Research Biotica 2021, 3(2):94-106 DOI: 10.54083/ResBio/3.2.2021.94-106

Review Article ***Article ID:*** RB0032

Technical Facts on the Current Scenario and Future Potential of Jackfruit Processing

G. S. Chikkanna

ICAR- Krishi Viyan Kendra, College of Horticulture Campus, Tamaka, Kolar, Karnataka (560 103), India

Open Access

Corresponding Author

G. S. Chikkanna

e-mail: chiksiari@gmail.com

Keywords

Artocarpus heterophyllus Lam, Carpels, Jackaline, Jackfruit, Seeds

How to cite this article?

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

Abstract

Jackfruit (*Artocarpus heterophyllus* Lam) is one of the important underutilized fruit belonging to the family Moraceae and is the largest edible fruit. Jackfruit is often called as "poor man's bread fruit" because it is cheaply available in large quantities during the season. Jackfruit seeds are normally discarded or steamed and eaten as a snack or used in some local dishes; seed flour is used in some biscuit factories in various bakery products, etc. The use of jackfruit bulbs, seeds, and its other parts has also been reported since ancient times for their therapeutic qualities. The health benefits of jackfruit have been attributed to its wide range of physicochemical applications. It contains high levels of carbohydrates, protein, starch, calcium, vitamins, free sugar (sucrose), fatty acids, ellagic acid, and amino acids like arginine, cystine, histidine, leucine, lysine, methionine, theanine, and tryptophan. The jackfruit has diverse medicinal uses especially antioxidant, anti-inflammatory, antimicrobial, anticancer, and antifungal activity. This chapter describes an overview of the functional, medicinal, nutritional, and health aspects of jackfruit.

1. Introduction

India is the second biggest producer of the fruit in the world and is considered as the motherland of jackfruit. In India, it has wide distribution in Assam, Tripura, Bihar, Uttar Pradesh, the foothills of the Himalayas and South Indian States of Kerala, Tamil Nadu and Karnataka. Jackfruit plays a significant role in Indian agriculture and culture. It was cultivating in India 3000-6000 years ago.

Jackfruit is widely grown as an important tree in Kerala's homesteads and also as a shade crop in coffee plantations. It is popularly known as 'poor man's fruit' n the eastern and southern parts of India. The tender fruits of the tree are used as vegetables and the ripe ones as table fruits. The traditional varieties bear fruits once in a year. Usually, the flowering starts from mid-November and extends till mid-February, depending on the location and the variety. The tender fruits come to market from March onwards and continue till August. The fruits begin to ripe in the month of June. However, the late varieties may ripen in October. Fresh and tender fruits are usually not available from November onwards.

Jackfruit (*Artocarpus heterophyllus* Lam) is one of the important underutilized fruit belonging to the family Moraceae and is the largest edible fruit (Alagiapillai *et al.,* 1996). Jackfruit is often called as "poor man's bread fruit" because it is cheaply available in large quantities during the season.

It is grown throughout the year in Karnataka and the total area planted is calculated as 6,777 ha, production is 2,31,568 tons, and value is Rs. 6,951 (in lakh) per annum (NHB 2019). In south India, the jack fruit is a popular fruit ranking next to mango and banana in total annual production. There are more than 1,00,000 trees in backyards and grown for providing shade in beetle nut, coffee, pepper and cardamom plantations (Anon, 2003).

Commercial cultiv3ation of jackfruit is still at a primitive stage in India, primarily because of the difficulty in procuring elite planting materials. Jack is easily propagated through seeds. The seedlings take 8-10 years to bear fruits. Due to the highly cross pollinated nature of the crop, vegetative propagation is essential in order to get true to type plants.

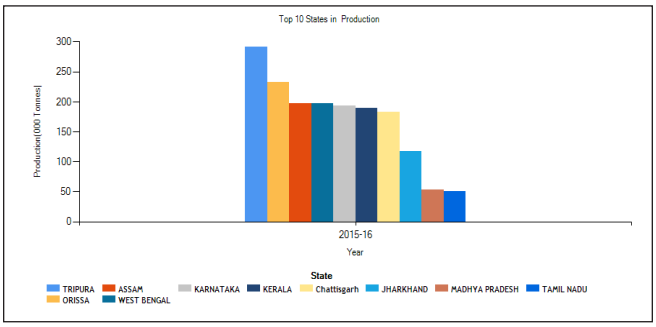

Figure 1: Jackfruit production

Article History

RECEIVED on 28th February 2021 RECEIVED in revised form 29th April 2021 ACCEPTED in final form 30th April 2021

In India, the total area under jackfruit cultivation is approximately 1,02,552 hectares, of which, an estimated 1,00,000 trees are grown in back yards and as intercrop in other commercial crops (betel nut, coffee, pepper and cardamom plantations) in south India. In India, the major area under jackfruit is in Kerala state and it was regarded as heavenly fruit in the ancient periods. It is grown in an area of 97,536 ha with annual production of 348 million fruits and productivity of 3,568 fruits per ha. The value of jackfruit in Karnataka has been calculated to Rs. 12,718 lakhs (Anonymous, 2018).

Jackfruit contains vitamin A, vitamin C, thiamine riboflavin, calcium, potassium, iron, sodium, zinc, and niacin among many other nutrients. Jackfruit has a low caloric content where 100 g of jackfruit only contains 94 calories. The fruit is a rich source of potassium with 303 mg/ 100 g of Jackfruit (Mukprasirt and Sajjaanantakul, 2004). Studies show that food rich in potassium helps to lower blood pressure. Jackfruit is also a good source of vitamin C which is an antioxidant that protects the body against free radicals, strengthens the immune system and keeps the gums healthy (Umesh *et al.,* 2010). Pureed jackfruit can be processed into baby food, juice, jam, jelly, and base for cordials (Roy and Joshi, 1995). Furthermore, it can be used to make candies, fruit-rolls, marmalades and ice cream. Jackfruit is also reach in pectin, thus making it favourable for processing Jam.

Among the fruit crops, jack produces abundant fruits every year in the farm lands and in secondary forest regions without application of additional care and farming practices. Therefore, by default, they are known to be organic produces. Jackfruit is a good source of different vitamins and minerals besides it also provides carbohydrates and develops flesh and strength in the body. The ripe jackfruit is considered to be delicious and nutritious. It is sweet and has an exotic flavour.

Jack fruit, has got immense potential for value addition. A wide variety of items can be prepared from jack fruit right from immature stage to well ripened stage. Each item has its own qualities in terms of taste, preference, shelf-life *etc*. Because of its heaviness and large size, transportation and packaging are huge impediments for the successful marketing of jackfruit. Therefore value added products have more relevance for commercial utility rather than the whole fruit. Entrepreneurship based on latest developments in jackfruit processing has the potential to contribute to a range of social and economic developments such as employment generation, income generation, poverty reduction and improvements in nutrition, health and overall food security in the national economy. The growth of this industry will bring immense benefits to the economy, reducing post-harvest losses, creating employment and raising life-standards of a large number of people across the state, especially those in rural areas or production catchments.

In recent years interest in the more diversified use of Jackfruit for value addition is gaining ground. As it offers exciting possibilities for adding new products to the food processing industry, and contributes towards enhancing farm income of rural people. The fruit will be available in large quantities during the production season and can be used effectively into many values added products (Munishammanna *et al.,* 2007).

Jack fruit was explored for product diversification and by product recovery. Fruits that are plenty during the season are hardly processed, accounting to huge losses of fruit wealth (Ukkuru and Pandey, 2006).

2. Fractions of Jackfruit and Their Processing

The fruit constitutes three parts *viz*. bulbs (34), seeds (18) and rind (48) % respectively. Generally sweet bulbs are consumed by the people. The remaining parts such as seeds and rind are usually wasted. Jackfruit seed encased in the soft coloured pulp is edible and constitute about 5.1-12 % of the fruit. It is eaten after roasting or boiling (Anon, 1975).

In the processing of the edible portion of Jackfruit into preserved products, the skins, peels and core are left as a waste material. These wastes constitute about 45 % of the total fruit weight and found to be a fairly good source of pectin (Jain and Lal, 2017).

Dehydration of Jackfruit was studied in Basti, Uttar Pradesh by Teaotia and Awasthi (1968) to determine certain physico-chemical properties in relation to maturity and season for dehydration of bulbs. The investigators concluded that the Jackfruit bulbs could be dehydrated from June to July 21st each year on commercial scale. A study on the freezing of jack fruit, mango and sapota was conducted.

The results revealed that freezing preserves the fresh colour, flavor and texture of fruits. Optimum conditions were worked out for freezing of Jackfruit, Mango and Sapota segments. During storage of the frozen product at -18 ºC for three months, there was practically no loss of colour and retention of texture was much better as compared to canned product (Prakash *et al.,* 1996). Edible bulbs of ripe Jackfruit are consumed for their taste and pleasant aroma. The edible portion was about 30% by weight of the whole fruit. About 50% of the fruit composed of rind and unfertilized floral parts, which are also rich in Jackfruit flavour, are usually discarded as waste because they are fibrous. A process for the preparation of clarified juice was developed which involves treatment of Jackfruit waste with a pectic enzyme at 0.3% concentration (v/w), incubation for 2 h at 40 °C and subsequent filtration, giving about 60% yield of clarified juice of 23 °Brix and 0.15-0.20 % acidity.

Sensory evaluation of ready-to-serve beverages was conducted and it was concluded that preparation of beverages from Jackfruit waste, brings the effective % utilization of the whole Jackfruit to > 80% (John and Narasimhan, 1993). Storage stability of canned Jackfruit juice at tropical temperature was investigated. It was estimated that properly processed

Jackfruit juice packed in plain tinplate cans could be kept well for > 17 months at storage temperatures < 30 °C and in the absence of corrosion accelerators such as nitrates (Seow and Shanmugam, 1993).

Potential development of a fruit leather product from undeveloped perianth or unfertilized floral parts of Jackfruitwas investigated, since the edible parts are rich in flavour. The unfertilized floral fruit parts were cooked in boiling water, pureed and added to a mixture containing 15% glucose syrup, 25% sugar, 5% water, 500 mug g^{-1} sodium metabisulphite and 200 mug g^{-1} ascorbic acids. The mixture was dried at 50 °C for 24 h at an air velocity of 1.6 m s^{-1}. Analysis of the leather revealed that water activity and moisture content were low, suggesting that it can be eaten as an intermediate moisture food.

Sensory analysis revealed that the new fruit leather was acceptable among the panel members; however, the market survey showed that the respondents more readily accepted the leather. Panel members were especially ethnic Indians (Che-man and Ku-K-Sin, 1997). Storage stability of Jackfruitbar in different packaging material was studied.

Jackfruit bars prepared as per FPO standard were packed in butter paper, polypropylene (PP) and metallized polyester polyethylene laminate (MPP) and stored at room temperature to study their storage behavior. During the storage, there was reduction in vitamin C, β carotene and total sugar contents of the samples irrespective of the packaging materials.

Organoleptic score of the bar sample in MPP was found to be higher followed by samples packed in PP and butter paper (Krishnaveni *et al.,* 1999). Jackfruit grows in India and Bangladesh, contributing to the food supply when staple food grains are in short supply. Jackfruit of 7-8, 10-12 and 14-16 week maturity were examined. Starch and total dietary fibre (soluble and insoluble) levels in Jackfruit were relatively high. Starch contents increased with maturity; total free sugar contents in perianth being higher in soft than firm variety and increases gradually with maturity (Rahman *et al.,* 1999).

According to a survey conducted in Malaysia the Jackfruit have been reported to be a relatively safe fruit (Punan *et al.,* 2000). Development of different value added products like Jackfruit finger chips, Jackfruit candy, Jackfruit halwa, Jackfruit flour, Jackfruit leather, Jackfruit papad, Jackfruit pickle, ready-to-serve (RTS) beverages from Jackfruit was carried out (Munishammanna *et al.,* 2007). Maia *et al.,* (2004) studied the aroma compounds from the hard and soft varieties of Amazonian Jackfruit. Isopentyl isovalerate (28.4%) and butyl isovalerate (25.6%) were the predominant components identified in the aroma concentrate from the hard variety. However, the predominant compound found in the aroma concentrate from soft Jackfruit was isopentyl isovalerate, followed by butyl acetate, ethyl isovalerate, butyl isovalerate and 2-methylbutyl acetate, which were present in proportions of 18.3, 16.5, 14.4, 12.9 and 12.0% respectively.

Jackfruit seed powders were tested as a substrate for the production of pigments by *Monascus purpureus* grown using solid-state fermentation (SSF). The fungus was grown at 30 °C on powders containing 50% initial moisture, and using an inoculation density of 9 × 104 spores per g DM. substrate. The yield of pigment after 7 days of incubation was 25 OD units per g DM fermented substrate. Use of these pigments in foods has a great potential (Sumathy *et al.,* 2007).

Nutrient composition of Jackfruit seeds results of the study indicated that the protein content in the jack fruit bean was 7.81-12.46%. Probably the protein content varies from seed to seed and it may also depend on the ripening stage of the seed (Anon, 1970). Begum *et al.*, (1989a) studied the nutritive value of the protein of Jackfruit (*Artocarpus integrifolia*) seed meal and effect of supplementing with methionine and tryptophan or milk proteins. Jackfruit seed meal was analyzed for chemical/ amino acid composition and found to be good source of protein (13.6 gm %) and iron (11.5 mg % / 100 g). The essential amino acid composition showed that seed meal protein was deficient in total S-amino acids (1.77 g/ 16 g N) and tryptophan (0.6 g/ 16 g N). They also reported the effect of supplementing Jackfruit seed meal with limiting amino acids (methionine and tryptophan) or with milk proteins on the proteins efficiency ratio of Jackfruit seed protein was determined in albino rats.

Supplementation with methionine or with methionine and tryptophan brought about significant improvement in the nutritive value raising the protein energy ratio (PER) from 0.43 to 0.73. Supplementation with milk proteins at 1:1 ratio, in a 10% protein diet also showed significant improvement in the protein quality. The protein energy ratio of Jackfruit seed meal was 1.65.

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

Kumar *et al.,* (1998) reported that the proximate composition of the Jackfruit seeds of 'Kathari' and 'Bharat' varieties of jack fruit suggests that they are good sources of carbohydrates (26.83-28.01 % protein (6.25-6.75 %) and minerals (1.16-1.27 %). Fractionation of nitrogen revealed that non-protein nitrogen forms 5.6% and 7.0% the total nitrogen in 'Kathari' and 'Bharat Baramasi' seeds, respectively. Globulin – nitrogen forms the major portion of total nitrogen in both the varieties. Jackfruit is available in plenty in various parts of India. After

consumption of the fruit, the seeds are usually wasted. The seeds are highly nutritious and provide around 135 Kcal/ 100 gm. It is a rich source of complex carbohydrates, dietary fiber, vitamins and minerals like calcium, zinc and phosphorous. They contain lignin, isoflavones, saponins, that are called phytonutrients and their health benefits are wide ranging from anticancer to antihypertensive, anti ageing, antioxidant, anti ulcer *etc*. Jack fruit seed powder has the ability to relieve discomfort due to indigestion (Helen *et al.,* 2006). The moisture content of the jack fruit seed was found to be 64.5%, carbohydrates - 25.8 g, energy - 135 Kcal, proteins - 6.6 g, total minerals - 1.2 g, iron - 1.5 mg, calcium - 50 mg, phosphorus - 97 mg, fibre - 1.5 mg (per 100 g of edible portion) (Praveenasri *et al.,* 2006).

Sharon and Usha (2006) reported that the bread fruit [*Artocarpus altilis* (park) Fosberg] flour contained 65.7% starch, 4.5% protein, 4.3% crude fibre, and 82.2 calcium, 67.3 phosphorous, and 5.3 iron (mg/ 100 g). No significant reduction was observed in the above nutrients during storage except for crude fibre. The moisture content increased significantly from 7.3 to 8.9%. A non significant increase in the total soluble sugar from 5.5 to 6.2% during storage was observed. A method to extract an acceptable jack fruit seed flour form the seeds was developed by Munishammanna *et al.*, (2007).

To extract jack fruit seed flour, jack fruit seeds were boiled for 15-20 minutes; water was decanted and cooled in order to remove the seeds and outer skin coat. Seeds were cut into 3-4 pieces dried in sunlight or hot air oven (400 °C) for 48 hours. Dried seeds were ground into flour sieved and stored. Tulyathan *et al.* (2002) took three kilograms of seeds which were treated with 5% NaOH for 2 min to remove the thin brown spermoderm that covered the fleshy white cotyledons to produce jack fruit seed flour. The seeds were then sliced into thin chips and tray dried at 500–600 °C and the chips were ground in a pin mil FFC - 23 to 70 mesh flours and packed in plastic pouches, stored in refrigerator.

In South India, jackfruit is used both as a fruit and vegetable. The crop is available only for four to five months. Is there a simple method to make raw (unripe) jackfruit available as vegetable for off-season? There are many ways like dehydration, freezing *etc*. But the easiest methos is brining. That is dipping it in salt solution. Whenever required, the brined arils (carpels) are taken out, rinsed and used. During heavy monsoon, villagers don't get enough fresh vegetables. On such occasions, this brined raw jackfruit comes in bearing world's largest fruit also known as poor man's fruit; Jackfruit is native to India, originated in the Western Ghats of India. It was distributed to West Indies, Malaya and African countries. It is a fairly good source of vitamins and minerals. Ripe fruit flakes (bulb) contain carbohydrates (16-20%), total soluble solids (25-29 °brix), carotene (500-580 IU), thiamin (30 g), pectin (1.5-6%) and minerals like iron (500 mg), phosphorus (30-40 mg) and calcium (20-30 mg)/ 100 g of edible portion.

Jackfruit trees are cross pollinated and are mostly propagated by seed in earlier days. Seedling trees exhibit a wide range of variation in morpho-agronomic characteristics. Variation exists in the fruits density, size and the shape of spines on the rind. Fruits also show variation in sweetness, flavor and taste. Variation exists between and among populations and this can be selected for clonal propagation. Therefore, there is ample scope to exploit the genetic diversity and to select superior clones from existing jackfruit trees.

Several jackfruit producing countries have attempted sporadically to collect germplasm. The collection, characterization, documentation and evaluation of accessions (or provenances) from the region of origin and centre of diversity are far from complete. There is an urgent need to establish targeted collections from the Indian sub-continent and also from Southeast Asia. A major effort has been made to initiate selection by carrying out standard characterization and identification of trees with desirable characteristics. This was done under the auspices of UTFANET (Underutilized Tropical Fruits in Asia Network) in a participatory mode. Some of the cultivars/ varieties released by different countries along with their distinguishing characters are presented below. Jackfruit is an under exploited crop capable of giving very high yields. Jackfruit is a hardy crop and the tree grows very well even under neglected conditions and in poor and marginal lands. It is grown mainly on homestead farms and produces multiple products for food, feed and industry as well as contributing towards soil management for sustainable development.

It fits well in the 'organic' food and identification of ideal varieties based on agro-ecological zones is the need of the day. Genetic studies and molecular characterization are to be done for exploiting the wide range of variability available in jackfruit and efforts in this direction will help in breeding superior varieties for the benefit of jack growers.

3. Germplasm Collection, Characterization, Conservation and Utilization India

So far, there is no well-defined variety in jackfruit and different types are known differently in different localities. As a result of local survey, some better types have been collected. Since raw Jackfruits have good demand in India as vegetable for culinary purpose, emphasis is also given on fruit characters like thickness of rind and softness of flesh at premature stage of fruit development.

In South India (Kerala, Tamil Nadu and Karnataka), different forms of jackfruit (Varikka, Koozha, Navarikka) are available and the maximum diversity has been reported from Waynad Plateau of Western Ghats of Kerala. The Guinness world record for the biggest jackfruit (34.4 kg) stands in the name of a Hawaiian farmer. However, the jackfruit grown in the orchard of Karunakaran, a farmer in Melmambattu village of Tamil Nadu in India, recorded 81 kg fruit. In Melmambattu

and Maligaipattu villages of Tamil Nadu, the huge Jackfruit trees grown have wide variability with respect to size, taste and bearing habit.

The studies on pollination and hybridization between jackfruit and breadfruit were undertaken at Kallar. Further, the performance of jackfruit varieties under Burliar conditions was studied and results showed that the selections Virudhachalam and Singapore were tall types. The Tamil Nadu Agricultural University (TNAU), Coimbatore (India) has developed two improved varieties, *viz*., Palur-1 and PPI Jack which have shown good performance in the state and further efforts are needed to popularise these varieties.

A jackfruit variety known as Singapore or Ceylon Jack, introduced from Sri Lanka is a popular variety. Certain other varieties named as Velipala, Hybrid Jack, Panruti Selection, Burliar I and Muttam Varikka are also popular in different localities.

Ceylon Jack variety produces fruits from 3rd year of planting and fruit weighs 5-20 kg. In Uttar Pradesh (UP), a small fruited (2-8 kg) jackfruit variety known as Barka and a large fruited variety Kapa are grown. The Kapa variety locally known as Kathal in UP produces fruits as big as 40 kg in weight and the fruit is very sweet in taste on ripening.

The work on collection and conservation of jackfruit started at Indian Institute of Horticultural Research (IIHR), Bangalore (India) during 2000-01 under Underutilized Tropical Fruits in Asia Network (UTFANET) project funded by International Centre for Underutilized Crops (ICUC) for promotion of research on underutilized fruit species. During the same time, Indian Council of Agricultural Research (ICAR) also initiated collection and conservation of jackfruit under the All India Coordinated Research Project (AICRP) as one of the mandate crops. The objectives of these programmes are to survey, collect and characterize jackfruit diversity available in different parts of the country.

4. Characterization using Morphological Characters

4.1 North-Eastern India

In North-Eastern region of India, jackfruit is very popular among the tribals and the crop is grown almost in a semi-wild condition. Soft-flesh varieties predominate the market. A survey was conducted in 1996 in the lower Brahmaputra Valley of Assam (25°30′ N latitude and 89°40′ E longitude). The climate of the zone is humid subtropical with an annual rainfall of 2,789 mm. The cultivated types identified are named as KJF (Kahikuchi jackfruit). Twelve distinct types were identified, with fruit ripening period varying between early June to late July coinciding with rainy season. Significant variations in fruit bearing habit and fruit quality were recorded. Wide variation was noted in number of fruits ranging from 4-60 per tree per season. Viviparous seed germination was observed in certain genotypes.

4.2 Eastern India

a) West Bengal: Identification of superior clones by evaluation and subsequent maintenance/ multiplication of the selected clones by vegetative propagation were initiated at the Bidhan Chandra Krishi Viswavidyalaya, West Bengal (India) in 1991.

Surveys were conducted to identify superior clones possessing one or more of the following characters:

i) regular bearing,

ii) early flowering to use as vegetable in December-January,

iii) bearing more than once a year,

iv) high yield potentiality,

v) higher fruit weight,

vi) acceptable fruit size with good quality to use as table fruit.

b) Bihar and Jharkhand: From the Eastern India, some collections were made and the seedling selections were evaluated at the Regional Station of the ICAR Research Complex for Eastern Region at Ranchi (Jharkhand, India). Superior clones of firm flesh type Khajwa were identified based on their growth habit, fruit yield and quality. Based on the performance of the seedling selections, a budded Khajwa selection (Accession No. 3/2) was identified and is being cultivated.

4.3 South India

Detailed survey was conducted in major jackfruit growing areas of Kerala, Tamil Nadu and Karnataka states and based on tree and fruit characters, 200 different types were selected. The seeds were sown and seedlings were selected based on seedling vigour and planted at the Mannuthy Campus of Kerala Agricultural University at Thrissur, Kerala. The plants have started fruiting and have been characterized.

Based on characterization, the promising types, were selected. In South India, the jackfruit is classified into two general types: Type 1 jackfruit having firm flesh is called Varikka is more important commercially and possesses crispy carpels/ flakes of high quality. On the other hand, Type 2 jackfruits have soft flesh and are called Koozha. They have small fruits whose flesh is fibrous, soft, mushy, but it has very sweet carpels/ flakes. The fruit of the Koozha variety is consumed mainly in the raw stage like preparing pickles or cooking different vegetable dishes. The fruits of the Koozha variety if allowed to ripen, do not taste as good as the Varikka variety because the flesh is soft or soggy. In contrast, the Varikka variety is used both in the raw (unripe) and ripe stages. If used in the unripe stage, it is usually made into curries and deep-fried chips. The Varikka types are preferred for canning in the processing industries. Sreenivasan (1970) described a Varikka type of jackfruit from the seedling progeny of a type from Muttam in Alleppey district Germplasm Collection, Characterization, Conservation and Utilization 27 of Kerala. This type is named as Muttam Varikka with fruits weighing 7.0 kg and flakes 3.6 g. The pulp is crisp, fleshy, nonfibrous, golden yellow and has

very good edible quality. Mathew (1995) described physical characteristics of 29 types jackfruit which exhibited a wide range of variation in edible and non-edible parts. Joseph and Kumaron (1996) studied the fruit set, fruit drop and fruit development in Varikka and Koozha types in jackfruit and did not find any significant difference among them in any of the above characters.

A total of 204 trees belonging to 67 accessions including wild and cultivated types from Kerala, Karnataka and Tamil Nadu are maintained at the National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Thrissur, Kerala. The seedlings generated through seed progenies are maintained in the field along with checks such as Singapore Jack and Muttam Varikka.

Being seedling progenies, trees within the accession vary for fruit characters. Characterization and evaluation for 16 fruit characters in 12 trees have been completed. Results showed that all except one belonged to Varikka type with firm flesh. Trees numbering V-504-1A, IC 96152-1A, IC 9/624-1A and IC-91737-IA were excellent table fruit types. IC 93388-2A was the only Koozha type with soft bulbs used for fruit puddings. IC-99627-I A had very thin flakes, good for chips preparation. OBL 8 was extra early (off-season) with fruit initiation in the month of August. IC-97624-IA though had early fruit ripening (March), but was highly susceptible to fruit borer (*Congethes punctiferalis*). IC 91665-2A and OBL-I (Undachakka) had small round fruits with single fruit weight ranging from 0.75-2.0 kg.

These cultivars exhibiting early fruit maturity were desirable for vegetable purpose. IC 96148-3-A had coppery red flakes which are thick and crisp with good aroma. 28 Jackfruit Improvement in the Asia-Pacific Region - A Status Report From agroforestry point of view, promising lines, IC 97625-2A and IC 91126-IA having very small leaves and IC 91126-IA having pyramidal canopy were identified. Six accessions belonging to different species, namely, *Artocarpus lakoocha*, *A. communis* and *A. hirsuta* were also maintained. Reddy *et al.* (2004) studied physio-chemical characteristics of jackfruit clones from South Karnataka and found diversity in several characters.

Jagadish *et al.,* (2007) analyzed 24 different firm type jackfruit clones from Western Ghats and found variation in total soluble sugars (TSS), acidity, TSS: acid ratio, sugars, starch and carotenoid contents in the bulbs. Jagadish *et al.,* (2007) also found variability in fruit quality among 95 selected accessions from Western Ghats. They evaluated physio-chemical characters of fruits and found significant differences thus indicating wide genetic variability. However, the relative contribution of characters reflected that number of seeds per fruit contributed the maximum divergence followed by TSS: acid ratio, single bulb mass, percentage of edible portion, fruit length and TSS. Diverse types were selected based on desirable characters. Das and Das (2005) also observed wide diversity in jackfruit in homestead gardens in Assam.

At the Indian Institute of Horticultural Research, Bangalore, under UTFANET project, the diversity collected in jackfruit includes most of the common types and special types, viz., the trees bearing heavily and fruit weight ranging from 650 g to 35 kg. Fruits with low latex (gumless jack), firm flakes and colour ranging from creamy white, yellow, orange and coppery red were included in the field gene bank. Flakes with champak and rose scented collections were also found during surveys. Further, selections were made from these accessions for selecting the promising types supported by fruit quality attributes (Anonymous, 2004).

5. Future Prospects and Strategy for Jackfruit Production and Utilization

In view of the increased population growth coupled with limitations on resources, the steady supply of food and adequate nutrition in many developing countries assumes greater significance. Thus, the quality and quantity of food have become an important issue at the global level in view of widespread malnutrition. Carbohydrates, proteins and fat are in general supplied from cereals, pulses and oilseeds, respectively but there are notable vitamin and mineral deficiencies in many regions. In this context, high levels of vitamins and minerals have been recorded in a number of underutilized fruits. Recent commercial interest in several tropical underutilized fruits has resulted in an increased cultivated area in Asia and other regions of the developing world. The export of fruits from Asia alone has been increasing by a little over 10% annually.

Jackfruit is grown mainly on homestead farms and produces multiple products for food, feed, and industry as well as contributing towards soil management for sustainable environments. Jackfruit in Asia is still considered as a minor fruit crop. Unpredictable yield, strong odour of ripe fruit and its large size, long gestation period, limited choice of suitable varieties, crop losses due to disease like bacterial wilt in Malaysia, *etc*. are some of the negative attributes of jackfruit. Above all, commercial scale cultivation is still quite low in most of the countries and improved cultivation practices are not being followed by most of the farmers. Planting materials raised from seedlings show wide range of variation in their performance. Vegetative propagation is not yet widely practised in most of the developing countries of Asia in view of lack of perfected techniques. Due to limited development of downstream products, jackfruit has remained mainly as a minor fresh fruit in domestic markets. Although the importance of jackfruit for these purposes has been well recognized, very little research work has been done on this important fruit species.

In recent decades, a number of scientific and economic interests have emerged to promote and commercialize jackfruit products. The primary reason for this is that the crop is already well-suited to the household and farming systems of small farmers vulnerable to food shortages and nutritional

deficiencies.

Diversification within these systems, through enhanced use of jackfruit could lead to increased production of new products which can be sold to raise income as well as to satisfy the subsistence needs.

To address these issues, suitable approaches need to be adopted by policy makers, researchers, extension workers, food processors and traders to improve the crop. Suggestions have been made in particular for research requirements and for technology transfer to remove the constraints being faced by the farmers and the industry.

Documentation of area, production and productivity needs to be undertaken and effective method of documentation has to be worked out.

6. Genetic Resources of Jackfruit

For the efficient utilization and conservation of jackfruit germplasm, the researchers are showing keen interest in studying genetic diversity of this species. Underutilized crops have been overlooked for improvement by scientists possibly due to lack of knowledge of the crop. In jackfruit, collecting, characterization, documentation and evaluation from the region of origin and centres of diversity have been sporadic and are far from complete. There is an urgent need to undertake targeted collecting from the Indian sub-continent and other jackfruit growing countries of Southeast Asia to assemble the diverse germplasm and use in the varietal improvement. In terms of genetic resources, collecting of wild species will not be justified unless they are evaluated and used for crop improvement. However, pointers can be derived from data recorded on local knowledge and ethnic uses.

The following points need consideration:

• Future collecting and genetic diversity studies should focus on specific desirable characters and the germplasm need to be conserved both in *in situ* and *ex situ* conditions.

• There is a need to develop strategic plans based on the results of research and cooperation between neighbouring countries or regions, for genetic conservation of the jackfruit gene pool, needs to be strengthened.

• Germplasm collecting, characterization (including use of DNA markers as a tool), evaluation, and documentation the genetic diversity needs to be given a greater thrust. Through farmer participatory studies, quality planting materials need to be identified, in particular to meet the marketing needs.

• A comprehensive understanding of genetic diversity and molecular characterization of jackfruit cultivars is needed for formulating appropriate sampling and management strategies.

• A detailed analysis of a large number of genetic markers will provide with useful gene conservation strategies and help in popularizing this species as a commercial crop.

• Jackfruit is thought to be originated in the Western Ghats region of India, and there is a possibility of occurrence of wild forms which need to be collected. The original progenitor of the cutiligens is not precisely known and it is not confirmed whether truly wild material still exists which needs to be explored.

7. Varietal Improvement

The basic understanding of the existing clones is an essential prerequisite for the further improvement in jackfruit. Some trees produce sweet aromatic fruits; others are nearly dry and sour. Better selection and vegetative propagation of clones is practicable and efforts should also be made to extend the fruiting season. Although little work has been done on rootstock and scion compatibility, the evidence so far is that there is a wide variability in scion performance with different rootstocks. At present, selection in jackfruit has not been rigorous. Farmer's selection criteria include high yield, fruit quality, sweetness, early fruiting types and off-season types. However, there are no true cultivars developed as such, but local types have been identified which have been given specific names. Little is known about the breeding of jackfruit. This may be due to it being a long-lived tree and a minor fruit. Any attempt to produce improved jackfruit cultivars needs to be targeted both for commercial production and for their value in home gardens and for small growers, thus adding substantially to the latter's income generation and food requirement.

The following important aspects need consideration for varietal improvement:

• In breeding for improvement of qualitative traits, studies on genetic correlations between traits need to be undertaken in order to decide the parents for the hybridization programme.

• An assessment of the patterns of existing genetic diversity needs to be made. Such a study will help planning for national genetic conservation activities, either in natural ecosystems or on-farm sites, or in well-known, well-described and focused *ex situ* collections.

• Suitable cultivars/ varieties need to be developed to meet the specific needs for fruit and timber production as well as for multipurpose use.

• Information on the mode of inheritance of important characters need to be generated and identification of gene(s) for seedlessness, dwarfness, resistance against fruit fly, fruit-rot and soil salinity need to be initiated on priority.

• The close relatives need to be identified and species relationships needs to be studied so as to throw light on the taxonomy of the genus, *Artocarpus*, which can be made use in the breeding programmes.

8. Package of Practices for Enhanced Production

For homestead gardens and small orchards, land preparation requires technical skills (Coronel, 1983) but for commercial or large scale plantations, land preparation requires much more

attention to attain the desired tilth. Most cultivated material is of seedling origin which often represents relatively inferior genetic material.

There is a need to promote vegetatively propagated material thus improving uniformity and also early bearing. Extension efforts to improve nursery techniques and provision of better planting materials are urgently needed. Region-specific production techniques for jackfruit are not well established as limited research work has been done in this area. Systematic experimentation is needed to develop optimum agronomic packages for jackfruit in different agro-ecological areas. The potential of the crop in different cropping systems has not yet been adequately investigated. The crop can be more widely grown once the combination of crops in agroforestry systems has been established.

Thus, the future research has to focus on the following areas:

• There is a great need for developing of optimum and standard vegetative methods of propagation for the use by small farmers who can develop small businesses through the establishment of nurseries.

• Greater thrust needs to be given for developing reproducible *in vitro* methods of propagation to multiply promising planting materials.

• Systematic studies on the wild species need to be conducted to assess grafting compatibility to identify vigorous and genetically stable rootstocks.

• The production technologies including organic production techniques need to be standardized for better crop management and input use efficiency.

• Suitable strategies need to be developed for integrated pest and disease management (IPDM) using botanicals and biological control agents (BCA).

• Efforts need to be made to established appropriate mechanism for transfer of information and technology to the farmers.

• There is a need to study the impact of climate change on the performance of jackfruit.

9. Post-Harvest Handling, Processing and Product Development

Possibilities and opportunities exist for small food producers to process jackfruit for local income generation and employment. In rural areas in jackfruit producing countries, food processing is a major source of employment. It is not only important to the national micro-economy but also is one of the fastest growing sectors and is particularly relevant to marginalized and vulnerable women. Enhanced income allows this group of women the flexibility to spend on education, nutrition, and health. As a result, it increases their income capacity and raises their status in the society so that women command increased respect from families and communities. The present status of post-harvest handling and processing of jackfruit is very poor. There is high degree of wastage because seasonal production causes gluts in the market and low prices. A major constraint is the lack of accessible practical information, in particular on post-harvest handling and processing. However, the policy environment is also important. Agro-processing sectors involved with major crops receive government support in the form of subsidies, foreign exchange allowances, price stabilization or guarantees, and access to specialists and consultants. Small-scale processors involved with underutilized fruits do not have such advantages.

The following important points need consideration:

• Appropriate methods for post-harvest handling, processing and product development for local and regional markets should be developed.

• At the local level, technology needs to be transferred to promote products, packaging techniques and better long distance transportation.

• Current information on the possible efficacy of some of the remedies might be based upon some limited phyto chemical screening and very limited amount of clinical testing greater efforts need to be made in this direction to explore and utilize in a therapeutic manner.

• For jackfruit seed powder, pasting behaviour of jackfruit seed flour at different level of incorporation and utilization in non bakery industry need to be investigated.

• Outreach activities need to be strengthened for popularizing the utilization of jackfruit seed flour at household level.

• A cumbersome process is involved in cutting and scooping out the bulbs/ flakes and making it ready besides big size fruit which small family finds difficult to consume in a day. Hence, there is a need to develop efficient mechanical methods for cutting and scooping out the bulbs/ flakes.

• Greater efforts need to be made for processing, value addition and product development.

10. Economics and Marketing

There are a number of factors, limiting the potential exploitation of jackfruit, the major reason being unorganized supply chain management. Unlike other potential crops, absence of strong marketing system is the major hindrance in its commercial exploitation. Although a number of indigenous methods are available for post-harvest handling including processing and value addition, these fruits have not been widely cultivated involving scientific management practices. In spite of sizable production, the growers by and large neglect it. Cutting and cleaning of the fruit is also cumbersome and this also results in neglect of the fruit.

The following aspects need urgent attention:

• To improve income of growers and producers, government agencies and institutions should carry out policy research and

stimulate the formation of cooperatives, women's self–help groups or other such associations so that they can reach regional and international markets.

• It is extremely important that systematic information is gathered and disseminated to all concerned, including those involved in rural development, growers, product producers and small entrepreneurs.

• There is a great need to establish appropriate market linkages so that the jackfruit farmers/ growers can channelize the sale of their produce in an efficient and cost-effective manner.

With a view to leverage and make use of this tremendous and abundant natural resource, which is currently being wasted, a MISSION JACKFRUIT is proposed to be launched with the following objectives.

• To catalyze and promote sustainable rural and urban livelihoods through the processing and value addition of jackfruit by small scale and nano enterprises.

• Creation of a value chain for jackfruit products and generating employment opportunities along the value chain for unemployed youth.

• Addressing food security and nutritional issues of the state in the long run.

• Protection and preservation of catchment areas through promotion of the widespread cultivation of jackfruit for its food, timber, health and soil amelioration benefits.

• Providing an additional source of income for rural and urban families through the commercialization of its processing and value addition.

• Developing the markets for jackfruit and its value added products through a focused and professional go to market and field to fork strategy.

The Mission aims to achieve the above through adoption of the following implementation strategy:

• Action Research programme for Local Varietal identification, germplasm survey, technology sourcing & transfer.

• Varietal improvement through the introduction and propagation of improved varieties/ grafts via nurseries in both public and private sectors.

• Demand driven R&D for product and process development, design and development of equipment, improved storage, shelf-life, packaging etc.

• Establishment of a Food Testing Laboratory with NABL/ FSSAI certification.

• Promotion of jackfruit cultivation in 2000 hectares of catchment areas and promoting the formation of jackfruit collection, aggregation, agro processing clusters & FPOs.

• Establishment of 3 Techno-Incubation Centres (TICs) for providing hands on training, technical assistance and incubation to entrepreneurs and to also to act as a common processing facility for jackfruit.

• Promoting the establishment of 50 SMEs in jackfruit processing through a credit linked start-up fund.

• Promoting the establishment of 200 Nano jackfruit processing/ brining enterprises at village level through a credit linked Nano start-up fund.

• Conduct of Hands on Training for 10,800 entrepreneurs/ master trainers in the incubation centres over the next 5 years.

• Conduct of Village level Go Mobile trainings on plant management and minimal processing for 69,300 partners over the next 5 years.

• Development and creation of IEC materials, training manuals, publications, Z-cards etc

• Organization of Jackfruit Melas/ awareness camps in all 30 (Thirty) districts every year for the next five years.

• Organization of a State Jackfruit Festival to celebrate the fruit every year for the next five years.

• Training cum Exposure visits on Value Addition of Jackfruit for around 2100 partners over the next five years.

• Creation of a Jackfruit brand, hygienic and modern packaging, brand building, Advertising, trade promotion, Marketing and export promotion/ facilitation.

11. Jackfruit Cluster Formation

Jackfruit is a heavy fruit which presents unique supply chain challenges in the movement of the fruit from the producing farms to markets. As things stand today the fruit is sold in its raw form in local and roadside markets sometimes at throwaway prices. Many farmers do not even harvest the fruit and allow it to rot on the ground due to the difficulties of transporting it and the very low prices that they get. For the processing and value addition of the fruit to take off on a commercially viable scale there is a need to create agro processing clusters that can function as collection/ aggregation centres located within the producing areas and to encourage entrepreneurs and the formation of FPOs/ FIGs or cluster groups that can take on the responsibility of aggregation and perhaps to a certain extent carry out primary or minimal processing of the fruit before shipping it to a larger facility. Such cluster can be linked to markets/ processing/ aggregation centres through the platform of the Department. Furthermore in view of the well known property of Jackfruit to ameliorate soil moisture regimes, clusters can be encouraged to take up systemic area expansion of the tree for catchment areas and spring sheds protection in collaboration the Community groups like SHG with which will not only ensure the continued existence of the catchment and springs but will also provide livelihood and enterprise opportunities to the cluster through aggregation and value addition.

12. Techno Incubation Centres

The Mission will have establish three (3) Techno Incubation Centres (TICs) in Karnataka at the start of the Mission, at locations with well developed infrastructure like hostels, water,

electricity, buildings, work space, classrooms, laboratories.

The Techno Incubation Centres have been conceived of as Centres for Training and Technology Support for local entrepreneurs and groups interested in the business of promoting jackfruit. The Centres will be equipped with the necessary essential equipment/ facilities and training by the partner Universities under this Mission and will be a place where prospective entrepreneurs can get an idea of and be trained on the essential infrastructural requirement for setting up a processing unit for jackfruit based value added products. Training will be a major activity under the Techno-Incubation Centre, so that a large number of people could derive benefit from it. This benefit could be translated into an income generating activity not only for the entrepreneurs, but also for the jackfruit farmers through backward integration. The TICs will also function as Common Facility Centres (CFCs) for entrepreneurs, Self Help Groups and Cooperative society members who can utilize the facility to process their produce by paying a nominal user fee and earn profits from sale of the produce, without investing too much in the establishment of machinery and equipment.

The objectives of the TICs would be:

- To organise awareness, training programmes on value addition of jackfruit to stake holders viz., farmers, entrepreneurs, officers of Agril./ Horti Departments.
- To provide hands-on training on preparation of value added products from jackfruit.
- To provide incubation facilitation to prospective entrepreneurs for the production of value added products from jackfruit.
- To provide technical assistance to innovative entrepreneurs for product development in jackfruit.
- To act as a production/ processing unit of jackfruit based products for its widespread popularisation.
- To effectively disseminate the value addition technologies, as more and more people would become convinced about the benefits of the technology by producing the various products by themselves.

12.1 Processing Units

- Fried chips manufacturing unit (FCMU).
- Pickle making unit.
- Powdering/ Dehydrated products making unit.
- Jackfruit Preserve, bites, jam and jelly making unit.
- Quality control lab.

12.2 Products of the TICs

The TICs will provide training and incubation on the following value added products of Jackfruit:

- Ripe jackfruit Preserve
- Jackfruit Chips
- Jackfruit pulp
- Jackfruit Mixture
- Dehydrated Ripe jackfruit: Bites
- Dehydrated Ripe jackfruit pulp: Chew
- Ripe Jackfruit Squash
- Jackfruit Pickle
- Dehydrated Tender Jack fruit
- Dehydrated raw Jackfruit
- Ripe Jackfruit frozen RTS juice
- Ripe Jackfruit Jam
- Ready to cook tender jackfruit
- Jackfruit seed flour
- Raw jackfruit flour
- Jackfruit leathers

The establishment of the TICs will be done with the active collaboration and support of institutions of higher and technical learning like the University of Horticultural Sciences, Bagalkot, and the ICAR-C KVK, Kolar. Personnel of the TICs will be trained at the three institutions so that a cadre of Master Trainers can be incubated to further propagate the knowledge and technologies to the larger audience. The Directorate of Food Processing and MIE will work together to bring all the various stakeholders, mobilize resources, identify entrepreneurs, incubate and handhold them after their trainings. Since the facilities of the TICs are also common and applicable to the processing of other fruits and vegetables, the TICs would also train entrepreneurs in their processing during the jackfruit off season so that the facilities are not idle and are able to deliver maximum benefit to the people of the state. To ensure immediate takeoff, the TICs would initially focus on incubating the 300 odd entrepreneurs and society members already identified and capacitated by the MIE. During the trainings the trainees will be simultaneously screened and evaluated through socio economic and psychometric analysis tools to assess their potential as prospective entrepreneurs for further incubation.

The techno incubation centres will operate on a service driven revenue generating model through the incubation of entrepreneurs and enterprises, provision of processing, packaging, common facilities, training and capacity building services. Assets generated by the Mission will be operated and maintained by the respective TIC hosting institutions.

12.3 Start-Up Funding for Jackfruit SMEs

Post the training the Mission will facilitate the establishment and incubation of 50 small scale value addition/ processing enterprises over a five year period and handhold them till marketing of their products. The units will be selected from amongst the best performing society/ groups/ entrepreneurs based on the socio economic/ psychometric evaluation conducted during the training and based on their having in their possession existing minimum infrastructure facilities like

work sheds, sufficiently large jackfruit plantations and working capital. The enterprises incubated through this Mission will be linked to buyers and market nationwide by the Mission which will provide credit linked start-up fund support of Rs. 8.00 lakhs each for minimum processing equipment, while working capital, human resources and raw material will have to be met by the enterprises through their own investments or through bank linkages which will ensure greater stakeholder participation, ownership, continuity and sustainability of the enterprise. The Directorate of Food Processing and MIE will facilitate the establishment of the enterprises in coordination with the Departments of Commerce & Industries, Cooperation, Labour, Legal Metrology, the FSSAI, financial institutions, insurance brokers, market strategists and brand designers to ensure a smooth take off. Assets created through this Mission will be operated and maintained by the respective enterprises.

12.4 Start-Up Funding for Nano Processing/ Brining Units

Jackfruit also lends itself admirably to home scale or Nano processing either as chips, pickles, kurkure, sweets, jams, papad etc. which is yet another avenue for additional livelihood and income support especially for housewives, marginalized and vulnerable women. The processes are simple and with very little training and using commonly available household utensils, women can easily make such products at home which can then be sold in the local shops and markets. There is great potential under this component to target large numbers of households that can benefit from the jackfruit trees that grow in their own backyards.

12.5 TIC Trainings/ Incubation

The TICs will take up the training, skilling and incubation of 360 batches of trainees covering 10,800 partners/ entrepreneurs with 30 trainees per batch spread over 5 years. The trainings will be residential with each training spread over 6 days in the TIC campuses. Necessary manuals of operation and processing will be developed by the UHS, Bagalkot with inputs from all the concerned institutions.

The trainings will be structured to emphasise more on the practical aspects of processing, packaging, handling of machinery and equipment, food safety and hygiene. To this end the module is being tentatively structured to impart 2 days of theory cum practical and 4 full days of hands on processing practice. During the trainings an evaluation of the entrepreneurial competencies of the partners will be conducted by the MIE using socio economic and psychometric tools like the Focused Behavioural Event Interview (FBEI) to shortlist potential entrepreneurs for further facilitation in setting up their enterprises.

13. Conclusion

There is a need for commercial utilization of the jackfruit in developing countries and can serve as a possible alternative of many vitamins in the body. An activity of certain phyto chemicals along with their antioxidant properties further supports the cause of commercial utilization of the fruit. The antioxidant constituents present in the fruits play important role in scavenging free radicals and reactive oxygen species which are responsible for a number of human disorders. The jackfruits and fruit products hold potential in the diet as they possess not only pleasant taste but also source of naturally and readily available source of instant energy. In Ayurveda the jackfruit is used as a cooling tonic and pectorial, roots in diarrhea and fever, leaves to activate milk in women and animals, as a source to treat anti-syphilic and verminfuge, leaf ash applied to ulcers wounds and the warmed leaves have healing properties if pasted on the wounds. The richness of jackfruit in bioactive natural metabolites encourages their consumption. Furthermore, the aqueous extracts activity suggests that it may be useful for food and pharmaceutical industries. The valued jackfruit material, which nowadays is largely discarded by the population, might have an important economic impact for the producers.

14. References

Adebowale, K.O., Olu-Owolabi, B.I., Olawumi, E.K., Lawal, O.S., 2005. Functional properties of native, physically and chemically modified breadfruit (*Artocarpus artilis*) starch. *Industrial Crop and Products* 21(3), 343-351.

Alagiapillai, O.A., Kuttalam, P.S., Subramanian, V., Jayasekhar, M., 1996. Jack : A new high yielding, regular bearing jack fruit variety for Tamil Nadu. *Madras Agril. J.* 83(5), 310-312.

Ahmed K., Slalek, M., Jahan, K., Salmatullah, K., 1986. Nutritive value of Food Stuff, 3rd edn., Institute of Nutrition and Food Science, University of Dhaka, Bangladesh, pp. 16-17.

Anderson, R.L., WOLF, W.J., 1995. Compositional changes in Trypsin inhibitors, phytic acid, saponins and is flavones related to soybean processing. *J.Nutr*. 125, 581S-588S.

Anonymus, 1970. Chemical studies on mango kernel and jack fruit part 1. *Indian Food Packer* 22(2), 39-42.

Anonymus, 1975. Central Food Technological Research Institute, Mysore, Annual report, pp. 24-25.

Anonymus, 2003. Horticultural crop statistics of Karnataka State at a glance, Government of Karnataka, Directorate of Horticulture, Lal Bagh, Bangalore - 560004.

AOAC, 1980. Official method of analysis, Association of analytical Chemists, Washington D.C.

AOAC, 1980. Official methods of analysis, 11th edition. Association of official agricultural chemists, Washington, D.C.

Ayodele, M.S., Oginni, E.O., 2003. Utilization of breadfruit (*Artocarpus incisa*) flour for confectionery products. *FTA.* 38(12), 710.

Balbach, A., Boarim, D.S.F, 1992. As frutas na medicina natural, Saopaulo, Editora Missionaria.

Begum, K., Umapathy, P.K., Daniel, V.A., Swaminathan, M., 1989a. Nutritive value of jack fruit (*Artocapus integrifola*)

seed meal and effect of supplementing with methionine and tryptophan or milk proteins. *The Ind. J. Nutr. Dietet* 26, 68-74.

Begum, K., Umapathy, P.K., 1989. Effect of partial replacement of cereal in rice and ragi diets by jack fruit seed flour on the nutritive value of diets. *The Ind. J. Nutr. Dietet* 26, 141-143.

Berry, S. K., KALRA, C.L., 1988. Chemistry and technology of jack fruit (*Artocarpus heterophyllus*) - a review. *Indian Food Packer* 42(3), 62-76.

Bhatia, B.S., SIDDAPA, G.S., LAL, G., 1956. Development of products from jack fruit. V. dried jack seeds, flour, roasted nut and jack papad and toffee. *Indian Food Packer* 10, 9.

Bobbio, F.O, DASH-EL, A.A., Bobbio, P.A., Rodrigues, L.R., 1978. Isolation and characterization of the physicochemical properties of the starch of jack fruit seeds (*Artocarpus Heterophyllus*). *Cereal chem*. 55(4), 505-511.

Burkill, H.M., 1977, the useful plants of West Tropical Africa. Vol (4) 2nd Ed., Royal Botanic Gardens, Kew, pp. 160-161.

Cavalcante, P.B., 1991, Frutas comestiveis da amazonia. Belem:Museu Paraense Emilio Goeldi, Editora CEJUP.

CHE-MAN, Y.B., KU-K-SIN, 1997. Processing and consumer acceptance of fruit leather from the unfertilized floral parts of jack fruit. *J. Sci. Food Agric*. 75(1), 102-108.

Daramola, B., ADEGOKE, G.O., 2007. Production and partial characterization of food grade breadfruit acetylated starch. *J. Food Agriculture & Environment* 5(2), 50-54.

Decandole, A.P., 1886. Origin of cultivated plants, 2nd edition, hafner, Newyork, pp. 300-301.

EKE, O.S., AKOBUNDU, E.N.T., 1993. Functional properties of African yam bean (*Sphenostylis stenocarpa*) seed flour as affected by processing. Food Chem. 48, 337-340.

Fassasi, O.S., Eleyinmi, A.F., OYAREKUA, M.A., 2007. Effect of some traditional processing operation on the functional properties of African bread fruit seed (*Treculia africana*) *flour*. *LWT*. 40, 513-519.

Ferrao, J.E.M., 1999, Fruticultura tropical: especies com frutas comestivels. (I) *Lisboa; Instituto de Investigacao Cientifica Tropical.*

Gopalan, C., SASTRI R., Balasubbramaninan, 2002. Nutritive value of Indian foods, National Institute of Nutrition, Hyderabad.

Griswold, M.R., 1962. In the experimental study of foods.

Gunasena, H.P.M., Ariyadasa, K.P., Wikramasinghe, A., Herath, H.M.W., Wikramasinghe, P., Rajakaruna, S.B., 1996. Manual of jack cultivation in Sri Lanka. Forest Information Service, Forest.

Helen, S.A., Praveensari, B., PRIYA, R., 2006. Value added product from jack fruit seed flour, ICFOST, Hyderabad: 66.

Hossain, A.K.M.A., HAQ, N., 2006. Jack fruit (*Artocarpus heterophyllus*) Field manual for extension workers and farmers, SCUC, Southampton University, UK.

IYER, L., Singh, V., 1997. Functional properties of wheat and chickpea composite flours. *Food Australia.* 49, 27-31.

JAIN, N.L., LAL, G., 1957. Some studies in the utilization of jack fruit wastes as a source of pectin. *The Ind. J. Hort.* 17, 213-222.

Jagadeesh, S.L., 2005. Studies on dessert and processing potential of jack fruit seeds *(Artocarpus heterophyllus L*) diversity, *M.Sc., Thesis,* University of Agricultural Sciences, Dharwad.

Jayaraman, J., 2001. Biochemical preparation-Laboratory manual in Biochemistry, New age International (P) Ltd., publishers, p. 154.

John, P.J., Narasimhan, P., 1993. Processing and evaluation of carbonated beverage from jack fruit waste. *J. of Food Processing and Preservation* 16(6), 373-380.

Joshi, K.C., GANDHI, A.P., 2001. Production technology for soy flour and its storage, inserted in course manual on production of soy milk and soy panneer, Central Institute of Agricultural Engineering, Bhopal: 41.

Kakade, M.L., RACKIS, J.J., MCGHEE, J.E., PUSKI, G., 1974. Determination of tryps in inhibitor activity of soy products: collaborative analysis of an improved procedure. *Cereal chem*. 51, 376-382.

Krishnaveni, A., Manimegalai, G., Vennila, P., Saravankumar, R., 1999. Storage stability of jack fruit bar in different packaging materials. *Indian Food Packer* 53(6), 67-69.

Kumar, S., SINGH, A.B., ABIDI, A.B., Upadhyay, R.G, SINGH, A., 1998. Proximate composition of jack fruit seeds. *J. Food Sci. Technol*. 25(5), 308-309.

Le Cointe, P., 1947. Amazonia Brasileira III. Arvores e plantas uteis. Rio de Janeiro : Compan hia Editora Nacional department, p. 48.

Mahmood, I., GHUGRE, S.P., UDIPI, S.A., 2006, Resistant Starch in Raw and Processed Roots and Tubers. *J. Food Sci. Technol.* 43(3), 282-285.

Maia, J.G.S., RADE, H.A., ZOGHBI, M.D.G.B., 2004. Aroma volatiles from two fruit varieties of jack fruit (*Artocarpus heterophyllus Lam*.). *Food Chem*. 85(2), 195-197.

Manorama, R., SAROJONI, G., 1982. Effect of different heat treatments on the tryps in inhibitor activity of soybeans. *The Ind. J. Nutr. Dietet.* 19, 8-13.

Mukprasit, A., Sajjaanantaul, K., 2004. Physico-Chemical Properties of Flour and starch from jack fruit seeds (*Artocarpus heterophyllus* Lam) compared with modified Starches. *J. Food Sci. Technol*. 39(6), 271-276.

Munishamanna, K.B., Ranganna, B., Subramanya, S., CHANDRU, R., PALANIMUTHU, V., 2007. Development of value added products from jack fruit bulbs (*Artocarpus heterophyllus* L.) to enhance farm income of rural people, proceedings of the International conference on 21st centaury challenges to sustainable agri-food system: 508-516.

Prakash, K.M.S., Madaiah, N., Naginchand, Varadaraj, M.C., Nanjundaswamy, A.M., 1996. Studies on the freezing of jack fruit, mango and sapota. *Indian Food Packer* 50(6), 83-87.

Praveenasri, B., Priya, R., Helen, S.A., 2006. Studies on incorporation of jack fruit seed flour on extruded products, ICFOST, Hyderabad: 66.

Punan, M.S., SHUKOR, A., Rahman, Latifah, M., Nor, Muda, P., SAPII, A.T., Rohani, M., Yon, Som, F.M., 2000. Establishment of a Quality Assurance System for Minimally Processed jack fruit, Quality assurance in agricultural produce, edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb., ACIAR Proceedings 100 (printed version published in 2000).

Rahman, M.A., NILUFAR-NAHAR, Mian, A.J., Mosihuzzaman, M., 1999. Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus L.*) with maturity and climatic conditions. *Food Chem*. 65(1), 91-97.

Reddy, B.M.C., Patil, P., Shashikumar, S., Govindaraju, L.R., 2004. Studies on physico-chemical characteristics of jack fruit clones of south Karnataka. *Kar. J. Agril. Sci.* 17(2), 279-282.

Sumathy, B., Soccol, C.R., Pandey, A., 2007. Solid-state fermentation for the production of *Monascus* pigments from jack fruit seed, *Bioresource-Technology* 98(8), 1554-1560.

Teaotia, S.S., Awasthi, R.K., 1968. Dehydration of jack fruit (*Atrocarpus heterophyllus* Lam). *Indian Food Packer* 22(5), 6-14.

Tulyathan, V., Tanauwong, K., Sangjinda, P., Jabiboon, N., 2002. Some Physico-chemical properties of jack fruit (*Artocarpus heterophyllus* Lam) seed flour and starch. *Science Asia* 28, 37-41.

Ukkuru, M., Pandey, S., 2006. Jack fruit a boon to food industry, ICFOST, NOV., Hyderabad: 66.