limits. No pathogenic organisms could be detected in both types of flours. Ojure and Quadri (2012) reported that total plate count of the plantain flour was observed to be 2.1 x 10^2 cfu/g and fungal count was observed to be 1.1x 10^2 cfu/g. However no coliforms or staphylococcal was detected in plantain flour. Nasheeda (2006) reported that the bacterial population of banana powder packed in poly propylene covers ranged between 5.6-6.88 x 10^3 cfu/g.

Thus we see that, raw jackfruit flour is observed to be rich in dietary fibre, protein, carbohydrate and total minerals which make it a valuable source of nutrients. It is also shelf stable in terms of moisture and microbes. It can, therefore, be concluded that raw jackfruit flour can be used as a potential source for the development of extruded products like noodles enriched with nutrients. The present study unveils raw jackfruit flour as a promising material for the development of noodles.

5.4 EXTRUSION OF NOODLES

Noodles have become popular owing to their simple processing requirements, desirable sensory attributes, long shelf-life, together with diversity and nutritive value. Noodles could serve as a suitable food for fortification or enrichment purposes. Substitution of wheat flour with local raw materials is increasing due to the growing market for confectioneries as reported by Aziah and Komathi (2009). Thus, several developing countries have encouraged the initiation of programmes to evaluate the feasibility of incorporating alternative locally available flours as a substitute for wheat flour (Abdelghafor *et al*., 2011).

5.4.1 Formulation of noodles

In a study by Rooney *et al*. (1972) it was reported that composite flour has an advantage where import of wheat flour is concerned because it promotes the use of local crops, reduces wheat flour procurement and increases utilization of indigenous resources

In the present study composite flour were prepared by using JF bulb and seed flour in combination with refined flour. In all the combinations the proportion of bulb and seed flour was varied while refined flour remained same except one. The preparation of noodle has been depicted in Fig 2. The proportion of RF: JBF: JSF were 40:30:30, 50:25:25, 50:30:20, 50:40:20, 50:40:10, 50:20:10 in the various treatment.

Wani *et al*. (2011) evaluated the quality of noodles by adding cauliflower leaf powder to the noodle formulation at the level of 0, 10, 15, 20 per cent. Rittiruangdej *et al*. (2011) prepared noodles by substituting wheat with 10,20,30,40 and 50 % banana flour. Akanbi *et al*. (2011) standardised bread fruit starch with wheat in the combination of bread starch and wheat flour in the ratio of 100:0, 80:20, 60:40, 40:60, and 20:80. The FAO reported that the application of composite flour in various food products would be economically advantageous because if the imports of wheat could be reduced or even eliminated demand for bread and pastry products could be met by the use of domestically grown products instead of wheat (Jisha *et al*., 2008).

5.4.2 Setting up the extruder

Santacruz *et al*. (2009) extruded noodles from *Canna edulis* (arrowroot) by using a Brabender single screw extruder (Germany). The feed-supply was kept at 66 g/min; the particle size of the material was between 8 to 35 meshes with a moisture content of 24%. Four temperature profiles along the barrel, 50-50-50, 80-80-80, 80-100-120, and 100-120-150ºC, together with a rotating speed of 80, 120 and 150 revolutions per min, and a die of 3 mm of diameter were used during the extrusion.

In the present investigation, composite flour from RJB, RJSF and RJSF were moistened at 33 per cent by adding deionising water in three phases. The flour was kept in Brabender single screw food extruder (Japan) and the temperatures set at three different zones were 35^0C, 45^0C, and 60^0C. The other parameters set out before the extrusion were screw speed - 40 min-1,dosing screw speed - 15 min-1, speed of feeder - 16 rpm, Screw 40 rpm and size of the die were 2 mm x 4 strands. Sheeted noodles were dried at 60^0c for 6 hrs. Finally they were packed in HDPE and laminated covers.

In a study by Hardi *et al*. (2007) noodle blends were made to a total moisture content of 32.2% by mixing for 15 minutes at 80 rpm using a commercial laboratory mixer. The resulting dough was fed in between the rollers of a laboratory noodle sheeting and cutting machine, at room temperature to give noodle strands of a die size of 2 mm.

Deshpande and Poshadri (2011) reported that extrusion cooking of composite flour (Foxtail millet; Amaranth; Rice; Bengal gram; Cow pea in the ratio of 60:05:05:20:10) was carried out using a twin screw extruder at optimised extrusion parameters namely temperature: 115˚C and 90°C for two different heating zones, die diameter of 3 mm and screw speed of 400 rpm.
Bui and Small (2007) reported that noodles were dried for 6 hrs at 50-55 ^{0}C. After drying they were cooled and packed in polyethylene bags and stored under ambient temperature. In another study by Sinha and Masih (2014), it was reported that beetroot pomace powder and pulse powder in different combinations were fed into single- screw extruder through feed hopper and collected at the die end. The product was kept in a hot air oven at 60^{o}C for 1-2 hrs, and then the product was stored in LDPE bags for further studies.

5.5. STANDARDIZATION OF COOKING PROCEDURE
Cooking procedure of noodles was standardized with respect of cooking time and cooked weight.

5.5.1 Cooking time
The degree of cooking can be observed either by image analysis and texture assessment (Sozer *et al*., 2007). In the present study, it was determined by the disappearance of the core of the noodle strand during cooking by pressing between glass slides in 2 min intervals. Cooking time of the treatments ranged from 8.26 to 9.36 min.
Data further revealed that treatments which contained highest amount of bulb flour took more time for cooking. RF: JFBF: JFSF in the ratio of 50:40:10 took longer time for cooking i.e. 9.36 min. Cooking time of commercial noodles

was 7.16 min. All the treatments were found to have higher cooking time than control. This may be because refined flour contains starch gelatinised easily. This variation may also be accommodated to the high fibre content present in T_4, which contain more amount of bulb flour.

Ojure and Quadri (2012) standardised unripe plantain flour and reported that the cooking time ranged from 4.5 to 7.62 min. The author also reported that branded noodles (refined flour) had a cooking time of 8.21 to 8.29 min. In another study on banana flour noodles by Rittiruangdej (2011), it was reported that the optimum cooking time of all noodle samples ranged from 13.0 to 14.5 min. Vijaykumar *et al.* (2009) reported that cooking time of developed noodles from composite flour varied from 15- 18 min, which was significantly higher than the cooking time of branded noodles. The cooking times for all the treatments were higher than that of market noodles which was reported to be 8 min. This difference may be attributed to the incorporation of composite flour in its production as reported by Omeire *et al*. (2015).

5.5.2 Cooked weight

Cooked weight was evaluated to know the percentage increase of weight of noodles from raw to cooked state. In this study percentage increase of cooked weight of developed noodles ranged from 100.45 to 140.62. Cooked weight of commercial noodle had shown lowest percentage increase (90.87). The RJF bulb and seed flour is hygroscopic and may have the ability to absorb and hold water during heat treatment. During the cooking process, RJB and RJS flour might also have gelatinized in addition to the starch. The gelatinization of both bulb and seed flour during the cooking process might have contributed additional water, which increased the weight of the noodles after cooking.

Omeire *et al*. (2015) standardised the cooked weight of cassava noodles and reported that cooked weight of noodle samples ranged from 115.60 – 213.56 per cent. The author also further reported that the high cooking weight could be attributed to the high starch and protein content of the noodle samples

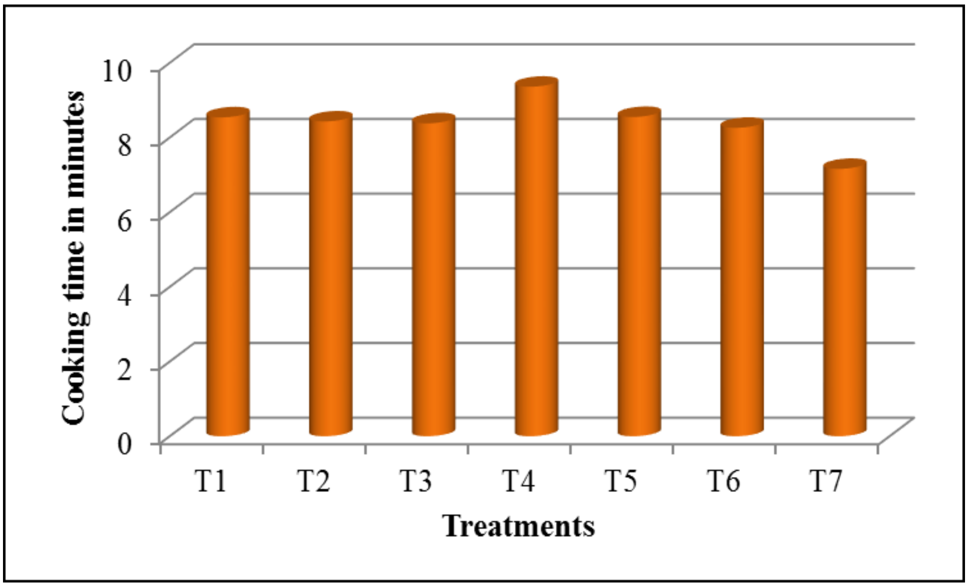


Figure 3. Cooking time of noodles of different treatments

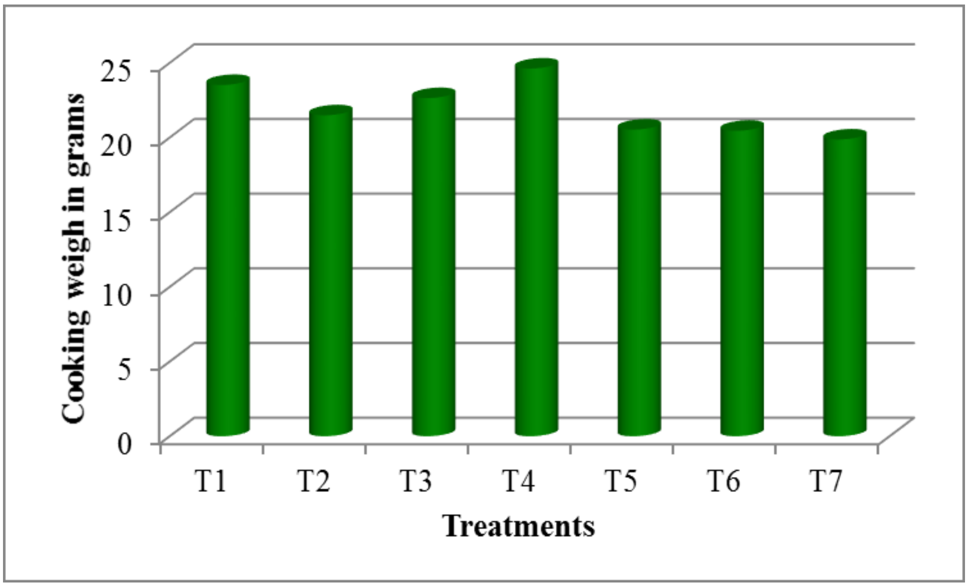


Figure 4. Cooked weight of noodles

5.6 QUALITY ANALYSIS OF NOODLES

Food quality is a complex concept that is frequently measured using objective indices related to the nutritional, microbiological or physiochemical characteristics of food or in terms of the opinion of designated experts (Cardello, 1995). Different combination of noodles from JFB and JFS flour with refined flour were analysed in terms of cooking, physical, chemical, nutritional, and sensory and shelf-life qualities.

5.6.1 Cooking characteristics

The cooking characteristics of noodles are the ultimate tests in determining its quality. It is one of the most important attributes that consumers consider to buy a product. It is characterised here by cooking loss and water absorption.

5.6.1.1 *Cooking loss*

The cooking loss represents the particles that diffused out from the noodles into the cooking medium during cooking. The cooking loss property reflects the surface characteristics of the noodles. It is an important attribute in noodles, as it evaluates the amount of irrecoverable solids in cooking water. It is highly vital that the structural integrity of noodles need to be maintained throughout the cooking process.

In present study, cooking loss ranged from 9.13 to 15.37 per cent. Cooking loss of treatments was high but it was lesser than commercial noodles. Non-wheat ingredients leads to discontinuity within the gluten matrix and results in weak dough properties as reported by Manthey *et al*. (2004). The study further revealed that the treatment which contained highest amount of bulb flour had less cooking loss i.e. T_4. The reason for low cooking loss may be due to high fibre content in bulb flour and high protein in seed flour.

According to Shiau and Yeh (2001), higher the cooking loss, the stickier the noodle surface will be. High cooking loss is unacceptable as there can be high amount of solubilized starch present, which leads to cloudy boiling water and 'sticky' mouth feel with lower cooking tolerance as reported by Chakraborty *et al*. (2003).

Rittiruangdej *et al*. (2011) reported that an increased cooking loss with noodles containing banana flour may have been due to weakening of the protein network by the presence of banana flour. This may have allowed more solids to be leached out from the noodles into the cooking water. These results are in the agreement with the study of Martinez *et al*. (2007) who reported that partial or complete substitution of durum wheat semolina with fibre material can result in negative changes to pasta quality, including increased cooking loss.

In another study of banana flour noodles Ojure and Quadri (2012), reported that cooking loss ranged from 6.39 to 10.40 per cent. They further reported low cooking loss by the incorporation of xanthum gums which favoured high water absorption.

Purwandari *et al*. (2014) reported that cooking loss of noodles with pumpkin and tapioca, ranged from 11.20 – 27.38 per cent whereas cooking loss observed in breadfruit noodle was 12.45 to 17.04 per cent. Higher cooking loss resulting from the dilution of gluten and weakening of the starch-protein network as was reported in wheat spaghetti fortified with legume flours by Gopalakrishnan *et al*. (2011).

Tudorica *et al.* (2002) reported that the uneven distribution of water within the pasta matrix due to the competitive hydration of fibre, led to prevention of starch swelling and hence increased cooking loss was due to the disruption of protein-starch network.

5.6.1.2 *Water absorption*

Water absorption is the increase in weight of dried noodles after cooking in boiling water according to their cooking time (Purwandari *et al*., 2014). Water absorption of noodles was found to be higher and it ranged from 90.87 – 140.62 per cent. Water absorption of noodles was found to be higher in T_4 treatment which contained more amount of bulb flour. In these treatments it was seen that as the concentration of bulb flour increased water absorption increased. Abraham and Jayamuthunagai (2014) reported that JF seed flour has a good ability to bind

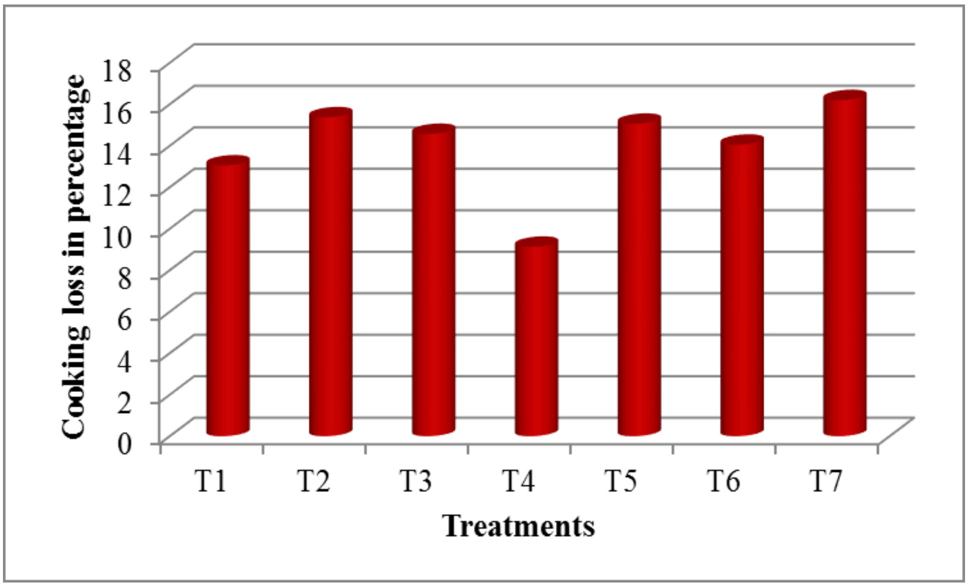


Figure 5. Cooking loss of the noodles

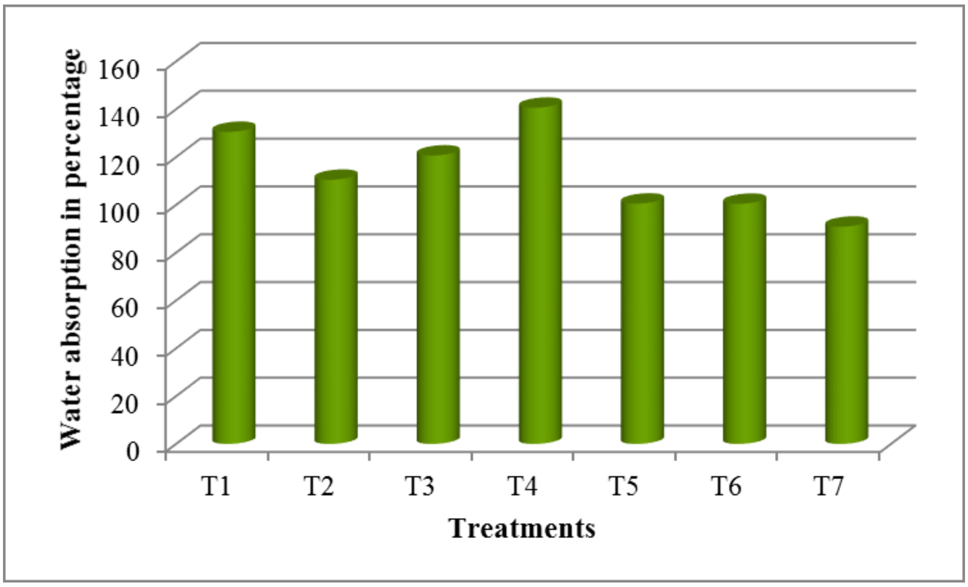


Figure 6. Water absorption of noodles

water. Less water absorption was found in commercial noodles which contained only refined flour.

In a study on banana flour noodles Ojure and Quadri (2012), reported that water absorption of noodles ranged from 105.50 to 124.20 per cent. They further reported that branded noodles had water absorption of 111.30 and 112.58 per cent. Several authors reported that the water absorption capacity depends on the behaviour of the protein denaturation, the function of the amylose/amylopectin ratio as well as the chain length distribution of amylopectin (Kober *et al*., 2007).

5.6.2 Physical characteristics

Physical characteristics help in the qualitative assessment and acceptability of any new product. Physical characteristics namely extrusion behaviour, firmness, shape, uniformity of strands, packaging quality, bulk density, true density, swelling index, yield ratio, processing loss and colour of product were ascertained.

5.6.2.1 *Extrusion behaviour*

Extrusion behaviour usually depends on the raw ingredients of extruded products. It was studied here by assessing residence time, uniformity of strands and external appearance during extrusion. Residence time was noted as the time taken by 300g of flour to extrude into noodle. This depends on the viscosity of flour. As JF flour is viscous, it took less time to extrude. In the present study residence time of flour was found to be lower in T_6 with 31.05 min. It was also observed that as the concentration of seed flour increased, residence time decreased. This may be the due to higher viscosity of seed flour. Ocloo *et al*. (2010) reported that JF seed flour had high viscosity.

Regarding uniformity of strands, the present study revealed that T_3 and T_6 had higher scores. These treatments had RF: RJBF: RJSF in the ratio of 50:30:20 and 50:20:30 respectively. From this, it can be concluded that bulb and seed flour in this specific and appropriate combination (20:30) scored better with respect to

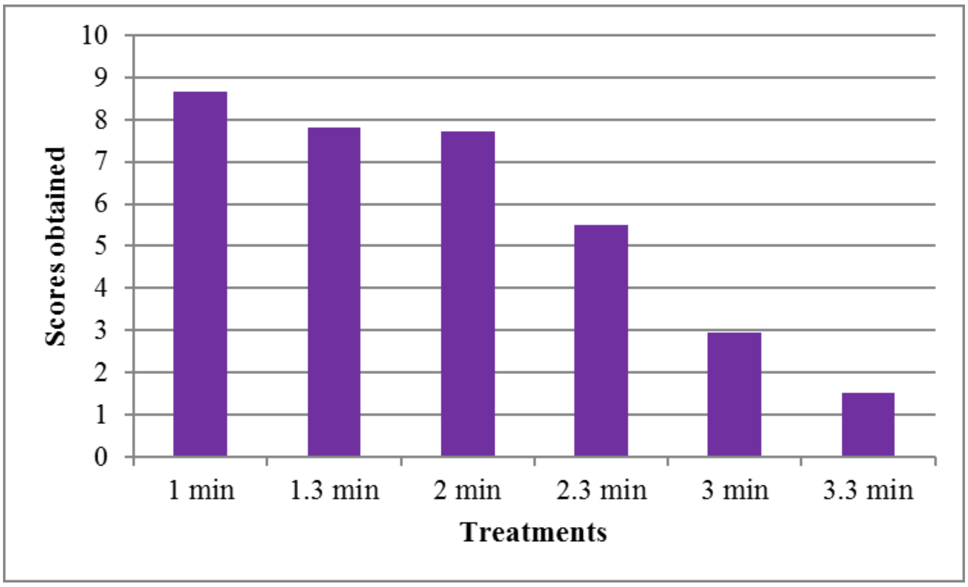


Figure 7. OVQ scores of blanched bulbs

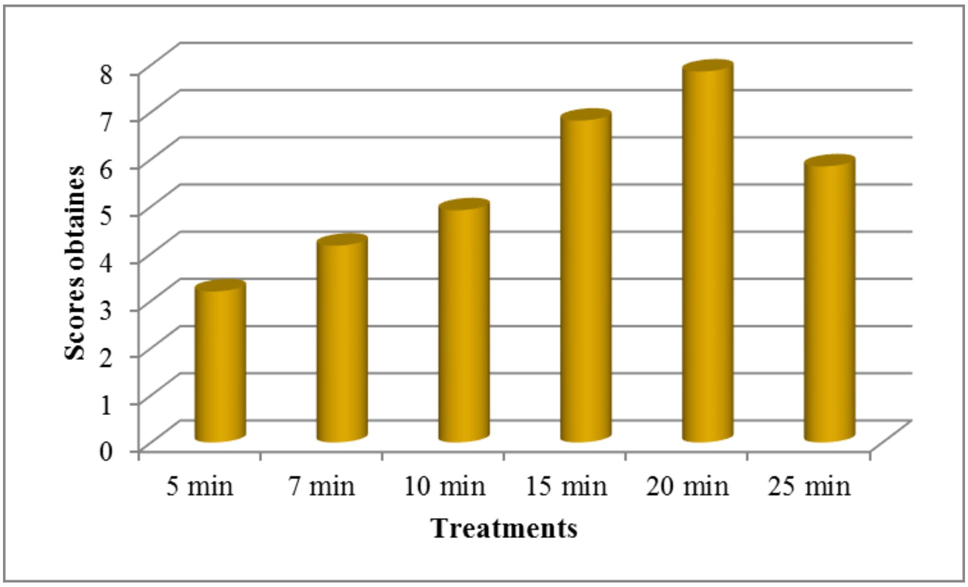


Figure 8. OVQ scores of boiled seeds

this parameter. Blending in the right proportion of flours is essential for an acceptable product with excellent gluten formation.

External appearance of noodle after coming out from the extruder was recorded and it was observed that T_5 and T_6 had high values for appearance. This might be due to more of seed flour which was finer as well more whiter in colour. In a similar study on extruded foods, it was revealed that the formulation with refined flour, tapioca flour and soya flour got the best rating for extrusion behaviour (Karoline, 2004).

Firmness is a measure of the toughness of noodle. It determines how the material will withstand packaging and handling. In the present study with respect to firmness the scores ranged from 4.23 to 4.50. It was found to be higher in T_3 (4.50) which was on par with T_6 (4.48). From the result it was clear that treatment which contains appropriate combination of bulb and seed flour (fibre and starch) had good firmness quality. This might also be due to high protein content in seed flour and fibre content in bulb flour. Firmness depends on the degree of gluten development in the noodle. It was reported that firmness of noodles was decided by the internal structures of the cooked product (Edwards *et al.,* 1993).

The difference in firmness of noodles was not caused by differences in cooking loss. Protein strength has been suggested as a possible cause for the difference in surface integrity of cooked pasta by Dexter *et al*. (1981). They proposed that strong gluten in pasta may give a more rigid but only less flexible structure than weak gluten and that such a structure would be more susceptible to rupture under the stresses of swelling during cooking. Flour protein content has a positive correlation with noodle hardness.

Regarding the shape of noodles scores, it was found to be highest for T_6 (4.68) and T_3 (4.64). This may be because these treatments had optimum quantity of bulb and seed flour ratio. The score for uniformity of strands ranged from 4.06 - 4.75. The highest score was obtained by T_3 (4.75).

Regarding tensile strength the score ranged from 4.21 – 4.65. The highest score was obtained by T_4 (4.65) and it was seen to be on par with T_3 (4.58). This may be because these treatments had higher bulb flour. Incorporation of seed flour in the developed noodles had increased the protein content and this may be the reason for higher tensile strength. Exudate breaking strength is important to both the processor and consumer. If the product has a low breaking strength; it will break easily and disintegrate during packaging and distribution. On the other, if the product has a larger breaking strength, the consumer will find the product difficult to bite and to chew (Liu and Maga, 1993).

Packaging quality is the ability of the product to withstand microbial contamination, absorption of moisture, gases, heat and dynamic stress (Shivashankaran 2000). In this study all the treatments had good packaging suitability as the result has shown no significant difference in the scores for packaging quality among treatments and all the treatments were found to be on par. Packaging quality was found to be high in the sev comprising of maida, rice flour and soya flour in the combination of 60:30:10 (Karoline, 2004).

5.6.2.2 ***Bulk density***

Bulk density is generally affected by the particle size and density of the flour. Bulk density helps to determine the packaging material which adds in handling and various applications in wet processing in the food industry. The lower loose bulk implies that less quantity of the food samples can be packed in constant volume there by ensuring an economical packaging.

Bulk density of the developed combinations ranged from 0.68 to 0.91g/ml. Present study revealed that as the quantity of bulb flour increased, the value of bulk density also increased. Control sample had lesser bulk density than the developed treatments. This may be due to the big particle size of bulb and seed flour than refined flour. Kumar *et al.* (2011) reported that the bulk density of chicken meat mince enriched noodles ranged from 0.47 to 0.50g/ml.

5.6.2.3 *True density*

True density means mass per unit volume of grains which does not include pore spaces between granules (Tapash and Bhaskara, 2006). It indicates how much product had expanded after coming from die. In this study true density of treatments ranged from 0.01 to 0.04 and there was significance different from control. True density of T_4 was higher (0.4) than all the treatments along with control (0.01). The study revealed that as the concentration of bulb flour increased true was also density increased. This may be due to the higher fibre content of bulb flour and higher starch content in seed flour. True density of chicken meat mince enriched noodles ranged from 1.27 to 1.29 as reported by Kumar *et al*. (2011).

5.6.2.4 *Swelling index*

Swelling Index (SI) of noodles is an indicator of the water absorbed by the starch and proteins during cooking, which is utilized for the gelatinization of starch and hydration of proteins. Swelling index was found to be higher in all treatments though it was highest in T_4 which contained higher amount of bulb flour. SI was found to be lower in commercial noodles. According to Cleary and Brennan (2006), increased swelling index values might be related to greater water absorption during cooking due to the high water-binding capacity of fibre.

Gopalakrishnan *et al*. (2011) reported the restricted swelling (low SI values) in the pasta products compared to the reported values of 1.8 - 1.9 for durum semolina pasta which indicates that the added proteins also may be competing with starch for water. Akanbi *et al*. (2011) reported that swelling index of bread fruit starch with wheat flour noodles ranged from 3.04 to 3.4. Wijesiri *et al*. (2014) reported that swelling index of rice noodles incorporating drumstick leaves was 2.5 % and also stated that it was higher than control.

5.6.2.5 *Yield ratio (noodles)*

Drying removes moisture, the food shrinks and decreases in size and weight, thus requiring less space for storage. Yield of dried products are directly related to how much water is in the original product. Yield ratio of extruded product varied from 0.86 to 0.97 per cent. T_1 treatment had lowest value and T_6 had the highest value. There was an increase in the yield among the treatments from T_1 to T_6 with increase in amount of bulb flour.

5.6.2.6 *Processing loss (jackfruit)*

Processing loss indicates the removal of un-edible portion of raw material and reduction of moisture. To get the flour of raw material there is a need to remove un-edible portion like stalk leaf peel etc. Removal of moisture by drying too reduces weight. Processing loss of jackfruit ranged from 66.45 to 73.98 per cent. This difference might be due difference in the size and shape of identified bulb. Bulb and seed size also varied with tree location and climatic condition. This study was in line with the findings of Swami *et al*. (2014) who reported that jackfruit is heavy and bulky and the actual recovery of bulbs or edible portion varies from 20% to 25%.

5.6.2.7 *Colour*

Colour is one of the important parameters used by consumers to evaluate visual quality and is useful for the better marketability of noodles (Asenstorfer *et al*., 2010).

In the present study, colour properties of the noodles were characterised by measuring the primary colour coordinates ‘L’, ‘a’ and ‘b’ and from these values total colour change values and whiteness index values were calculated.

The values were observed on 3rd day of preparation. Considerably high ‘L’ value was obtained for commercial noodle, indicating the degree of white colour. L value of treatments ranged from 75.23 to 80.07. It was found that there was no significant difference in colour value of the treatment but the values were significantly different from commercial noodles. It was seen to be highest in T_3 treatment. Flour protein content had a negative correlation with noodle brightness as reported by Hou and Kruk (1998).

The degree of redness value ‘a’ was less for commercial noodles. Presence of red colour or ‘a’ value was higher in developed noodles. It ranged from 2.12 to 3.07. This may be due to jackfruit bulb flour which contains carotenoids pigments.

Among the developed noodles yellowness value was less in commercial noodles and it ranged from 19.43 to 23.27. The value of yellowness was high in developed noodles due to JF bulb flour which contains higher carotene content as compared to wheat flour.

Total colour difference ranged from 27.55 to 33.53 and it was seen to be higher than commercial noodles. The low value of control is because it has only refined flour incorporated. So from the above experiment it can be concluded that addition of many ingredients in noodles increases the total colour difference value.

Whiteness index values, though in general increased with increase in concentration of bulb flour, but at higher concentration of the bulb, the manifestation was not observed in T_4. Jackfruit bulb and seed have higher minerals content which also might have affected the whiteness of flour. Flour ash content has been rated as one of the important specifications because it affects noodle colour negatively as reported by Hou and Kruk (1998).

In a study by Hatcher *et al*. (2002) it was reported that after being stored for two to five days, fresh noodles had a tendency to darken, which holds true for our observations too. Darkening usually happens due to the protein content of noodles. The higher the protein content, the higher is the tendency for noodles to get darkened after storage and this is attributed to the oxidation process occurring between protein and phenol compounds as reported by Asenstorfer *et al*. (2010).

5.6.3 Chemical composition

Chemical composition plays an important role in determining the shelf stability of product. Chemical constituents were analysed with respect to moisture and fibre content of product.

5.6.3.1 *Moisture*

Moisture content of the dried product is an indicator of efficiency of dehydration. In the present investigation, moisture content of developed treatments ranged from 6.40 – 6.47 per cent. The reason in variation may be because the developed treatments had different ratios of RF, RJBF and RJSF. Meanwhile, the moisture content of commercial noodles was found to be 5.79 per cent. Lower moisture content in commercial noodles may be because of the additives that are added to maintain the moisture level. Though all treatment showed almost similar moisture content, their value was found to be higher in T_5 (6.47) and it was on par with T_6 with a score of 6.45. This may be because seed flour contains higher moisture and therefore may be more hygroscopic in nature than bulb flour.

This observation is in line with the findings of Akanbi *et al*. (2011) who had observed that moisture content of bread starch and wheat flour noodles ranged from 4.65 (60% BS:40% WF) to 5.45% (100% BS:0% WF). They also reported that these values are far lower than the Joint FAO/ WHO standards for fried and non-fried instant noodles, which are 10 and 14%, respectively (FAO/ WHO, 2003). An inference can therefore be drawn that RJF noodles apart from being healthy and free of additives, also conform to the standards of world food and health regulatory agencies.

5.6.3.2 ***Fibre***

Dietary fibre components exert beneficial effects mostly by way of their swelling properties, and thereby increasing transit time in the small intestine. Consequently, they reduce the rate of release of glucose and its absorption, thus help in the management of lifestyle disease. Dietary fibre components also bind to bile salts, thereby promoting cholesterol excretion from the body and thus reducing blood cholesterol levels, and food toxins in the gut (Gopalan *et al*., 2009).

In present study, crude fibre was present in higher concentration in all the treatments. This is because both the bulb and seed flour contained high amounts of fibre. Their value was found to be higher in T_4 and T_3. The combination of RF: RJBF: RJSF in T_4 and T_3 were 50:40:10 and 50:30:20 respectively. From the study it was also observed that as the amount of bulb flour increased in treatments, the value of fibre content was also increased. The reason for high fibre in general is due to jackfruit especially *Koozha*. Hence, RJF noodles could be acceptable in places where fibre diets and lower fatty foods are desired. Supplementation of jack fruit seed flour to the wheat flour in bread increased fibres and slightly decreased protein (Ejiofor *et al*., 2014).

Fibre content of commercial noodles was found to be of negligible quantity. This is because commercial noodle are made of refined flour which is a poor source of dietary fibre. Kulkarni *et al*. (2012) found 3.6 and 3.80 g of crude fibre in 30% unmalted and malted ragi flour noodles and also reported that their concentration was high due to ragi which is good source of fibre.

Yadav and Gupta (2015) reported that dietary fibre level varied in direct proportion with the amount of apple pomace powder. The control samples showed low value of dietary fibre while the noodles containing 10% apple pomace powder possessed 13.28 % total dietary fibre. In another study Pereira and Ludwig (2001), reported that high-fibre diets are associated with lower food intake as this triggered maximal sensory stimulation in the mouth due to increased need for chewing.

5.6.4 Nutritional composition

The processed and convenient foods, available today have more of trans fats, salt, sugar and empty calories. So consumption of processed foods predisposes to various health problems. WHO and FAO strongly recommend food manufacturers to develop innovative nutrient rich convenient foods from natural sources (Astrup *et al*., 2008). Nutritional compositions are also attracting consumers to make sure that there are a definite proportion of nutrients in each food. Food manufacturers also recognize the importance of safe and healthy food (Rivera *et al*., 2004). Hence nutrient assessment is an inevitable part of a new product development.

5.6.4.1 *Proximate composition*

Proximate constituents comprises of energy, carbohydrate and protein. **Energy** content of all the treatments ranged from 291.60 – 372.00 kcal which included control. Among the treatments energy content was found to be higher in T_5 (380.86 kcal) and T_6 (366.93 kcal). This may be because these two treatments had higher seed flour content compared to all other treatments. The value of energy content was found to be higher than control (372.00 kcal). The reason for such a variation is because composite flour had protein content which is also considerable source of energy as carbohydrate.

Carbohydrates are one of the most abundant and widespread organic substances in nature. Carbohydrates are generally regarded as an immediate and cheap energy source. In the present study carbohydrate content was found to be higher in T_5 (70.91g) and T_6 (63.54g) in the proportion of RF: RJBF: RJSF as 50:10:40 and 50:20:30 respectively however their value was lower than control (81.50g) but these values were higher than all other treatments. This differences in carbohydrate content in comparison to control is because control made from high carbohydrate source. Among the treatments T_5 and T_6 had more seed flour which is also rich in starch content.

Results further revealed that as the concentration of bulb flour increases, carbohydrate content was found to be decrease. This finding is also supported by Singh *et al*. (2015) who stated that carbohydrate content decreased with the increase in amount of banana peels powder. Yadav and Gupta (2015) reported that the formulation with 10 % formulation of apple pomace powder and wheat flour had carbohydrate content of 67.20 %.

Protein content was also notably high in T_5 (13.49g) and T_6 (12.92g) treatments and it was also found to be high than control (11.50g). This may be because the treatments contained more amount of seed flour which is a rich source of protein. Since refined flour has lower protein content, commercial noodles have lower protein than developed noodles. These findings are in agreement with the findings of Abraham and Jayamuthunagai (2014), who found that crude protein of the seed flour, was 13.49%. Amin (2009) reported that jackfruit seed in noodles increased the protein content and improved the overall nutritional value of the noodles.

Mineral content of treatments shows the presence of essential minerals like calcium, potassium magnesium and sodium. Mineral content of noodle was found to be higher in all treatments. The differences observed could be attributed to the variety of jackfruit and the geographical location of the plant.

The amount of calcium (146.94 mg), potassium (787.33 mg), magnesium (162.24 mg) and sodium (42.73 mg) were found to be high in T_5. This observation may be because jackfruit seed flour is rich source of minerals. This is in line with the finding of Ocloo *et al* (2010), who stated that jackfruit seed flour prepared is rich in calcium (3087 mg/kg), magnesium (3380 mg/kg) and potassium (14781 mg/kg). Dried drumstick leaves incorporating into rice flour at 3 % can be recommended for manufacturing noodles having higher amount of calcium as reported by Wijesiri *et al*. (2014).

Calcium has an important role in prevention and treatment of osteoporosis (together with vitamin D), colorectal cancer, kidney stones (Hall, 2002) while, magnesium is important for prevention or treatment of hypertension and heart diseases, diabetes, osteoporosis, migraine, headaches and asthma (Tucker *et al*., 1999).

In general nutritional and chemical composition of the study revealed that presence of analysed chemical constituents like moisture was higher in $T_5$and T_6 and fibre content was high in T_4 and in T_3. With respect to nutritional quality, T_5 and T_6 showed higher nutrients. Amin (2009) reported that chemical composition in noodles substituted with jackfruit seeds indicated decrease in fat and moisture content compared to control noodles. Ash and crude fibre contents in 30 % substitution of jackfruit seed flour were higher than that of control noodles.

5.6.5 Sensory qualities of noodles

Acceptance of a new product by the consumer is the ultimate goal as consumers are the end users of products hence sensory quality evaluation is vital whenever a new food product is developed. This is also important when consumer acceptability towards a food product needs to be predicted (Lawless and

Heymann, 2010). Sensory evaluation was conducted with respected to appearance, colour, texture, taste and overall acceptability

5.6.5.1 ***Appearance***

Visual appeal creates the first impression and is a major factor for acceptance of a food. The study came out with high score for T_5 (4.59) among all the six treatments for appearance though control scored slightly higher value 5.00). This may be because T_5 had higher seed flour and seed flour was whiter in colour than bulb flour which had a slightly yellowish appearance. The score for T_4 was lower for appearance because this treatment contained more amount of bulb flour which turned slightly brown after drying may be due enzymatic browning.

5.6.5.2 ***Colour***

Determining visual colour as a part of sensory quality is important because the first parameter of a food product, assessed visually by a consumer is the colour (Hutchings, 1977). Colour is a clear indicator of quality, as fresh noodles are expected to maintain white colour. High quality noodles are generally characterized by the presence of white and translucent colour (Fu, 2008).

In present study, colour of the noodles was found to be superior in T_5 and T_6 which contained higher amount of seed flour. Seed flour was whiter in colour than bulb which had slightly yellowish colour. Since a certain amount of yellow colour develops as a result of natural pigments in bulb flour, control was found to be superior in colour in comparison to all the samples because refined flour is whiter in colour because of having got bleached. In this context it can be infered that natural colour can score values on par to commercial noodles.

5.6.5.3 ***Texture***

Texture has been recognized as the second most assessed sensory property of food (Bourne, 2002). Texture of cooked noodles is the most critical characteristic, which determines consumer acceptance of the product. Sensory score for texture was high in T_5 and T_6 with a score of 4.89 and 4.75 and they were found to be on par. This may be because these treatments contained more seed flour. Seed four has high starch content and so their flour is finer than bulb. Highest score was obtained for control (4.91) with respect to texture which may be because refined flour has good elastic property owing to its high amylopectin content.

This study is in line with findings of Hatcher *et al*. (2002), who reported that textural quality of noodles was found to be affected by flour particle size. Flours with fine particle produced wheat noodles with the best textural parameters. Similarly, sorghum flour with smaller particle size produced stronger and firmer noodles (Suhendro *et al*., 2000). This suggests that the texture of the modified noodles was slightly altered by incorporating RJF.

5.6.5.4 *Taste*

Taste is the sensation produced when substances in the mouth reacts chemically with receptors of taste buds. Sensory scores of freshly prepared noodles were assessed and the results revealed that taste of the developed noodles was appreciably high in all the treatments as shown in Table 25. All the treatments had scored higher values, though the highest was scored by T_6 (4.93) and T_5 (4.87). This could be because jackfruit seeds have their own distinct taste and some people prefer nutty taste rather than bland. From the above values it can be inferred that RJF noodles had their own distinct taste. Commercial noodles had higher values than all the treatments (4.96) because it is was bland in taste and can easily accept any added flavours.

5.6.5.5 *Overall acceptability*

Overall acceptability depends on the concentration or amount of different components, nutritients and other hidden attributes and palatability or sensory quality. It comprises of attributes like appearance, colour, texture and taste and identifying which treatment can stands which product can stands best in all these parameters. In the present study, over all acceptability was found to be higher in T_5 (4.78) which had a combination of RF: RJF: RJSF in the ratio of 50:10:40. The next higher value was obtained by T_6 and T_3 with the score of 4.71 and 4.14

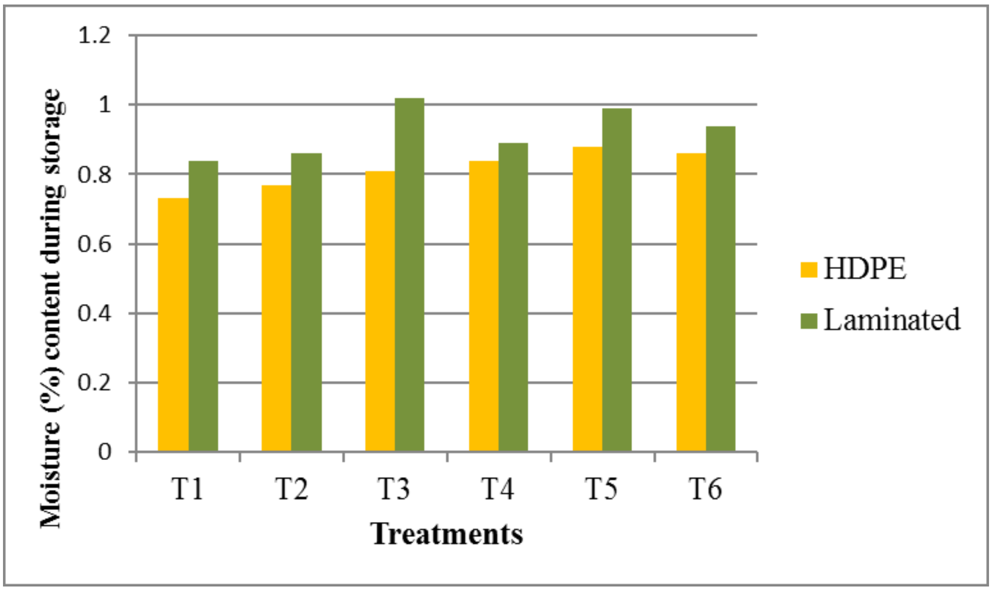


Figure 9. Moisture content of noodles during storage

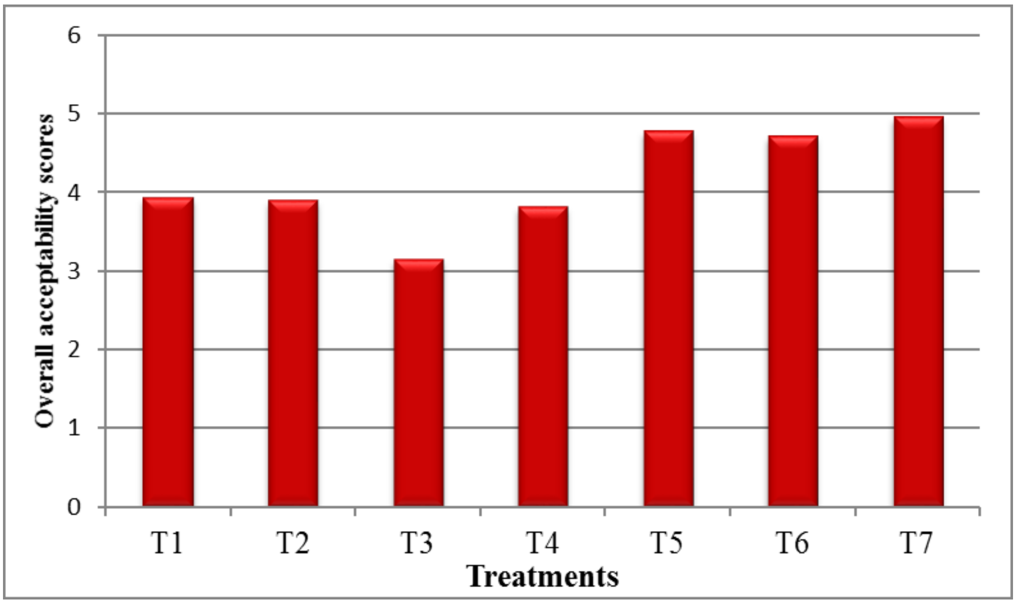


Figure 10. Overall acceptability scores of noodles

respectively and their compositions were 50:20:30 and 50:30:20. All the treatments had lower values than control. This may be due to the presence of additives which helps to retain freshness, colour, texture and taste. However, noodles from composite flour had highly appreciable scores. These finding are in in line with Vijayakumar *et al*. (2009), who reported that millet flour incorporated noodles had highly acceptable criteria.

5.6.6. Economic viability

Extrusion technology potentially offers a low cost means of producing convenience foods with variable functional and quality attributes. The strategies for the development of food products have to be based on affordable price and cost effectiveness. The continuous thrust is to reduce cost, improve quality, and improve convenience so as to attract consumers. This clearly shows that if prices are kept in tune with market prices of fresh produce, food product can attract consumers (Mallya, 2003). Hence the challenges in developing new food products are to keep the cost to a minimum.

In the present investigation jackfruit (Koozha) which is usually regarded as waste in Kerala conditions was procured at very low prices (Rs/ 4.00 -6.00 kg). After including processing charges, the price of product was found to be Rs 108/kg which was three times lesser than the cost of commercial noodles. It is clear from this that, by reduction of refined flour in each combination the cost of the product could be reduced.

5.7 STORAGE STABILITY OF NOODLES

The shelf life of a product begins from the time the food is prepared or manufactured. Its length is dependent on many factors including the types of ingredients, manufacturing process, type of packaging and how the food is stored. Inadequate shelf life will lead to consumer dissatisfaction and complaints, and eventually adversely affect the acceptance and sale of branded products (Robertson, 2003). In this study also shelf stability of developed noodles stored in HDPE and laminated covers were assessed for successive three months. The products were analysed for changes in sensory, moisture and microbial parameters at intervals of one month.

5.7.1 Sensory stability of stored noodles

Sensory evaluation encompasses evaluation by all senses and takes into account several different disciplines but emphasizes the individual perception. Here human judges measure the flavour and other sensory characteristics (Lengard, 2006). In short, sensory evaluation is a very organized holistic approach to product assessment. In the present study, organoleptic assessment was done for three consecutive months to the stored noodles. Each month the product was reconstituted and prepared with uniform recipes and presented to judges.

5.7.1.1 *Appearance of food*

Man generally regards the appearance of food with great interest. The look of a meal can stimulate appetite or cause depression; it can result in joy or total depression. When he or she is eating to enjoy, rather than merely to survive, pains are taken to have good colour and appearance so as to increase temptation and appetite prior to consumption. Many individual factors contribute to the total perception of the appearance of a food product. This total perception is built up from all the visual sensations experienced, when a product is viewed on the shelf, or being prepared or when it is presented on the plate. All three situations are extremely important to the consumer and hence to the processor (Hutchings, 1999)

In the present investigation there was a considerable change in the value of appearance and there were decreasing trends observed in scores during storage though it was acceptable to judges. Any product is universally accepted to be in the best form while fresh.

5.7.1.2 *Colour of stored noodles*

Colour is one of the important parameters used by the consumers to evaluate visual quality and is useful for better marketability of noodles (Asenstorfer *et al.*, 2010). Colour analysis was done and measured throughout storage as it provides vital information to food manufactures on the stability and strength of colour (Hatcher *et al*. 2010). In this study there was change in colour of noodles during storage periods and the colour scores were found to decrease after each month in all six developed treatments. However it did not make the product unappealing.

5.7.1.3 *Texture of stored noodles*

Texture is important in determining the eating quality of foods and can have a strong influence on food intake and nutrition. Perceived texture is closely related to the structure and composition of the food, and both microscopic and macroscopic levels of structure can influence texture. A complete description of food texture can only be achieved using sensory methods (Kilcast and Lewis, 1990). In the present analysis no considerable difference was observed regarding texture. It was observed that there was significant change in the score of texture during the storage period and rightly pointed out that though the fresh texture was not present, it was still acceptable and marketable.

5.7.1.4 *Taste of stored noodles*

During the storage period scores for taste of noodles also decreased with time. Significant difference and decreasing trend were observed, but it was not declared unacceptable by the panel.

5.7.1.5 *Overall acceptability*

In the present study, overall acceptability was found to show a decreasing trend with storage. But this also did not give a negative value to the product. On the whole, the sensory studies of developed noodles during the storage period showed a decreasing trend in all parameters but all the treatments were found to be acceptable by the panel. The decrease in values were expected, as a fresh product always differs from a stored product.

5.7.2 Moisture

Measurement of moisture content in food is very important with respect to shelf stability. With the progression of storage period, the moisture content increased from its initial value. Initially all the treatments had almost similar values. The values were 6.40, 6.45, 6.41, 6.47, and 6.45 for T_1, T_2, T_3, T_4, T_5 and T_6 treatments respectively. After the three months of storage the moisture content increased in varying levels; T_1 (7.13, 7.24), T_2 (7.22, 7.31) T_3 (7.22, 7.43) T_4 (7.24, 7.29), T_5 (7.35, 7.46) and T_6 (7.31, 7.39) in HDPE and laminated covers respectively. This is due to the varying composition of flour in different treatment and the moisture adsorption rate of packages.

This is in line with the findings of Wani *et al*. (2011) who reported an increase in moisture content in roasted wheat flour and cauliflower noodles from 9.55 to 10.92 per cent in 3rd month. They further stated that this might have resulted from the differences in the level of water added to dough containing various levels of cauliflower leaf powder before mixing. Similar findings were reported by Eyidemir and Hayta (2009), in noodles supplemented with apricot kernel flour.

Studies further revealed that both the packaging materials did not show much increase in the moisture content however there was lesser increase in HDPE packaging than laminated covers. This might be due to high water vapour transmission rate of laminated covers. According to Derek (2009), as the moisture content in food increased there was more chance for spoilage by microorganism.

5.7.2 Microbial profile of stored noodles

Simpson (2006) suggested processed foods and other food materials provide ample scope for contamination with spoilage organisms, thus necessitating microbial quality assessment as an integral part of processing. The microbiological safety of food is achieved as much as possible by ensuring the absence of pathogenic microorganisms and preventing their multiplication by all possible means (Beckers, 1988). Food products that have been subjected to adequate heat- treatments during processing are free of vegetative pathogens.

In the present investigation it was evident that there was no bacterial and fungal growth observed till 1st month. While in 2nd and 3rd month fungal growth was seen in T_2 treatments (1.5 x10^2 and 3.0 x10^2 cfu respectively. The reason may be due to mishandling and contamination during processing. No other treatments showed microbial and fungal growth during period of study, emphasizing that, developed product are shelf stable for three months. No coliforms were detected during storage period in all the treatments.

In a study on plantain flour noodles Ojure and Quadri (2012), reported that total plate count, fungi count, coliform count and staphylococcal were not detected.

5.8 SELECTION OF THE BEST COMBINATION

In the present study T_5 and T_6 was selected as best combination comprising of RF: RJBF: RJSF in the ratio of 50:10:40 and 50:20:30 respectively. Formulations of such type of functional foods can impart positive results against many diseases like cancer, cardiovascular diseases, obesity, heart problems etc. which are prevalent worldwide. Noodles of this kind can be a good functional food which can be processed, utilizing the under exploited jackfruit.

Wani *et al*., (2011) concluded that incorporation of cauliflower leaf powder in noodles up to 10 per cent along with roasted wheat flour not only improved the texture, taste and overall acceptability but also improved the nutritive value of these products without adding much to the cost of the product and cauliflower leaves, which were generally thrown away could be utilized in a better way thus reducing wastage.

Yadav and Gupta (2015) reported that noodles incorporated with 10% apple pomace powder were the most acceptable product both in terms of palatability and nutritional composition. In another study Kulkarni *et al*. (2012) standardised combinations of wheat and malted ragi flour noodles (90:10, 80:20, 70:30, 60:40 and 50:50) and found that among all the formulations tried, the noodle samples prepared from 70:30 flour combination had the same sensory score as that of control and higher values for protein, fibre and minerals (i.e. calcium, iron and phosphorous).

Quality analysis of the product with respect to sensory parameters, nutrient composition, shelf life and cost indicates the scope of jackfruit noodles emerging as the novel yet ethnic food product of Kerala, accepted the world over.

SUMMARY

6. SUMMARY

The study, entitled "Development of an extruded product from raw jackfruit" was carried out with the objective to develop an extruded product Viz. noodles from raw jackfruit (cv *koozha*) and ascertain its cooking, physical, chemical, nutritional, sensory and shelf life qualities. The study comprised of collection of jackfruit, processing of flour, quality analysis of flours, formulation of composite flour, extrusion of noodles, standardization of cooking procedures, quality analysis, and storage stability of noodles and selection of the best treatment. The major findings of the study are summarized below.

Raw mature jackfruits were collected from the trees grown in the Instructional farm, College of Agriculture, Vellayani and also from the adjacent home yards. The fruits were washed and bulbs and seeds were separated. The yield of edible portion was calculated. The edible portion ranged from 45.98 to 58.15 per cent and 15.03 to 21.03 on wet and dry weight basis respectively. The separated bulbs and seeds were sliced into various dimensions. The dimension of bulb slices of 2.5 x 1 cm and 1.5 x 1 cm sized slices for seed were selected as the optimum dimension for drying, by analysing the OVQ scores. In order to control enzymatic activities and to prevent browning of slices, the bulb slices were blanched for 1 min and the seeds were boiled for 20 minutes. The bulb slices were then immersed with 0.2% KMS.

Quality of bulb and seed flours were analysed with respect to physical chemical, nutritional and shelf life. Bulb flour had higher bulk density (0.96g/cm^3) compared to seed flour (0.92g/cm^3). Crude fibre was higher (4.03g) in bulb flour than seed flour (3.13g). Moisture analysis revealed that seed flour had higher value (7.97 per cent) than bulb flour (7.23 per cent). Carbohydrate content was found to be higher (81.46 g) in seed flour than bulb flour (74.13 g). Significant difference in protein content could be observed in seed flour (10.48g) and bulb flour (1.53g). Seed flour had higher values for energy (353.87 kcal /100g) than bulb flour (329 kcal /100g).

In case of minerals too, seed flour had shown higher values than bulb flour. Potassium content was higher in seed flour (1478.37 mg) than bulb flour (328.11mg/100 on dry weight basis). Magnesium was also found to be higher in seed flour (338.04 mg) than bulb flour (0.13 mg). Sodium (60.63 mg) and calcium (308.56 mg) was found to be higher in seed flour compared to bulb flour which had 35.06 mg of sodium and 30 mg of calcium respectively.

Both types of flour were stored in HDPE and laminated pouches up to three months. Moisture evaluation showed that among the two packaging materials HDPE covers had shown lesser increase of moisture content during storage. There was no insect infestation in the stored flour irrespective of type of packaging material, during the three months of storage period. Microbial evaluation revealed growth of bacteria and fungi was observed in the second and third months in both type of flours and their prevalence was higher in seed flour, though it was detected to be in negligible levels.

Three hundred grams of composite flour comprising of bulb flour (RJBF), seed flour (RJSF) and refined flour mixed in various combinations were prepared for extrusion. Extrusion of noodles was carried out in the Brabender single screw food extruder after setting the optimum parameters.

The developed noodles were further taken for detailed investigation with respect to quality aspects like cooking, physical chemical, nutritional, sensory and shelf life quality to determine the best combination. The developed noodles were compared with the commercial noodles which were taken as control.

Cooking quality analysis showed that cooking loss for T_4 was the least (9.13 per cent) and water absorption capacity was higher in T_4 (140.62 %). On analysing the cooking time, it was seen that T_6 took the least time (8.26 min.) for cooking but it was higher than control (7.16).

Analysing the extrusion behaviour it was found that with respect to residence time, T_6 took minimum time for extrusion (30. 50 min). As for rating of uniformity of strands it was seen that treatment T_3 obtained the highest score

(4.89), and for appearance of wet noodles T_5 got the highest score. Firmness was found to be higher in T_3 (4.50) which was on par with T_6 (4.48). The score for shape of developed noodles was highest for T_6 (4.68) and the lowest score was obtained by T_2 (3.86). In case of tensile strength the highest score was obtained by T_4 (4.65) and it was seen to be on par with T_3 (4.58) and T_6 (4.56) respectively. Packaging quality scores revealed that there was no significant difference among the treatments. Bulk density was found to be higher in T_3 (0.91) and lower in control (0.68). No significant difference was observed among treatments with respect to true density. Swelling index of developed noodles was highest for T_4 with a score 1.46 and all the treatments were seen to have higher values than control (1.00).

Yield ratio of different treatments ranged from 0.86 – 0.94. Results further revealed that T_6 having RF: RJBF: RJSF in the ratio of 50:20: 30 had the highest value (0.97). Colour analysis highlighted that commercially available noodles had whiter colour than the developed jackfruit flour incorporated noodles.

The analysis of chemical composition revealed that moisture content of developed noodles ranged from 6.40 to 6.45 per cent. Moisture content of all treatments were found to be higher than control (5.79 per cent). Fibre content of the treatments ranged from 5.03 to 5.42g. The proximate composition of the developed noodles showed that energy value of T_5 (380 kcal) was higher and it was higher than control (372 kcal). The maximum carbohydrate content was noted for T_5 (70.91g). Protein content was found to be higher for T_5 (13.49). T_5 revealed higher values for total minerals where as it was lowest in T_4. The nutrient studies further revealed that energy, carbohydrate, protein and total minerals were notably high in T_5.

For sensory investigation the developed noodles and control were reconstituted and cooked uniformly and evaluated by a panel comprising of 10 members using a 5- point score card. Results revealed that all the sensory scores for T_5 were higher than the other treatments. Cost analysis of the developed product was analysed and cost of 1400g of noodles was found to be Rs.108.00/ which was three times lower than the cost of control.

Shelf life studies for 3 months were conducted for the developed noodles. The noodles were packed in HDPE and laminated pouches and stored in room temperature and each month the product was analysed for its sensory quality, chemical changes and also microbial count. The products were declared as acceptable by the panel.

Moisture analysis during storage revealed that products packed in HDPE covers had lesser increase in moisture content in all the treatments. During the three month storage period, no bacterial colonies were found to appear in the developed products. Even though fungi were detected, it was present only in negligible levels within the permissible limit. No pathogenic organisms could be detected in the treatments.

For selecting the best combination, 9 parameters namely, appearance, uniformity of strands, overall acceptability, less cooking time, fibre, calorie, protein, and safety from microbial attack were considered to select the best combination. Based on factors like appearance, overall acceptability, colour, high protein, and safety from microbial attack T_5 was found to get the highest rating. With respect to less cooking time, T_6 got the 1^{st} position and 2^{nd} position in appearance, uniformity of strands, colour, overall acceptability and protein content. So treatment $T_6$and T_5 was selected as best combination with RF: RJBF: RJSF in the ratio of 50:10:40 and 50:20:30 respectively.

On the whole, the study concluded that the developed products were rated high with respect to organoleptic, nutritional, chemical composition and shelf stability. However the standardised products can be further scaled up for commercialization and marketing. The study proves that noodles from the ethnic raw jackfruit will be a product of demand amongst the health conscious population.

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Appendices

Appendix I

Scorecard for physical characteristics of the extruded product

Product: Tested by:

Date : Age :

1. Firmness

☐ ☐ ☐ ☐ ☐

5 4 3 2 1

Very firm Not at all firm

2. Shape

☐ ☐ ☐ ☐ ☐

5 4 3 2

Uniform stick Ununiform stick

3. Uniformity of strand

☐ ☐ ☐ ☐ ☐

5 4 3 2 1

Round strand Uneven strands

4. Tensile strength

☐ ☐ ☐ ☐ ☐

5 4 3 2 1

Withstand weight May not withstand weight

5. Packaging quality

☐ ☐ ☐ ☐ ☐

5 4 3 2 1

Highly suitable Not at all suitable

APPENDIX- 2

Scorecard for organoleptic qualities of the extruded food

Product: Date:

Tested by: Age:

Particulars	**Criteria**	**Scores**	**1**	**2**	**3**	**4**	**5**
Appearance	Excellent Good Satisfactory Mediocre Poor	1 2 3 4 5					
Colour	Cream Yellowish cream Brownish cream Light brown Dark brown	1 2 3 4 5					
Texture	Soft Soft but slightly hard Moderately hard Very hard Very soft and soggy	1 2 3 4 5					
Taste	Excellent Good Satisfactory Mediocre Poor	1 2 3 4 5					
Over all acceptability	Excellent Good Satisfactory Mediocre Poor	1 2 3 4 5					

Any comments:

Sign:

APPENDIX – 3

Overall Visual quality Score Card

Product: **Date:**

Tested by: **Age:**

Criteria	Score (√)
Excellent and fresh appearance	9
Good	7
Fair (Limit to marketability)	5
Fair useable not saleable	3
Unusable	1

Sign:

Abstract

DEVELOPMENT OF AN EXTRUDED PRODUCT FROM RAW JACKFRUIT

by

VEENA KUMARI

(2013-16-105)

Abstract of the thesis

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN HOME SCIENCE

(Food Science and Nutrition)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF HOME SCIENCE

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2015

ABSTRACT

The study, entitled "Development of an extruded product from raw jackfruit was carried out at the Department of Home Science, College of Agriculture, Vellayani, during the period 2013-15. The main objective of the study was to develop an extruded product *viz.* noodles from raw jackfruit and ascertain its physical, chemical, nutritional, cooking and shelflife qualities.

The preliminary processing methods for development of the product were standardised. Thus, dimensions of bulbs and seeds, blanching and boiling time and immersion in various pre-treatment media for different durations of time were identified. Raw jackfruit bulbs and seeds were processed into flour and their quality was evaluated.

Analysis of nutritional and chemical quality revealed that seed flour had higher levels of nutrients than bulb flour; energy (353 kcal), protein (10.48g), carbohydrate (81.46 g), magnesium (338.04 mg), calcium (308.56 mg), sodium (60.63 mg) and potassium (1478.37 mg). The nutrient composition of bulb flour was analysed for energy (329 kcal), carbohydrate (74.12g), protein (1.53 g), calcium (30 mg), sodium (35.06 mg), magnesium (0.13 mg) and potassium (328.11 mg) in hundred grams (dry weight basis). Shelf life quality revealed that bulb flour is more stable with respect to moisture, insect and microbial infestation.

Six treatments comprising of different combinations and proportions of refined flour, jackfruit bulb and seed flour were tried out for processing of noodles. These composite flour combinations formed the base material for noodles. Noodles were extruded with the Barbender single screw extruder at CTCRI Sreekaryam, Thiruvananthapuram.

The physical characteristics ascertained for the products were- colour, bulk density, true density, swelling index. Extrusion behaviour was evaluated with respect to three parameters namely residence time, appearance and uniformity of strands. Whiteness index (an indicator of colour) ranged from 66.20 to 85.36. Treatment T_3 (5:3:2) had revealed higher bulk density (0.91g/cm^3) while treatment T_6 (5:2:3) showed the least value (0.78g/cm^3). The lowest value for swelling index (1.05) was obtained for the treatment T_5 (5:1:4) while T_4 (5:4:1) was seen to have the highest value for swelling index (1.46). No significant difference for true density was observed among the treatments.

Cooking characteristics analysed were cooking time, cooking loss, cooked weight and water absorption. When T_6 recorded lowest time for cooking (8.26 min), T_4 took the highest time (9.36 min). Cooking loss ranged from 9.13 to 15.37%. T_4 was observed to have the highest cooked weight (24.62g) and T_7

(commercial noodles) had the lowest (19.87g). There was variation with respect to nutrients in all treatments. Among the developed noodles calorie (380 kcal), carbohydrate (70.91) and protein (13.49) content was highest in T_5.

On organoleptic analysis, T_5 obtained the highest values with respect to appearance (4.59), colour (4.77), texture (4.89), and taste (4.87) and over all acceptability (4.78). These values were seen to be lower than the values of control but this difference was not statistically significant.

When the products were packed and kept for storage for 3 months in HDPE and laminated pouches, it was observed that moisture, microbial contamination, sensory qualities did not show significant change irrespective of packaging material. Physical characteristics, shelf-life parameters, nutrient and chemical profile, were seen to be on par among the treatments. However T_5 and T_6 can be recommended with respect to better sensory qualities. (Refined flour, jackfruit bulb flour and jackfruit seed flour in the ratio of 5: 1: 4 and 5: 2: 3).

From the above study, it can be concluded that noodles with high consumer acceptability can be developed from this underexploited fruit, which has good nutritional, organoleptic and shelf life qualities.