Annex IV: Review of the literature

(part of the First Partnership Inception Workshop Report)

Breadfruit Sector Consortium

(Mauritius, 2012)

Review of Literature

(8 Feb 2012)

Key:

1. **Source 1; Breadfruit: Promoting the conservation and use of underutilized and neglected crops (Diane Ragone, 1997)**
2. **Source 2; *Artocarpus atilis* (Diane Ragone, April 2006)**
3. **Source 3; Breadfruit. Morton, J.1987**
4. **Source 4; Regeneration guidelines for breadfruit (Ragone D. 2008)**
5. **Source 5; Postharvest handling Technical Bulletin (New Guyana Marketing Corporation, 2004)**
6. **Source 6;Farm and Forestry Production and Marketing Profile for Breadfruit(Diane Ragone, 2011)**
7. **Source 7; Report of First International Symposium on Breadfruit Reasearch and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)**

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1. Origin/ Distribution of Breadfruit

Breadfruit is an ancient domesticated cultigen and its origin, domestication and distribution must be considered within a geographic and cultural context. It was first domesticated in the western Pacific and spread by humans throughout the region beginning 3000 years ago. The breadfruit is believed to be native to a vast area extending from New Guinea through the Indo-Malayan Archipelago to Western Micronesia. The Bismarck Archipelago being the centre of diversity for wild seeded forms of *Artocarpus altilis*(Parkinson) Fosberg. Few-seeded and seedless forms occur throughout the Pacific Islands, with the greatest diversity found in the eastern Pacific in Polynesia. Seedless breadfruit has been widely distributed throughout the tropical world.

Another related species, seeded *Artocarpus mariannensis*Trécul, is endemic to Belau and the Mariana Islands in the western north Pacific. This species has been involved in introgression with *A. altilis* in Micronesia, and numerous seeded and seedless hybrid forms are cultivated throughout these islands.

The wild, seeded, ancestral form of breadfruit, *Artocarpus camansi* Blanco, or breadnut, is native to New Guinea, and possibly the Moluccas (Indonesia) and Philippines. Breadfruit, both seeded and seedless forms, does not naturally occur in the Pacific islands, although long-abandoned plantings are sometimes mistaken for wild trees.

Jarrett's (1959) revision of breadfruit placed it with a group of species thought to naturally occur in the Moluccas, New Guinea and the Philippines. Most of the cultivars (seeded and seedless) of breadfruit in Micronesia east of the Mariana Islands exhibit characteristics of both *A. altilis*and *A. mariannensis*. *Artocarpus mariannensis* grows wild on the uplifted rock islands of Belau and on the limestone ridges of Guam and the Northern Mariana Islands (Fosberg 1960; Coenan and Barrau 1961). Native fruit bats have contributed to its dispersal. It is cultivated throughout the islands of Micronesia and south into Kiribati, Tuvalu and Tokelau. *Artocarpus mariannensais*nd hybrids are well adapted to atoll conditions and are more tolerant of salinity than *A. altilis.*

Historical distribution

Breadfruit is cultivated on most Pacific islands, with the exception of New Zealand and Easter Island. It is now pantropical in distribution. It is said to have been widely spread in the Pacific area by migrating Polynesians, and Hawaiians believed that it was brought from the Samoan island of Upalu to Oahu in the 12th Century A.D. It is said to have been first seen by Europeans in the Marquesas in 1595, then in Tahiti in 1606.

The dissemination of seedless breadfruit beyond Oceania is well documented and involves only a handful of cultivars, primarily Tahitian. Breadfruit has been an evocative symbol of Oceania since Europeans first ventured into the region in the late 1600s. After the long, often arduous, sailing voyage from Europe to the islands, ship-worn sailors were amazed and delighted by a tree that produced prolific fruits that, when roasted, resembled fresh bread. They were especially impressed by the ease with which this abundant food was produced. Numerous accounts were published about this wonder fruit, beginning with Quiros who sailed with Mendana on voyages during 1595-1606. He described seedless breadfruit in the Marquesas and seeded breadfruit in the Solomon Islands (Markham 1904). The Spanish may have introduced seedless breadfruit to Guam from elsewhere in the Pacific in the 1600s to help provision their new colony. They did introduce seedless breadfruit to the Philippines in

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

the 17th century (Wester 1924). Dampier (1729) was the first to document the use of breadfruit in the Mariana Islands. He was particularly enthusiastic about breadfruit's use and potential, crediting it for saving the lives of his starving, scurvy-ridden crew in 1686.

At the beginning of the 18th Century, the early English explorers were loud in its praises, and its fame, together with several periods of famine in Jamaica between 1780 and 1786, inspired plantation owners in the British West Indies to petition King George III to import seedless breadfruit trees to provide food for their slaves. Various accounts by participants of Captain James Cook's first voyage to Tahiti in 1768 had a major impact and focused much attention on breadfruit. The botanist John Ellis (1775) summarized the accounts of early voyagers and was one of the first to suggest in writing that the breadfruit be most useful to all the inhabitants, especially the slaves.

In the late 1700s several seedless varieties were introduced to Jamaica and St. Vincent from Tahiti, and a Tongan variety was introduced to Martinique and Cayenne via Mauritius. These Polynesian varieties were then spread throughout the Caribbean and to Central and South America, Africa, India, Southeast Asia, Madagascar, the Maldives, the Seychelles, Indonesia, Sri Lanka, and northern Australia. Breadfruit is also found in south Florida

There is good evidence that the French navigator Sonnerat in 1772 obtained the seeded breadfruit in the Philippines and brought it to the French West Indies. It seems also that some seedless and seeded breadfruit plants reached Jamaica from a French ship bound for Martinique but captured by the British in 1782. There were at least two plants of the seeded breadfruit in Jamaica in 1784 and distributions were quickly made to the other islands.. There is a record of a plant having been sent from Martinique to the St. Vincent Botanical Garden before 1793. The story of Captain Bligh's first voyage to Tahiti, in 1787, and the loss of his cargo of 1,015 potted breadfruit plants on his disastrous return voyage is well known. He set out again in 1791 and delivered 5 different kinds totaling 2,126 plants to Jamaica in February 1793. On that island, the seedless breadfruit flourished and it came to be commonly planted in other islands of the West Indies, in the lowlands of Central America and northern South America. In some areas, only the seedless type is grown, in others, particularly Haiti, the seeded one is more common. Jamaica is by far the leading producer of the seedless type, followed by St. Lucia. In New Guinea, only the seeded type is grown for food.

It has been suggested that the seeded breadfruit was carried by Spaniards from the Philippines to Mexico and Central America long before any reached the West Indies.

In recent years, some breadnut trees have been planted in French Polynesia, New Caledonia, Palau, Pohnpei, and Hawai'i, mainly by Philippine immigrants.

Effect of high winds on plants

Breadfruit trees are prone to damage or destruction from high winds and the accompanying salt spray and intrusion of salt water into the water table during severe storms. The low-lying atolls, such as the Marshall Islands, Tokelau and parts of the Federated States of Micronesia, have been repeatedly inundated by storm generated tides, resulting in uprooting or destruction of numerous breadfruit trees. In the past decade, many atolls and high islands have experienced destructive storms of hurricane strength. The same applies to the Caribbean where many islands were hard hit by hurricanes during the 1990s. The impact of storms on islands that rely heavily on breadfruit for a staple food is devastating. For example, in 1990, Hurricane 'Ofa' destroyed as much as 100% of the breadfruit crop in Samoa, and between 50 and 90% of big; mature trees were blown over, depending on location (Clarke 1992). A

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

continuing global trend of warmer ocean temperatures which increases the likelihood of hurricane-force storms has serious implications for island nations throughout the Pacific and Caribbean. Droughts also contribute to erosion of breadfruit germplasm, and prolonged droughts have resulted in the destruction of trees in the Micronesian atolls. Droughts have also caused damage to trees in Guam, Pohnpei, Samoa, the Marquesas and other high islands.

Introduction in Mauritius

In the late 1700s several seedless varieties were introduced to Jamaica and St. Vincent from Tahiti, and a Tongan variety was introduced to Martinique and Cayenne via Mauritius.
The French were also avidly trying to procure breadfruit and introduce it to their colonies in the West Indies and elsewhere. These activities centered on the Pamplemousse Botanical Garden in Mauritius. The French introduced a Tongan variety of seedless breadfruit known as *kele kele*to their Caribbean colonies of Martinique and Guadeloupe, and to Cayenne, French Guyana in the 1790s (Leakey 1977). Rouillard and Gueho (1985) elaborated upon the fascinating background of this introduction. It was collected on the island of Tongatapu (Tonga) during the expedition of La Pérouse. When the ship arrived in Java in 1793 it was detained by the Dutch who controlled the island. Some members of the crew, including the botanist, Labillardière, escaped and managed to reach France. Another member of the crew, La Haye, the gardener, remained in captivity for 2years, during which time he continued to care for the breadfruit plants. In 1796 a French ship arrived in Java to find the captured crew members. The plants (and gardener) were rescued and taken to Mauritius. Two trees were still living 100 years later and this single introduction was the ancestor of all the seedless breadfruit planted in Mauritius, and subsequently was the source material for all the seedless breadfruit distributed by the French to other tropical areas.

Distribution in Mauritius
(Map); CSO stats

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

2. Germplasm

Most of the studies and utilization of breadfruit have focused on a very limited number of seedless cultivars of *A. altilis*. Yet enormous breadfruit germplasm resources exist in the Pacific Islands that encompass the wide range of variability in *A. altilis* as well as cultivars that are hybrids between *A. altilis*and *A. mariannensis*.
Despite its widespread distribution and use, surprisingly little work has been done on characterization, evaluation and description of breadfruit germplasm.

Varieties in the world

Dr Diane Ragone , Director of the Breadfruit Institute,National Tropical Botanical Garden (NTBG), has compiled voucher specimens and photographs of close to 400 accessions from cultivated trees, especially few-seeded or seedless cultivars, representing the great diversity of breadfruit throughout the Pacific Islands and also stated that more than 120 varieties from the Pacific are conserved in the world's largest collection of breadfruit (over 200 accessions) at the NTBG in Hawaii. (Diane Ragone, 1997:2007)
Vouchers were also collected from wild trees in the Mariana Islands. These materials are housed in the herbarium of the National Tropical Botanical Garden (NTBG). A wide range of wild, seeded trees from New Guinea and seeded forms from the western Pacific and Indo-Malaysian islands needs to be collected and examined for morphological characters and molecular markers such as isozymes. These materials, supplemented by meticulous observation of live plants at all stages of growth and development, will help ascertain whether it is warranted to consider breadfruit as a single, variable species, *A. altilis*, or to retain *A. camansi*as a distinct species

The United States Department of Agriculture brought in breadfruit plants from the Canal Zone, Panama, in 1906 (S.P.I. #19228). For many years there have been a number of seedless breadfruit trees in Key West, Florida, and there is now at least one on Vaca Key about 50 miles to the northeast. On the mainland of Florida, the tree can be maintained outdoors for a few years with mild winters but, unless protected with plastic covering to prevent dehydration, it ultimately succumbs. A few have been kept alive in greenhouses or conservatories such as the Rare Plant House of Fairchild Tropical Garden, and the indoor garden of the Jamaica Inn on Key Biscayne.

Recommendations of 2007 Symposium:

Collaboration with these institutions in the future

Important facts to be considered for future collaborations:

- *Establish the utility core in tissue culture at Canadian Conservation Research Institute for Sacred Plants (CCRISP: University of Guelph and British Columbia, Canada) and transfer the utility core to national and regional laboratories in Africa, Asia, Caribbean and the Pacific.*

- *Transfer of the tissue culture multiplication protocol from CCRISP to labs in various locations, as appropriate, also providing technical training and supporting documentation for the transfer of tissue culture plants to greenhouses and subsequent field establishment.*

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- *Develop a standardized protocol for evaluating breadfruit which can be used for multi-locational studies. This would initially be used to evaluate the utility core collection.*

Essential issues for germplasm diversity and utilization:

- Carry out surveys and establish inventories of existing germplasm for each country, (to include distribution and uses of the germplasm).

- Develop a minimum set of descriptors to document and describe breadfruit; possibly photographs, covering leaf (e.g., size, glossiness, degree of lobing, number of lobes, depth of sinuses) and fruit at maturity (e.g., dimensions, mass, skin texture, flesh colour, latex colour), fruit quality, and seed number and size. Develop tissue culture and cryopreservation methods for exchange and conservation, and transfer technology where appropriate.

- Develop best practices for tree management in genebanks and germplasm exchange. The latter would obviously require conclusive evidence as to what viruses of breadfruit exist, if any. Countries would also have to be willing to share germplasm so any policy issues would have to be clarified.

- Adopt the strategy proposed for global conservation of breadfruit and develop the necessary project proposals and sourcing required to fund the prioritized activities.

Germplasm Exchange and Crop Improvement

During the 1st international breadfruit symposium report (April 16-19, 2007, Nadi, Fiji), a group discussed various systems/mechanisms for exchanging germplasm, especially to achieve easy access to the breadfruit collection held at NTBG. Bearing in mind the Symposium presentation about tissue culture work at CCRISP and the success in developing an *in vitro* system based on bioreactors, with the potential to generate large numbers of plants, the group felt that CCRISP is best placed to establish the initial tissue cultures of the NTBG accessions, with special emphasis on the utility core. These cultures will then be distributed to laboratories, either national or regional, for further multiplication and distribution. In order to achieve this, NTBG will either have to supply CCRISP with marcots and/or root suckers, or the CCRISP will have to establish tissue cultures directly from the trees in the NTBG field genebank, using the Breadfruit Institute Field Station tissue culture laboratory. A potential timeframe was suggested, with September 2008 being highlighted as when the 20 utility core varieties will be conserved in tissue culture and have been disseminated to recipient laboratories for further multiplication.
The group also discussed a breadfruit improvement programme that could be put in place once the utility core has been widely distributed. Participating countries could compare this core with local varieties, using a standardized protocol. These multi-locational trials would focus on a range of traits (e.g., yield, taste, fruit quality, seasonality, adaptability, drought and salt tolerance). This information would then be made widely available to assist countries/growers in selecting varieties for specific needs.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The Germplasm Exchange and Crop Improvement group made the following recommendations:

1. Establish the utility core in tissue culture at CCRISP.
2. Transfer the utility core to national and regional laboratories in Africa, Asia, Caribbean and the Pacific.
3. Transfer the tissue culture multiplication protocol from CCRISP to labs in various locations, as appropriate.
4. Develop and provide technical training and supporting documentation for the transfer of tissue culture plants to greenhouse and field establishment.
5. Develop a standardized protocol to evaluate breadfruit varieties which would initially be used to evaluate the utility core collection.
6. Carry out DNA fingerprinting of the NTBG collection to facilitate the identification of a genetic diversity core.
7. Address any quarantine issues pertaining to the exchange of breadfruit germplasm.
8. Investigate methods for extending seed shelf life to enable the exchange of seeds between countries.

Varietal characterization

Phenotypic/Morphological

In general, breadfruit trees are large, attractive and evergreen, reaching heights of 15 to 20 meters. The tree has smooth, light-coloured bark, and the trunk may be as large as 1.2 m in diameter, occasionally growing to a height of 4 m before branching. The wood is an attractive golden colour, turning darker upon exposure to air. Latex is present in all parts of the tree. Two large stipules enclose the terminal bud. They are up to 30 cm long at maturity, yellowing and falling with the unfolding of leaves or emergence of inflorescences.

The fruits of breadfruit are globose to oblong, ranging from 12 to 20cm wide and 12 cm long. The rind is light green, yellowish-green or yellow when mature and the flesh is creamy white or pale yellow. The fruit surface varies from smooth to slightly bumpy or spiny with individual disks ranging from areolate to slightly raised and flattened, to widely conical up to 3mm high and 5mm across at the base, to narrowly conical up 5 mm long. In comparison, The fruits of breadnut *(A. camansi)* are oblong and spiny with flexible, elongated sections 5-12 mm long that narrow to a point.

Throughout the Pacific, breadfruit exhibits great morphological variability, ranging from true seedless fruits to fruits with numerous,minute, aborted seeds, to fruits with one to few viable seeds, to fruits with numerous seeds. Many authors have taken the broad view and encompass all of this variability within one species

Brief descriptions of breadfruit species are given below:

Artocarpus altilis

- Leaves broadly obovate to broadly ovate, almost entire with only slight lobing to deeply pinnately lobed with sinuses from 2/3 to 4/5 of the distance from margin to midrib, or deeper; blade generally smooth with few to many pale to reddish hairs, especially on the midrib and veins.
- Fruits globose to oblong, skin light green, yellowish-green or yellow, flesh creamy white or pale yellow; surface smooth to slightly bumpy or spiny with individual disks ranging from areolate, to slightly raised and flattened, to widely conical up to 3 mm

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

high and 5mm across at the base, to narrowly conical up to 5 mm long. Seedless, with some forms seeded.

Artocarpus camansi

- Leaves pinnately lobed with sinuses cut halfway to the midrib; densely pubescent on upper and lower surfaces, midribs and veins.
- Fruits oblong, light green with white flesh; spiny with flexible, elongated sections 5-12 mm long. Seeded.

Artocarpus mariannensis

- Leaves broadly obovate to broadly elliptic; entire or a few lobes mostly in the distal third or half of the leaf; sinuses cut less than half way to the midrib; blade smooth; midrib and veins on the underside covered with dense, appressed reddish hairs.
- Fruits cylindrical or asymmetrical, skin dark green, flesh dark yellow; perianth disks conical when immature, flattened on top when mature. Seeded.

In most regions of the world breadfruit varieties are seedless triploid forms (2n=84). In some parts of the Pacific, diploid (2n=56) varieties are also found, some of which produce fertile seeds while others are less fertile (Ragone 2001; Zerega et al. 2004). Low fertility in diploids probably resulted from continuous vegetative propagation accumulating genetic abnormalities (somatic mutations). Breadfruit is outcrossing but produces seedless fruit parthenocarpically if there is no fertilization. This crop is maintained *ex situ* as clonal trees in field genebanks. Trees can live 80 years or more.

Genetics

Breadfruit is genetically diverse, especially the seeded forms in the western Pacific and hybrids (with *Artocarpus mariannensis*) in Micronesia. The genetic diversity of breadfruit throughout the world — with the exception of some of the Pacific Islands — rests on a very narrow base. Globally, this now widespread, important crop has derived from only a few Polynesian cultivars. These in turn represent a narrowing of the genetic diversity of breadfruit in the Pacific Islands from west to east with little genetic variation in eastern Polynesia. Even though numerous cultivars exist in eastern Polynesia, they are primarily clones selected from a few original introductions many centuries ago. In addition, the few cultivars that Captain Bligh collected may not have been the best cultivars, but merely those that were readily available.

Genetic erosion of many clonally propagated traditional crops, including breadfruit, is a serious problem in the Pacific Islands (Ragone 1990, 1991a; Lebot 1992). Although an important staple crop, the cultivation and use of breadfruit has decreased in the past 50 years, and replanting has not kept pace with the losses incurred throughout the Pacific by drought, storm damage, natural attrition and other factors. This has resulted in a decrease in numbers of trees, and a number of cultivars have already disappeared or are becoming rare. The genetic erosion of breadfruit can be attributed to environmental factors, changes in traditional lifestyles and the nature of the crop itself.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Besides, somatic mutations in existing clones and creation of new clones from selected seedlings resulted in some new cultivars unique to each island.
Numerous Polynesian triploid varieties are genetically identical but morphologically distinct. These Polynesian triploids tend to not thrive under atoll conditions, while both seeded and seedless hybrid varieties are best adapted to these conditions.

Recommendations of 2007 Symposium:

Furthermore, it is important to study and determine the genetic diversity of the NTBG collection to identify a genetic core. Other desired traits should also be taken into account in developing specialized core" collections and with increased problems of climate change, special attention should be given to include varieties with salt and drought tolerance.

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3. Environmental Requirements

Weather

The breadfruit is ultra-tropical, much tenderer than the mango tree. It has a wide range of adaptability to ecological conditions, much greater than that usually cited in standard books on crop production in the tropics. It grows best in equatorial lowlands below 600–650 m (2000–2160 ft) but is found at elevations up to 1550 m (5100 ft). Breadfruit has adapted to local climates and soils, including saline soils of coral atolls.

The latitudinal limits are approximately 17°N and S; but maritime climates extend that range to the Tropics of Cancer and Capricorn (the maritime climates of islands such as Hawaii allow growth to 20-23°N).

Rain apparently stimulates extension growth, flowering and rate of growth of the fruit. Annual rainfall of 1525-2540 mm was considered optimum (Purseglove 1968), yet breadfruit will yield regularly on atolls which receive more than 1000 mm of rain annually (Barrau 1961). Breadfruit prefers rainfall of fairly equal distribution but is quite tolerant of short dry periods (Coronel 1983).

Breadfruit grows best in equatorial lowlands below 600-650 m; it is occasionally found in the highlands, but yield and fruit quality suffer in cooler conditions. (Chandler 1958; Coronel 1983; Rajendran 1992). It grows only in the lowlands of Central America and is not found above 600 m elevation (Popenoe 1920). It grows from sea level to 900 m in southern India (Singh *et al.* 1967). In Sri Lanka the tree is cultivated anywhere in the moist zone from sea level up to 900 m but is not suited to the dry zone (Parsons 1933). Breadfruit may be cultivated at elevations up to 1550 m in New Guinea (Powell 1976).
Breadfruit generally grows in the coastal lowlands but flourished in extensive plantations planted at 300-600 m on the island of Hawaii (Handy *et al.* 1972)

Breadfruit can withstand drought for a few months but will prematurely drop its fruits.
Young trees can be grown in 20–50% shade when young but develop a more compact, dense canopy when grown in full sun.

Full sun
The tree does best in full sun and forms the overstory canopy in traditional mixed agroforests.
Shade
Young trees prefer 20–50% shade when young but can be grown in full sun.
Fire
It can sprout back from the roots after a small fire, but the trunk and branches are not fire-tolerant.
Frost
It is damaged by frost, which causes it to lose all fruits and leaves, and some branch die-back may occur.
Waterlogging
It can tolerate waterlogged soils for only very brief periods.
Salt spray
It can tolerate some salt spray for brief periods, but the leaves will turn yellow and fall.
Wind
The branches break and shed in heavy winds, especially with a heavy fruit load, but new shoots and branches quickly regrow.

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In general, breadfruit (including breadnuts) is a crop for the hot, humid tropical lowlands and does best at temperatures of 21-32°C (Purseglove 1968). Other authors have expanded the temperature range from as low as 15°C to as high as 40°C (Singh *et al.* 1967; Rajendran 1992). It will not grow where the temperature goes down to 5°C (Coronel 1983; Crane and Campbell 1990). Rajendran (1992) gave annual rainfall requirements of 2000-3000 mm.
According to Morton, J. (1987), it has been reported that breadfruit requires a temperature range of 60° to 100°F (15.56°-37.78°C), an annual rainfall of 80 to 100 in (203-254 cm), and a relative humidity of 70 to 80%. However, in southern India, it is cultivated at sea level and up humid slopes to an altitude of 3,500 ft (1,065 m), also in thickets in dry regions where it can be irrigated. In the "equatorial dry climate" of the Marquesas, where the breadfruit is an essential crop, there is an average rainfall of only 40 to 60 in (100-150 cm) and frequent droughts.
Newly planted trees may require daily watering during dry periods until established, but mature trees normally tolerate dry conditions and do not require irrigation.

Mean annual rainfall
1500–3000 mm (60–120 in), but trees can yield regularly on Pacific atolls that receive 1000 mm (40 in)

Rainfall pattern
It prefers climates with summer rains.

Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)
0–3 months

Mean annual temperature
15–40°C (59–104°F), does best at 21–32°C (70–90°F)

Mean maximum temperature of hottest month
32–38°C (90–100°F)

Mean minimum temperature of coldest month
16–18°C (61–64°F)

Minimum temperature tolerated
5–10°C (41–50°F)

Soil suitability

It is believed that there is great variation in the adaptability of different strains to climatic and soil conditions, and that each should be matched with its proper environment. The ability to grow on coral soils may have been a crucial factor in the nowwidespread distribution of hybrids throughout the low-lying Micronesian atolls.

Kahanu Garden (Hawaiian island) encompasses 123 acres at sea level with fertile, well-drained, volcanic soils in an area that averages close to 2000 mm of rain annually.

Breadfruit can be grown on a variety of soils and thrives on alluvial and coastal soils (Massal and Barrau 1954). They do best in deep, fertile, well-drained sandy loam or clay loam soils (Coronel 1983) with pH 6.1–7.4.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

However, some of the best authorities on South Pacific plants point out that the seedless breadfruit does well on sandy coral soils, and seeded types grow naturally on "coraline limestone" islands in Micronesia. In New Guinea, the breadfruit tree occurs wild along waterways and on the margins of forests in the flood plain, and often in freshwater swamps. The Tahitian 'Manitarvaka' is known to be drought-resistant. The variety 'Mai-Tarika', of the Gilbert Islands, is salt-tolerant. 'Mejwaan', a seeded variety of the Marshall Islands, is not harmed by brackish water nor salt spray and has been introduced into Western Samoa and Tahiti.

Breadfruit can be grown on a variety of soil types but does best in well-drained sandy loam or clay loam soils. Trees may shed their fruit and leaves and eventually die if the soil remains excessively wet or waterlogged.

Good drainage is essential whatever the soil type, and trees may shed their fruits when the soil is excessively wet. Some cultivars, especially interspecific hybrids, have adapted to shallow calcareous soils and appear to tolerate higher saline conditions (Catala 1957; Coenan and Barrau 1961; McKnight 1964).

Soil texture
Breadfruit prefers light and medium soils (sands, sandy loams, loams, and sandy clay loams).
Soil drainage
It requires freely draining soils.
Soil acidity
Neutral to alkaline soils (pH 7.4–6.1)
Special soil tolerances
Breadfruit tolerates saline soils, as well as coralline soils and atolls.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

4. Propagation Methods and Planting Materials

Breadfruit trees are generally propagated vegetatively (MacCaughey 1917; Pope 1926; Otanes and Ruiz 1956; Chandler 1958; Purseglove 1968; Handy *et al.* 1972; Rowe-Dutton 1976; Ragone 1991a) from root shoots or root cuttings, by air-layering branches, or from seeds. Breadfruit can also be grafted using various techniques. Stem cuttings are not used. Seeds are rarely grown because they do not develop true to type. Vegetative propagation is a must for seedless varieties, and root shoots or root cuttings are the preferred methods for both seeded and seedless varieties.

They are traditionally propagated from root cuttings or shoots. The roots grow on or slightly below the surface of the ground and will often produce a shoot, especially if it is cut or damaged.

Root shoots and cuttings are normally collected after the fruiting season and when the tree is in an active vegetative stage. This is when carbohydrate levels in the roots are at their highest. Breadfruit roots tend to spread and can intermingle with those of adjacent trees so follow a root back to the source tree to make sure it is from the desired parent tree.

Pacific islanders and others will intentionally wound roots to induce shoot production. When the shoot is 0.5-0.75 m high and has developed its own root system, it is removed by cutting the root 10-15 cm on either side of the shoot.

Raising root shoots / root cuttings

- Select healthy, undamaged roots that are growing just beneath the surface of the soil and carefully excavate them. Do not use surface roots because they tend to dry out and are less successful. Look for roots with small rounded bumps (adventitious buds) on the surface which will develop into new shoots (see photo).
- Use roots 1.5–6 cm in diameter (3–4 cm for best results). Removing roots larger than 6 cm can damage the tree as the wounded area will heal more slowly.
- Use a sharp machete or clippers to sever the root. The remaining attached root will often develop a root shoot at the cut end.
- Cut harvested roots into 10–25 cm sections.
- Wash and scrub root cuttings to remove soil and discard any pieces that are damaged or misshapen. Treat with fungicide to prevent root rot. Hormone treatment is not required but standard hormone mixes can be used according to the manufacturer's recommendation.
- Place root shoots and cuttings in a propagating bed, flats, or individual pots and label each piece with its accession number (see photo below left).
- Space 10–15 cm apart in a row, with 15–20 cm between rows in beds or flats.
- Use well-drained potting media or clean, washed silica sand with coir dust or sawdust (2:1 ratio). Do not use beach sand because it is too saline and alkaline.
- Place cuttings either horizontally (lightly covered with media) or at a 45 degree angle with the upper quarter exposed.
- Keep cuttings shaded (up to 60% shade) and moist, but not wet; misting is recommended and the roots should never be allowed to dry out.
- The percentage of rooting ranges from 30 to 85% (photo photo below right).
- Shoots begin to develop from adventitious buds after 3–4 weeks.
- When shoots are 20–25 cm tall with their own roots, usually in 4–6 months, carefully uproot and transplant the cutting into a 1–2 gallon pot; use a well-drained

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media (e.g. potting mix with perlite or volcanic cinder, clean local loamy or sandy soil) and fertilize sparingly, at half the manufacturer's recommendations.

- Keep plants in partial shade and weed free.
- Grow to a size of 0.6–1.6 m over 6–9 months and then plant in the field.
- If plants are to be field planted in full sun, gradually move to full sun conditions in the nursery for about 2 months to condition them to the site conditions. Keep plants moist and do not expose to strong wind.

Air-layering or marcottage is one method which has shown good results (Rowe- Dutton 1976) and is widely practised in Tokelau (Ragone 1988). It is best to air-layer branches at the beginning of the rainy season when the tree is in an active vegetative stage, producing new shoots and leaves, and before fruits appear.

- Select newly developed shoots, and do not use the ends of branches that have previously flowered or fruited.
- Branches (5-15 cm, and occasionally up to 30cm, in diameter) are prepared for air-layering by removing a strip of bark 2.5-5 cm wide around the circumference of the branch (Ragone, D; 1997)
- Branches 2–4 cm (0.8–1.6 in) are prepared for air-layering by removing a strip of bark 3–5 cm (1.4–2 in) wide around the circumference of the branch(Ragone, D; 2006)
- Use a sharp knife and be careful not to cut into the wood.
- Rooting hormone is not required but if used, follow the manufacturer's recommendations.
- Wrap moistened sphagnum moss, compost, mulch or other organic media, around this area and hold it in place with a piece of plastic, aluminum foil, burlap, or copra bag tied around the branch.
- Up to 50% of air-layers will not root but instead form a ring of hardened callus along the end of the cut. Also, the branches are brittle and may snap off in high winds. They can be braced with bamboo splints placed over the wrapped air-layer.
- After 2-6 months, roots develop and grow through the bag, and new shoots may grow from above the wounded area.
- Remove the air-layer by cutting the branch directly below the roots.
- Place in a 1–2 gallon (10-20 cm) pot in a well drained medium (or in a hole containing organic materials.) until the plant has an established root system (about a year).
- Depending on the size of the air-layered branch, the tree will fruit in 3 to 4 years.
- Airlayers are most frequently made on branches that have previously borne fruit as the airlayer will bear fruit as soon as 1-2 years after planting.

Another refined method which promised to facilitate propagation of breadfruit is the use of stem cuttings under intermittent mist (Lopez 1975; Hamilton *et al.*1982). With this method, leafless stem cuttings were treated with rooting hormone and placed under intermittent mist. After 10weeks, 95% of the cuttings had produced sufficient root and shoot growth to be transplanted into larger containers. They were ready for planting in the field after 4 months (Hamilton *et al.* 1982). In Puerto Rico, the cuttings are transplanted into plastic bags containing a mixture of soil, peat and sand, kept under mist for a week, then under 65% shade, and given liquid fertilizer and regular watering. When the root system is well developed, they are allowed full sun until time to set out in the field.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The seeded breadfruit is always grown from seeds. Seeds are extracted from ripe fruits and immediately planted since they lose viability within a few weeks (Rowe-Dutton 1976; Rajendran 1992). Coronel (1983) outlined the germination and care of seedlings. Seeds have little or no endosperm and no period of dormancy; they germinate immediately and are unable to withstand desiccation. Seeds are distributed by flying foxes, where they occur. They are planted about 5 cm apart and 1 cm deep and germinate about 2 weeks after sowing. The germinating bed should be kept moist; seedlings can be transplanted into individual containers as soon as they sprout. They grow quickly and are ready for planting in the field when they are about 1 year old. Breadnut trees tend to grow slowly and may start fruiting in 6-10 years. Asexually propagated breadfruit trees start fruiting in 3-6 years. Seeds are rarely used for propagation because seedlings are not true-to-type.

Seedless varieties can be grafted onto seeded rootstock using various techniques such as approach grafting or cleft grafting. Under good conditions, grafted trees can begin bearing in 2 years.
In India, it is reported that breadfruit scions can be successfully grafted or budded onto seedlings of wild jackfruit trees.

Regardless of the method used to propagate trees, young plants do best under shade, but trees require full sun once established.

Outplanting techniques

- When plants are to be field planted in full sun, gradual- ly move to full sun conditions in the nursery for about
- 2 months to harden them to site growing conditions.
- Keep plants moist and do not expose to strong wind.
- Reduce the size of the lower leaves by ½–⅔ to reduce transpiration. Do not remove or damage the growing point where new leaves develop.
- Protect from wind and excessive heat during transport.
- Dig a hole the same depth and twice as wide as the container. Add a small amount of mulch or slow-release balanced N-P-K fertilizer to the bottom of the hole and cover with soil.
- Carefully remove the tree from the container to pre- vent damage to the root system; place the tree in the hole; add soil no higher than the level of the plant in the pot; mulch and water well.
- Success rates close to 100% can be expected.

Young plants prefer partial shade. It is best to plant at the onset of the rainy season, but if the weather is dry, irrigate for the first 1–3 months of establishment.
It is important to practice deep irrigation to encourage a deep root system. Mulching young plants is beneficial to keep soil moist, supply nutrients, and control weeds around the root system. Do not use herbicides around the base of the tree since they can damage the surface roots or young trunk. Protect young trees from pigs, cattle, goats, and horses that may eat the bark and tender shoots. Once established, breadfruit trees can withstand a dry season of 3–4 months, although it prefers moist conditions.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

5. Agronomy and Cultural practices

The breadfruit (*Artocarpusaltilis*) is a widely grown and nutritious tree fruit. It is a member of the genus *Artocarpus*(Moraceae) which contains about 50 species of trees that grow in the hot, moist regions of the Southeast Asian tropics and the Pacific Islands.

Breadfruit is fast growing in favorable conditions, growing in height 0.5–1.5 m (1.7–4.8 ft) per year and trunk diameter of 0.5–1 m (1.7–3.3 ft) in the first 10–12 years. Small branch- es often die back at the tip after fruiting, but new shoots and branches continue to develop throughout the life of the tree.

Breadfruit is an attractive evergreen tree, typically 12–15 m (40–50 ft) tall with a 0.3–1 m (1–3.2 ft) diameter trunk, of- ten with buttress roots. Milky white latex is present in all parts of the tree. Male and female flowers occur on the same tree. Male inflorescence is an elongated club-shape, up to 5 cm (2 in) in diameter and 45 cm (18 in) long, comprised of thousands of tiny flowers attached to a central spongy core. The tree is deciduous. Female inflorescence is more rounded and consists of 1,500–2,000 reduced flowers at- tached to a spongy core. Flowers fuse together and develop into the skin and fleshy, edible portion of the fruit. Large glossy dark-green leaves are alternate, ranging from almostentire to deeply dissected, with up to six pairs of lobes and a large apical tip. Fruit are usually round, oval, or oblong, weighing 0.25–5 kg (0.5–11 lb). Skin is greenish-yellow, pat- terned with hexagonal markings, and has a smooth, bumpy, spiny, or spiky surface. Flesh is creamy white or pale yellow and contains none to many seeds, depending on the variety. Seeds are brown, typically shiny, rounded or obovoid, irreg- ularly compressed, 0.5–2 cm (0.2–0.8 in) thick, and embed- ded in the pulp. Seeds germinate immediately and cannot be dried or stored.

Ragone (2006) stated that the attractive, evergreen trees grow to heights of 15 to 21 m (48 to 70 ft) or more and the trunks may be as large as 2 m (6.6 ft) in diameter at the base. The trees begin bearing in 3–5 years and are productive for many decades. They are easy to propagate, require little attention and input of labor or materials, and can be grown under a wide range of ecological conditions. It is moderately fast growing in favorable conditions, growing 0.5–1.5 m (1.5–5 ft) per year.

Size

Trees can reach heights of 21 m (70 ft) or more at maturity, more commonly around 12–15 m (40–50 ft). The trunk may be large as 2 m (6.6 ft) in diameter, occasionally growing to a height of 4 m or more (13 ft) before branching. A white milky latex is present in all parts of the tree.

Size in an urban environment

Trees can reach heights of 18 m (60 ft) or more but are typically 12–15 m (40–50 ft). Some varieties are relatively short-statured, reaching average heights of 9 m (30 ft). The canopy is generally about two-thirds of the height.

Flowers

Monoecious with male and female flowers on the same tree and the male inflorescence appearing first. Male flowers are club-shaped, up to 5 cm (2 in) in diameter and 45 cm (18 in) long. Thousands of tiny flowers with two anthers are attached to a central, spongy core. Female inflorescences consist of 1500–2000 reduced flowers attached to a spongy core. The

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flowers fuse together and develop into the fleshy, edible portion of the fruit. It is cross pollinated, but pollination is not required for the fruit to form.

Leaves

Leaves are alternate, broadly obovate to broadly ovate, almost entire, with only slight lobing to deeply pinnately lobed, with sinuses up to 2/3 or more of the distance from margin to midrib, with up to six pairs of lobes and a large apical tip. Blade is generally smooth, glossy, dark green with green or yellow-green veins, and few to many white to reddish-white hairs on the midrib and veins. Leaves on new shoots and root suckers are generally larger and more hirsute than leaves on mature branches. Size is variable depending on the variety, ranging from 15–60 cm (6–24 in) long.

Fruit

Fruits are variable in shape, size, and surface texture. They are usually round, oval, or oblong ranging from 9 to 20 cm (3.6–8 in) wide and more than 30 cm (12 in) long, weighing 0.25–6 kg (0.5–13 lb). The tough skin is composed of five- to seven-sided disks, each the surface of an individual flower. Two strap-shaped, reflexed stigmas protrude from center of the disk and often leave a small distinctive scar when they blacken and wither. The skin texture varies from smoothly to slightly bumpy or spiny. The color is light green, yellowish-green, or yellow when mature, although one unusual variety ('Afara' from the Society Islands) has pinkish or orange-brown skin. The skin is usually stained with dried latex exudations at maturity. The flesh is creamy white or pale yellow and contains none to many seeds, depending upon the variety. Fruits are typically mature and ready to harvest and eat as a starchy staple in 15–19 weeks. Ripe fruits have a yellow or yellow-brown skin and soft, sweet, creamy flesh that can be eaten raw but rarely is in the Pacific.

Seeds

Throughout the Pacific, breadfruit exhibits great morphological variability, ranging from true seedless varieties to those with several small aborted seeds, or one to a few viable seeds, to varieties with numerous viable seeds. Seeded types are most common in the southwestern Pacific. Seedless varieties are most common in Micronesia and the eastern islands of Polynesia. All of the breadfruit varieties elsewhere in the tropics are seedless. Seeds are thin-walled, subglobose or obovoid, irregularly compressed, 1–2 cm (0.4–0.8 in) thick, and embedded in the pulp. The outer seed coat is usually shiny dark brown with a light brown inner seed coat.

Seeds have little or no endosperm and no period of dormancy; they germinate immediately and are unable to withstand desiccation. Seeds are distributed by flying foxes, where they occur. Seeds are rarely used for propagation.

Growing breadfruit as an integral part of a polyculture and has numerous advantages: total productivity, maximizing the use of available land, plant interactions, sustainability.

Inter-cropping

Breadfruit is a long-lived perennial tree crop that provides beneficial shade and a cooler microclimate beneath its canopy for humans, as well as plants and animals. When grown with other crops in agroforestry systems it provides support, shade and mulch.

It is grown around homes in villages and towns and is an important component of agroforestry systems, especially on the high islands of the FSM. It is associated with other staple crops such as taro (*Colocasia esculenta*), yam (*Dioscorea* spp.), banana, as well as

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Tahitian chestnut (*Inocarpus fagifer*), noni (*Morinda citrifolia*, Indian mulberry), coconut, kava (*Piper methysticum*), cacao, coffee, and various fruit trees such as citrus and papaya. Breadfruit does well interplanted with a wide array of plants, and more than 120 useful species have been documented in traditional breadfruit agroforests on Pohnpei. Vines such as *Merremia peltata*, if left unchecked, can smother and eventually kill the trees.

They are generally planted as part of a homegarden or mixed agroforestry system with a wide array of useful plants. Widely spaced trees in an orchard can be interplanted with small fruit trees, such as citrus, and a leguminous cover crop. Short-term fruit crops, such as pineapple, banana, and papaya, or field and vegetable crops including taro, tomato, and eggplant, can also be grown between breadfruit trees. A leguminous cover crop should replace these intercrops when they begin to interfere with orchard operations.

It is best to keep trees mulched and to use a non-climbing leguminous ground cover in orchards.

Some inter- planting systems include:

- In the Federated States of Micronesia (Pohnpei), bread- fruit is typically grown with yam (*Dioscorea* spp.). Yam vines climb trellises of beach hibiscus (*Hibiscus tiliaceus*) or bamboo and grow into the canopy of the tree during its non-fruiting period and are dormant while the breadfruit is harvested. This allows breadfruit to be picked without damaging the yam vines.
- In American Samoa, breadfruit is grown with taro, cas- sava, bananas, citrus, and cacao.
- In Palau, breadfruit is grown with betel nut, cassava, taro, citrus, and ornamentals.

Since full fruiting potential from new trees takes 3–4 years, intercrop with pineapples, papaya, banana or other faster yielding crops to achieve quicker returns, while the breadfruit reaches a productive age.

Planting density & methods

Breadfruits are grown mainly as backyard trees and, as yet, are not cultivated on a large scale. Once established they require little attention and input of labour or materials. As a backyard tree, elaborate land preparation is not necessary (Coronel 1983). Generally a hole just wide and deep enough to accommodate the root ball is sufficient. The soil is usually amended with mulch or other organic material, or less frequently, fertilizer is added. Plants should be set out at the onset of the rainy season and supplementary irrigation may be required to help the trees become established.

Mulching around the trees is beneficial and widely practised in the Pacific Islands and other areas. Breadfruit are known to grow and fruit well without irrigation, even in areas with a distinct dry seaso

An orchard would require thorough land preparation consisting of ploughing the land as deeply as possible followed by harrowing to attain the desired soil tilth (Coronel 1983). He recommended a spacing of 12-14 m, although distances as close as 10 m or less have been suggested. Approximately 100 trees can be planted per hectare if spaced 12 x 8 m or 10 x 10 m apart (Coronel 1983; Narasimhan 1990). When growing breadfruit for fresh fruit export markets, trees should be planted about 12 m (40 ft) apart (NWC 2005) to help with

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

orchard management and to reduce pest and disease problems. Closer spacing is possible in an orchard if trees are regularly pruned and shaped to maintain a low profile.

For multiplication in quantity, it is better to make root cuttings about 1 to 2 1/2 in (2.5-6.35 cm) thick and 9 in (22 cm) long. The ends may be dipped into a solution of potassium permanganate to coagulate the latex, and the cuttings are planted close together horizontally in sand. They should be shaded and watered daily, unless it is possible to apply intermittent mist. Calluses may form in 6 weeks (though rooting time may vary from 2 to 5 months) and the cuttings are transplanted to pots, at a slant, and watered once or twice a day for several months or until the plants are 2 ft (60 cm) high.

In field:

- Plant 1–3 trees of each accession 12–15 m apart in the field.
- Trim back the lower leaves by one-half to two-thirds to reduce transpiration. Do not remove or damage the growing point where new leaves develop.
- Protect from wind and excessive heat during transport.
- Dig a hole as deep as the container and twice as wide, add a small amount of slow-release balanced N-P-K fertilizer to the bottom of the hole and cover with soil.
- Carefully remove the tree from the container to prevent damage to the root system and place it in the hole.
- Add soil to no higher than the level of the plant in the pot, add compost and water well.
- Close to 100% success rate can be expected.

Young breadfruit trees are planted in well-enriched holes 15 in (40 cm) deep and 3 ft (0.9 m) wide that are first prepared by burning trash in them to sterilize the soil and then insecticide is mixed with the soil to protect the roots and shoots from grubs. The trees are spaced 25 to 40 ft (7.5-12 m) apart in plantations. Usually there are about 25 trees per acre (84/ha). Those grown from root suckers will bear in 5 years and will be productive for 50 years. Some growers recommend pruning of branches that have borne fruit and would normally die back, because this practice stimulates new shoots and also tends to keep the tree from being too tall for convenient harvesting.

In the absence of information about the fertilizer requirements, Coronel (1983) recommended the application of 100-200g ammonium sulphate per tree 1 month after planting and again at 6months. The amount should be gradually increased until the trees start to produce fruits; then 500-1000g complete fertilizer may be applied to each tree twice a year. A full bearing tree may require at least 2 kg complete fertilizer per application.

Cultural practices

- Proper husbandry practices, such as removing dead and dying branches and mulching, are essential to maintaining the health and vigor of the trees.

- Mulching young plants is beneficial by helping keep the soil moist and adding a steady supply of nutrients. It also helps control weeds around the root system. Use of herbicides to control weeds around the base of the tree can damage the tree if it comes

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

in contact with the surface roots or young trunk. Young trees need to be protected from cattle, goats, horses, and pigs that will eat the bark and tender shoots.

- Mulching with fallen breadfruit leaves and other organic material is favorable. This relativelylow-maintenance species can be fertilized once a year with a balanced NPK fertilizer, but trees can produce abundantly and thrive for years without supplemental fertilizer. Small tip branches often die back after fruiting and should be pruned and removed to maintain the long-term health of the tree.

- Pruning should be limited to the removal of dead branches, but trees are often topped to make it easier to reach and harvest fruits. However, the new shoots and branches are brittle and readily break. Young trees, especially those grown for commercial production, can be carefully pruned every year or so to encourage a good structure and branching habit. Keeping them low makes it easier to reach and harvest fruit.

- Pruning the parent tree will increase the number of suckers, and root pruning each sucker several times over a period of months before taking it up will contribute to its survival when transplanted. Some growers recommend pruning of branches that have borne fruit and would normally die back, because this practice stimulates new shoots and also tends to keep the tree from being too tall for convenient harvesting.

- Standard mixtures of NPK are applied seasonally. When the trees reach bearing age, they each receive, in addition, 4.4 lbs (2 kg) superphosphate per year to increase the size and quality of the fruits.

- Use compost or provide a complete fertilizer at the beginning and end of the fruiting season to maintain the health and vigor of trees, especially those that are 10 or more years old. Remove dead or damaged branches after the fruiting season.

- Avoid herbicide use around the base of the tree as it can cause damage if it comes in contact with the surface roots or tender trunk.

- If the weather is dry, irrigate for the first 1–3 months of establishment. Deep irrigation is important to encourage a deep root system.

Pest and Diseases

Breadfruit is a hardy tree and relatively free of diseases and pests although scale insects, mealybugs (Kiri- bati experienced fruit loss and tree decline as a result) and Cercospora leafspot can be seen on many trees (Marte 1986; Rajendran 1992).

Problems seem to be regional in nature: the two-spotted leaf hopper has been observed damaging trees in Hawaii; *Rastrococcus invadeniss* becoming a pest in certain parts of West Africa (Agounke *et al.*1988) and *Rosellininas*p. has been reported as a potential threat in Trinidad and Grenada (Marte 1986). Since it could kill the tree and spreads relatively rapidly,

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

attention must be paid to an effective control method. Liming the soil has been shown to be effective in reducing the damage caused by this fungus.
In Australia, fruit spotting bugs (*Amblypelta* spp.) have caused some commercial fruit to be downgraded through shape distortion and hard spots. The glassy-winged sharpshooter (*Homalodisca coagulata*), a destructive leafhopper, reached Tahiti and other islands in French Polynesia in 1999, be- coming a serious agricultural pest. It has been controlled by the introduction of a parasitic wasp in 2005. This leafhopper reached Hawai'i in 2004 and the Cook Islands in 2007. *Cercospora* leaf spot is seen on many trees.

Root-knot nematode (*Meloidogyne*sp.) has been reported as a serious problem in Malaysia and affected plants show retarded growth, sparse branching, yellowing of the leaves and very poor root systems devoid of feeder roots (Razak 1978).

In the 1960s, there was concern that breadfruit trees in Micronesia were being decimated by a problem known as ' Pingelap disease' . Die-back on many islands, in particular Guam and the Caroline atolls, was extensive (Zaiger and Zentmeyer 1966). A subsequent survey by Trujillo (1971) determined that there was no single pathological cause of this die-back. Rather, it was considered to be the result of a combination of typhoon damage, drought, aging of the trees, salinity and other environmental factors. This problem has recently been observed in several Caribbean Islands (L.B. Roberts-Nkrumah, 1990, pers. comm.). Recent work in the Mariana Islands has identified *Phellinus noxius*a s the causal organism of crown rot and dieback in breadfruit (Hodges and Tenorio 1984); it spreads through root contact, especially when the tree is planted in areas of native forest that have been recently cleared.

Several causal organisms are responsible for fruit rot of breadfruit. Fruits can be affected by *Phytophthora, Colletotrichum*(anthracnose) and *Rhizopus*(soft rot), but these can be controlled by prompt harvest of mature fruits and removal of diseased fruits (Trujillo 1971; Gerlach and Salevao 1984). *Phytophthora*w as controlled in India by two sprays of 1% Bordeaux mixture on the entire tree at intervals of 2 weeks at the ripening stage (Suharban and Philip 1987). The oriental fruit fly attacks fruits that are allowed to ripen on the tree as well as those that have fallen to the ground. Losses of 30% were estimated for the Philippines during certain seasons (Coronel 1983).

Tree decline and dieback is problematic throughout the Pacific and Caribbean Islands, especially on atolls. Since no pathological cause has been identified, they are considered to be the result of storm damage, drought, aging of the trees, or salinity.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

6. Fruiting

Pollination

The pollination mechanisms of breadfruit are not fully understood, with questions raised as to whether this is mediated by wind or insects. Breadfruit trees are monoecious with male and female flowers occurring separately on the same tree. Male inflorescences originate first, followed by female inflorescences. Male inflorescences are club-shaped, up to 5 cm in diameter and 45 cm long. The thick, spongy axis is covered by numerous minute flowers. Each flower consists of a reduced tubular perianth enclosing a single stamen with a two-lobed anther on a thick filament. In young flowers, the perianth has a narrow opening, but at anthesis its lobes are widely separated and the anther is exserted above the perianth (Sharma 1965).
Pollen is shed 10 to 15 days after the emergence of the male inflorescence for a period of about 4 days (Brantjes 1981). Female flowers are receptive 3 days after the emergence of the female inflorescence from the bracts and open in successive stages with basal flowers opening first. As with other members of this genus, breadfruit is crosspollinated.
Most authors have claimed that male inflorescences are odourless (Jarrett 1959; Purseglove 1968; Brantjes 1981). Yet, male inflorescences of many accessions, especially fertile forms, in the NTBG germplasm collection have a distinct odour similar to the "sweet scent of honey and burnt sugar" that Corner (1940) reported for *A. heterophyllus, Ain.tegera*nd,*A.dadah*. Honeybees have been observed actively working male inflorescences and collecting pollen, especially from fertile, seeded accessions. Other insects (such as earwigs) have also been observed on male inflorescences.

Seedless cultivars generally produce little viable pollen compared with fertile, seeded and few-seeded cultivars. In fertile cultivars, the anthers of hundreds of flowers will protrude and dehisce, releasing thousands of pollen grains, so much so that a dusting of pollen can be seen on leaves under the inflorescence. Only a few flowers in male inflorescences of seedless breadfruit produce and release pollen. Pollen grains from fertile cultivars are uniformly shaped and stain well, while those triploid cultivars have the lowest pollen stainability, averaging from 6 to 16%, and the pollen grains are typically malformed, clumped and poorly stained (Ragone 1991a). These facts were previously noted by Sunarto (1981), who showed that a seeded form had the highest pollen grain stainability (99%), while a few-seeded form had medium stainability (45%) and a seedless form had low stainability (6%). Thus pollen sterility may be one factor contributing to seedlessness in certain forms.

A study of five, presumably seedless, breadfruit trees by Brantjes (1981) documented nectar production in male, but not female, inflorescences. Bees were seen feeding on secreted nectar and collecting pollen but were not seen visiting female inflorescences. He suggested that the lack of nectar secretion and absence of pollinators on female inflorescences meant the bees' feeding merely promoted release of pollen from the protruding anthers with the small, powdery pollen grains being spread by the wind. Honeybees have been observed visiting mature and ripening fruits of cultivars in the NTBG germplasm collection. The bees appear to be collecting latex that has oozed from the fruit surface. It is not known whether bees also visit newly emerging and receptive female inflorescences. Additional observations are necessary to determine the mode of pollination in breadfruit. *Artocarpus altilis*is diploid (2*n* = 56) and triploid (2*n* = 84) (Barrau 1976; Jarrett 1959; Ragone 1991a).
Seedlessness in breadfruit generally has been attributed to sterility due to triploidy, but failure of breadfruit to set seed can also be due to other genetic factors. A preliminary cytological

study of breadfruit by the author (Ragone 1991a) suggests that triploidy is the cause of sterility for those cultivars with a somatic number of 2*n*=84. In areas such as eastern Polynesia, where the majority of cultivars are seedless triploids, little viable pollen is produced, and breadfruit cultivars with seeds are very unusual.
Triploidy obviously cannot account for reduced fertility among diploid cultivars. Reduced seed number in some diploid cultivars is probably a by-product of the practice of clonally propagating these plants using root shoots or sections of roots.

Improvement and selection of breadfruit should focus on identification of:

- a suite of cultivars that when grown together will supply a consistent supply of fruit year-round
- high-yielding cultivars
- cultivars with good texture and flavour
- cultivars with improved keeping qualities
- cultivars suitable for processing into flour, chips and other products.

Seasonality

Breadfruit is a seasonal crop bearing fruits over a 4- to 6-month period and most varieties producing one or two crops per year. The main crop typically occurs during the hot, rainy, summer months, followed by a smaller crop 3–4 months later.
The fruiting season typically coincides with the wet, rainy summer months, but a smaller flush may occur about 5 months later for some varieties. New leaves are produced year-round, with a heavy flush after a period of rest that follows the end of the fruiting season.

In the South Seas, the tree fruits more or less continuously, fruit in all stages of development being present on the tree the year around, but there are two or three main fruiting periods. In the Caroline Islands and the Gilbert Islands, the main ripening season is May to July or September; in the Society Islands and New Hebrides, from November to April, the secondary crop being in July and August. Breadfruits are most abundant in Hawaiian markets off and on from July to February. Flowering starts in March in northern India and fruits are ready for harvest in about 3 months. Seeded breadfruits growing in the Eastern Caroline Islands fruit only once a year but the season is 3 months long—from December to March. Seedless varieties introduced from Ponape bear 2 to 3 times a year. In the Bahamas, breadfruit is available mainly from June to November, but some fruits may mature at other times during the year.

Fruit production capacity

Breadfruit produces numerous root shoots when roots are cut or damaged. It quickly regrows new shoots and branches after wind damage or when topped to facilitate harvest. Even large trees 1 m (3.3 ft) or greater in diameter will regenerate and produce fruits again in as soon as 2 years after severe pruning.
Trees begin bearing in 3–5 years and are productive for many decades. Those grown from root suckers will bear in 5 years and will be productive for 50 years. However, trees can live 80 years or more.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The trees take from 3 to 7 years to begin production. Once in production, the tree sets fruit more or less continuously, with fruit in all stages of development being present on the tree year around. However, there are generally two or three main fruiting periods.

Indeed, breadfruit bears seasonally, with most varieties producing one or two crops per year. The main crop typically occurs during the hot, rainy, summer months, followed by a smaller crop 3–4 months later. Vegetatively propagated trees start fruiting in 3–6 years. Grafted trees can begin bearing in 2–3 years. Trees grown from seed begin to flower and produce fruit in 6–10 years, or sooner.

In the South Pacific, the trees yield 50 to 150 fruits per year. In southern India, normal production is 150 to 200 fruits annually. Productivity varies between wet and dry areas. In the West Indies, a conservative estimate is 25 fruits per tree. Studies in Barbados indicate a reasonable potential of 6.7 to 13.4 tons per acre (16-32 tons/ha). Much higher yields have been forecasted, but experts are skeptical and view these as unrealistic

Yields are extremely variable, ranging from less than 100 to more than 700 fruits per tree, depending on the variety, age, and condition of the tree. Average yields are 150–200 fruits per tree.
A study of Pohnpeian varieties recorded:

Variety	Number of fruits	Average yield
'Mein iwe'	30–268	141
'Meın padahk'	26–557	219
'Meı uhwp'	10–615	218

Under orchard conditions, yield estimates range from 16 to 50 mt per ha (7–23 t/ac) of fruit based on 100 trees/ha (40 trees/ac). Approximately 5.5 mt per ha (2.4 t/ac) are produced in a traditional mixed agroforestry system on Pohnpei.

Most yield estimates are very general and a figure often cited is 700 fruits per tree per year, each averaging 1- 4 kg (Purseglove 1968). In the Caribbean a mature tree could bear up to 900 fruits/tree but the average in the region has been estimated at 200 fruits/tree, each weighing 1-2 kg (Marte 1986). A very conservative figure of only 25 fruits per tree was given for the West Indies (Morton 1987).

Actually, yields vary depending upon variety, age, tree health, and growing conditions, ranging from less than 100 to more than 600 fruit per tree with average yields of 150–250 fruit or 160–500 kg (350–1100 lb) per year. Approximately 5.5 MT/ha (2.4 T/ac) were produced in a traditional mixed agroforestry system on Pohnpei. Farmers in Tanzania reported yields of up to 900 fruit/tree, with an average of 400 fruit/tree (Maerere and Mgembe 2007). Approximately 75% of the fruit is edible (pulp). The skin is also edible and nutritious, although considered less palatable, and, along with the pulp, can be ground into flour, especially for animal feed.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Production and Production Constraints

During the 1st international breadfruit symposium report (April 16-19, 2007, Nadi, Fuji), a group focused on the various systems of production, namely home gardens and cultivated orchards. In home garden or backyard production, the aim is to produce food for household and community consumption. In cultivated orchards, the aim is to produce fruit for commercial purposes, whether fresh or processed, and for both domestic and export markets.
The group recognized the need to determine and document the growing conditions for breadfruit (i.e., suitable temperature, altitude, and availability of water and suitable soil).
This would enable regions/countries to determine where breadfruit could be grown (assuming it is not grown now) and could help in areas where there are food security issues, such as in parts of Africa. Many countries and regions are cultivating local "well-known" varieties so new varieties are needed to extend production and address soil/environmental constraints. In addition, production techniques require optimization, including propagation, tree management (pruning, mulching), and harvesting, etc.

General constraints were identified as:

- Availability of land or competition for land.
- Lack of interest from government, farmers, and the target population.
- Availability and knowledge of planting material.
- Limited knowledge of production techniques.
- Poor or no research in areas such as salinity tolerance or fruit rot management, etc.

The group looked at ways in which traditional production systems could be improved; the Following essential aspects were identified:

- Raise awareness about the qualities of breadfruit.
- Plant different varieties to increase production and provide year round availability.
- Develop good production practices specific to the area and for different varieties of breadfruit.
- Address specific needs (i.e., salinity-tolerant varieties, fruit rot problems, nutrient deficiencies, etc.).
- Include breadfruit in agro-forestry projects.

Besides, the group identified a number of constraints to commercial production:

- Lack of interest in the crop.
- No real experience with commercial breadfruit orchards
- Availability of planting material and knowledge of planting material.
- Limited and un-dispersed knowledge of good production practices in an orchard setting
- Feasibility (e.g., What is the minimum farm size?).

This discussion enables the group to determine what needs to happen for commercial production to both expand and improve. The following suggestions were made:

- Plant breadfruit orchards and experiment with production techniques—pruning, harvesting, etc.
- Keep good records and make the information of successes and failures available globally.
- Successful growers should lead by example.

According to the group, there is no point in improving production without taking the market into account. Hence, the group highlighted the following:

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

- The focus for commercial production should be in countries where there are resources and infrastructure to support industry.
- Market identification is obviously crucial.
- Identify desired products and production practices designed specifically to meet the demand for “a product”.
- Packages of production practices should be designed/available to meet this market.
- Make product information available and disseminate this in a suitable form.

- Embark on commercial production by planting breadfruit orchards and experimenting with production techniques (e.g., pruning, harvesting, etc.)

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

7. Harvest and Postharvest

Breadfruits are harvested as needed and generally picked when mature but not yet ripe. They are typically ready for harvest about 3 months after flowering. The proper stage for harvesting breadfruit depends on the intended use. Careful harvest and postharvest handling is essential for maintaining fruit quality. Fruits that fall to the ground may be bruised and soften sooner than those that are gently handled. Breadfruits are usually harvested with a sharp scythe or curved knife attached to the end of a long, sturdy pole and are allowed to drop to the ground in most areas. Some common tools for harvesting fruit are a long picking pole with a forked end to clasp the stem or a woven or mesh bag to catch the fruit. Tripod orchard ladders are very practical, as the tripod de- sign allows them to be safely used on uneven or rough terrain. Made of aluminum they are lightweight, sturdy, and durable. Commercial ladders range in height from 1.5 m to 4.9 m (5–16 ft), depending on the manufacturer.

They are picked when maturity is indicated by the appearance of small drops of latex on the surface. Harvesters climb the trees and break the fruit stalk with a forked stick so that the fruit will fall. Even though this may cause some bruising or splitting, it is considered better than catching the fruits by hand because the broken pedicel leaks much latex. They are packed in cartons in which they are separated individually by dividers.

The principal external indices of harvest maturity are skin colour, texture and appearance of the fruit surface, and firmness.

Breadfruit should be harvested when green in colour and firm in texture if it is to be used as a starchy vegetable. The fruit should be left to ripen and harvested at a later stage when used as a dessert. The skin colour of ripe fruit becomes yellow-green with red-brown areas. In addition, the stem of ripe fruit becomes yellow-green in colour.

The texture and appearance of the fruit surface is indicative of harvest maturity. The surface of breadfruit is patterned with irregular polygon shaped segments which flatten and enlarge upon maturity. Breadfruit harvested as a starchy vegetable should have noticeable protruding segments on the surface that tend to be angular and ridged, while the individual segments of dessert-stage fruit should be smoother, flatter, and more round.

Harvest maturity is also indicated by the presence of latex stains on the surface of the fruit and a lack of luster. Fruit are ready for harvest as a starchy vegetable once small drops of latex appear on the surface or brown stains become noticeable (Figure 1). The amount of brown staining intensifies as the fruit become fully ripe. Fruit firmness can also be used to determine harvest maturity. Unripe starchy fruit will be solid and not yield when squeezed, while ripe dessert stage fruit will be noticeably softer and yield when squeezed.

The principal internal indices of breadfruit maturity are flesh colour and sugar composition. The flesh of mature but unripe breadfruit is white, starchy, and somewhat fibrous. Fully ripe breadfruit has a pale yellow flesh colour and is somewhat soft and fragrant. Unripe breadfruit has very little sugar and is consumed primarily for its starchy texture. The pulp of unripe breadfruit typically contains 25% to 30% carbohydrate, half of which is starch. As the fruit continues to mature, the flesh becomes noticeably sweeter due to conversion of some of the starch into sugar.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The fruit on a tree are of different physiological ages and do not reach maturity simultaneously. Therefore, harvesting involves climbing the tree and/or using a long pruning pole, where the fruit is cut and caught by hand or in a net, before hitting the ground. Where the fruit can be reached, they should be harvested by snapping the stem of the fruit off the tree at the point adjacent to the branch, and not the fruit. Latex typically exudes from stems cut too short, and if allowed to contact the fruit surface will result in brown staining. Stem length should generally be between 5 cm to 12.5 cm (2 in to 5 in). When the stem is cut too short, it should be allowed to drain before putting the fruit in the harvest container. Care must also be taken to avoid damage to the fruit surface during harvest. Latex exudes from damaged tissue and causes staining. Breadfruit should never be knocked from the tree or dropped to the ground, as the resultant bruising will cause rapid softening and a significant reduction in market life.

After detachment, the fruit should be carefully lowered to the ground and placed on a clean surface in a shaded area with the stem pointed outwards. The stem should be re-cut with a sharp knife to a length of several centimeters. The cut stem should be oriented downward to prevent latex exudation onto the fruit surface and subsequent brown staining of the skin. The latex flow will soon cease and the fruit should be graded in the field to remove decayed, damaged, undersized, over-ripe, or stem-less fruit.

The marketable breadfruit should be transferred to a strong wooden or durable plastic field container which is well ventilated and has a smooth inside finish to avoid abrasion damage of the fruit surface. Synthetic sacks or mesh bags should not be used as field containers. The coarse texture of the woven fabric will cause abrasion damage to the fruit surface as the sacks are transported. As a result, latex exudation will occur and the fruit surface will be stained.

The field containers should be carefully loaded and stacked in the transport vehicle to minimize handling damage to the fruit. There should be adequate ventilation through the field containers and the transport vehicle should have a protective cover over the breadfruit containers. Ideally, the fruit should be transported during the coolest time of
the day in order to minimize heat build-up inside the transport vehicle. Upon arrival at the packing area or consolidation facility, the field containers should be unloaded with care and put in a shaded well-ventilated area protected from rain.

Preparation for Market

Various steps should be followed in preparing breadfruit for market. These involve cleaning, grading/sorting, packing, possibly waxing, and in some cases storage.

Cleaning

The initial step in preparing breadfruit for market is to clean the surface of the fruit and remove any dirt or adhering leaf tissue. Latex stains should be avoided by using careful harvesting and handling practices. However, once the fruit surface has been stained, it is generally not possible to remove the stains.

Small scale operations usually choose to clean the individual fruit by wiping them with a damp cloth. Larger volume operations may choose to use a water dump tank or overhead spray wash system to clean the fruit. In order to avoid the spread of disease, the wash water should be clean and regularly sanitized by maintaining a 150 ppm sodium hypochlorite

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

concentration and a water pH of 6.5. The chlorine level and pH of the wash water should be checked frequently during the day with paper test strips or portable meters. Following cleaning, the fruit should be placed on a flat surface to air dry prior to grading/sorting, possibly waxing, and packing.

Grading/Sorting

The next step in market preparation involves making a final selection of the fruit according to the requirements of the market. The quality requirements of export grade breadfruit are considerably more stringent than domestic marketed fruit. However, there are no domestic or international grade standards for breadfruit. Regardless of the market destination, the fruit should be sorted according to size, shape, firmness, and appearance. The fruit should be mature, firm, clean, free of objectionable latex stains, uniformly shaped, free of wounds and cracks, and free of sunburn, insect damage and decay. In addition, the fruit should have an intact green stem with a length of several centimeters.

Breadfruit intended for the export market should have a minimum weight of 1.2 kg (2.5 lb) and a maximum weight of 3 kg (6.6 lb). The fruit should be classified into several different sizes. Fruit classified as large should weigh between: 2 kg to 3 kg (4.4 lb to 7 lb). Fruit classified as small should weigh between 1.2 kg to 2 kg (3 lb to 4.4 lb). Fruit shape can be either round or ovoid and the diameter should be between 20 cm to 30 cm (8 in to 12 in).

Waxing

Breadfruit may benefit from a postharvest wax application. Waxing reduces postharvest weight loss, minimizes shriveling, and extends market life. A thin coating of paraffin wax is most commonly used. It is applied by rapidly dipping the fruit in a solution of liquid paraffin. A carnauba-based wax may be used if the market prefers a more shiny surface. The simplest ways to make a carnauba wax application are as a manual rub or an overhead spray of water-emulsion wax as the fruit are rotating on a bed of soft brushes.

Packing

Breadfruit is packed in various types of containers, depending on the market destination. A strong, stackable, well-ventilated wooden crate is preferred for domestic marketing. The crates should be lined with newspaper to minimize abrasion of the breadfruit surface. Packing of breadfruit in large synthetic or mesh sacks should be avoided, as these types of containers offer little or no protection to the fruit. Considerable bruise damage and skin abrasion may occur to the breadfruit during transit and handling. Breadfruit destined for export is typically packed in strong, well-ventilated fiberboard cartons weighing either 9 kg or 18 kg (20 lb or 40 lb). Fruit are packed according to count (size). A single layer of uniformly sized and shaped fruit is put in each carton. Thin fiberboard dividers are used to separate the fruit within the carton in order to minimize surface abrasion and skin damage.

Principal Postharvest Diseases

Breadfruit is susceptible to several different postharvest diseases, although to a lesser degree than many other tropical fruit. Fungal and bacterial infections are usually seen when the fruits are very ripe and the internal structure begins to break down. Physical damage is the major cause of postharvest decay of unripe breadfruit. Physical damage may be incurred during harvest, by rough handling, from improper packaging, or during transport. Wounds such as punctures, cuts, abrasions, and cracks provide potential points of entry for decay organisms.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Postharvest decay can be adequately controlled by following a regular sanitation program in the field, application of pre-harvest fungicides, careful harvesting and handling practices to avoid wounding of the fruit, and holding the fruit at 12.5°C (55°F).

The principal postharvest fungal diseases causing fruit decay are brown rot (*Phytophthora palmivora*), soft rot (*Rhizopus artocarpi*), and pink rot (*Botryobasidium palmivora*). Brown rot is usually the most common and produces circular to oval-shaped brown lesions on the fruit surface.

Postharvest Disorders

Chilling Injury

Storage of breadfruit at temperatures below 12°C (54°F) will result in chilling injury (CI). It is a type of low-temperature injury that becomes more severe as the temperature decreases and the length of exposure increases. Damage from CI may occur within 7 days of storage at 4°C (40°F). Symptoms of CI include a brown scald-like discolouration of the skin, internal browning of the flesh, increased water loss, increased susceptibility to decay, and detrimental changes in flavour. Fruit texture will also be adversely affected, as the flesh will not soften uniformly.

Preservation

Since breadfruit is a seasonal crop that produces much more than can be consumed fresh, Pacific islanders have developed many techniques to utilize large harvesters and extend its availability (Murai *et al.* 1958; Barrau 1961; Yen 1975; Cox 1980; Atchley and Cox 1985; Aalbersberg *et al.* 1988; Ragone 1991b; Pollock 1984, 1992). Preserved breadfruit also adds diversity to the daily diet. The most common method of preservation is a preparation of fermented, pit-preserved breadfruit called *ma, massi, mahr, furo, or bwir*

Pit storage is a semi anaerobic fermentation process involving intense acidification which reduces fruit to a sour taste. Fermented breadfruit still made every season throughout Micronesia and to a limited extent in the pacific.

The traditional Pacific breadfruit preservation method of fermenting fruit in a leaf-lined pit, or more recently, in plastic or metal containers, deserves attention. Ripe fruit can be dried in thin sheets as a delicious "fruit leather" or mixed with other locally grown products to create fruit bars. Chips and other snack foods fried in coconut or other oil can be sold locally. For export, these snacks require greater investment in energy, equipment, packaging materials, and preservatives to maintain freshness and quality.

Drying is another common method used to preserved breadfruit. The simplest methods involve slicing raw or cooked breadfruit and drying it in the sun or on hot stones. Morton (1987) reported that seedless breadfruit are cut into slices and dried for four days at 49ºC in the Seychelles. In Sri Lanka, slices are dipped into a salt solution, blanched in boiling water for 5 minutes and dried at 80ºC for 4-6 hours. These will keep for 8-10 months. The dried pieces are placed in leaf-lined oven baskets, hung over the fireplace and can be stored for up to 3 years. Dried breadfruit is usually eaten without additional preparation but can be made into soup, or ground into meal and mixed with water or coconut cream to make porridge.

Minimally processed pulp has the appearance, texture, and taste of fresh breadfruit. Minimal processing involves placing slices or cubes of fruit in plastic bags, vacuum sealing, then immersing in boiling water so the heat penetrates through the bags and the surface of the pulp reaches at least 80°C (176°F) for 15 seconds (Beyer 2005). The pouches are immediately

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

cooled using cold water to prevent overcooking. This is repeated 24 hours later and again on the third day. This technique results in pack sterility.

Where refrigeration/freezer facilities are economically feasible, and enough product is available to process, peeled mature and ripe fruit can be frozen. Frozen fruit can be thawed, cooked, and mixed into dough that makes excellent extruded products. Frozen breadfruit "French fries" could replace imported fries made from potatoes.

In Jamaica, surplus breadfruits are often kept under water until needed. Fully ripe fruits that have fallen from the tree can be wrapped in polyethylene, or put into polyethylene bags, and kept for 10 days in storage at a temperature of 53.6°F (12°C). At lower temperature, the fruit shows chilling injury. Slightly unripe fruits that have been caught by hand when knocked down can be maintained for 15 days under the same conditions. The thickness of the polyethylene is important: 38-or even 50-micrometer bags are beneficial, but not 25-micrometer.

Some Jamaican exporters partly roast the whole fruits to coagulate the latex, let them cool, and then ship them by sea to New York and Europe.

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Temperature Control

The optimum storage temperature for breadfruit is 12.5°C (55°F). Potential market life at this temperature will be 3 weeks. Storage at higher temperatures will result in fruit softening and significantly reduce market life. Holding breadfruit at ambient temperature will likely allow for no more than 1 week of market life. On the other hand, holding breadfruit below 12°C (54°F) will result in chilling injury. Storage of breadfruit in poorly ventilated areas or with other high ethylene producing fruits should be avoided.

Relative Humidity

The optimal relative humidity (RH) for holding breadfruit is between 90% to 95%.
Weight loss and shriveling of the fruit surface is significantly higher at low RH's.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Shelf-life

Studies to extend the shelf-life of breadfruit (Thompson *et al.*1974; Marriott *et al.* 1979; Passam *et al.* 1981) demonstrated that whole fruits can be stored in sealed polyethylene bags at low temperatures; however, fruits showed symptoms of chilling injury at temperatures below 12°C. Fruits of the 'White heart' cultivar in Trinidad were successfully stored at 14°C for up to 10days. Unwrapped fruits ripened within 7 days at this temperature.

Studies in the Caribbean have emphasized the need for careful post-harvest handling, since losses may reach as high as 50% (Narasimhan 1990). Careful postharvest handling will improve the shelf-life and quality of breadfruit (Maharaj and Sankat 1990). Fruits of the 'Yellow heart' cultivar were carefully harvested and precooled in the field and during transport using chipped ice. They were further precooled to an internal temperature of 16°C in an ice-water bath, then air-dried and stored untreated or in sealed polyethylene bags under ambient and refrigerated conditions. At ambient (28°C) temperature untreated fruits lasted only 2-3 days before softening while those stored in water had a maximum shelf-life of 5 days.Fruits sealed in polyethylene bags have a shelf-life of 5-7 days and waxed fruits can last 8 days.

The shelf-life of untreated and packaged fruits was markedly increased by refrigeration. Packaged fruits at all temperatures were still firm at day 25 but quality declined and chilling injury appeared after only 4 days at 8°C when fruits showed considerable browning of the skin. Under refrigeration, satisfactory fruit quality can best be maintained at temperatures of 12-16°C. At these temperatures, a shelf-life of 10 days appears possible for untreated fruits and 14 days for packaged fruits. Waxed fruits at 16°C were able to store for about 18 days in the first trial and about 10 days in the second trial as external browning limited acceptability in storage.
Breadfruits kept at 16°C in atmospheric containers of 5% carbon dioxide and 5% oxygen showed significantly less skin browning and remained firm for 25 days. Controlled-atmosphere storage has excellent possibilities for breadfruit preservation. However, it may not be feasible for most breadfruit-producing areas because of the cost. Additional research in this area will help expand the use of fresh breadfruit beyond the local market.

Shelf life can be extended by careful harvesting and pre-cooling fruits with chipped ice in the field and during transport. Covering fruits with water can also delay ripening for a few days.

Waxing

Breadfruit may benefit from a postharvest wax application. Waxing reduces postharvest weight loss, minimizes shriveling, and extends market life.

Packing

Breadfruit is packed in various types of containers, depending on the market destination. A strong, stackable, well-ventilated wooden crate is preferred for domestic marketing. The crates should be lined with newspaper to minimize abrasion of the breadfruit surface. Packing of breadfruit in large synthetic or mesh sacks should be avoided, as these types of containers offer little or no protection to the fruit. Considerable bruise damage and skin abrasion may occur to the breadfruit during transit and handling. Breadfruit destined for export is typically packed in strong, well-ventilated fiberboard cartons weighing either 9 kg or 18 kg (20 lb or 40 lb). Fruit are packed according to count (size). A single layer of uniformly sized and shaped fruit is put in each carton. Thin fiberboard dividers are used to separate the fruit within the carton in order to minimize surface abrasion and skin damage.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

New Zealand requires that imported fruit go through a high temperature forced air quarantine treatment to kill fruit fly eggs and larvae. The fruit is then inspected, packed, and held at 15°C (40°F) for shipment; at which temperature fruit can remain firm for 10 days (Stice et al. 2007).

Recommendations of 2007 Symposium:

A variety of convenient products with extended shelf life to replace imported less-healthy staple foods and snack foods, targeting all age groups can be developed.

A methodology for extending seed shelf life to enable the exchange of seeds between other countries should be investigated

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

8. Product Development and Marketing

Processing

Traditional breadfruit products

The nutritional composition of fermented breadfruit *madrai* prepared in the traditional way has been reported for Fiji (Aalbersberg *et al.*1988). Peeled, seedless, whole mature breadfruit were placed in a pit, and samples were removed and analyzed after 5 days, weekly for 7 weeks, then at weeks 15 and 21. The pH in the pit decreased from 6.7 (close to neutral) for fresh fruit to a quite acidic value of 4.3 in 2 weeks. Protein and carbohydrate levels remained relatively unchanged for the entire time. Fat content increased slightly from 0.71 g for fresh fruit to a high of 1.13 g after 3 weeks. Iron and calcium levels were slightly higher for fermented breadfruit, reaching their maximum at 15 or 21 weeks.

The starch is broken down first to maltose, then glucose, and eventually to lactic acid and carbon dioxide. Lactic acid in fresh breadfruit is only 0.09 g but rises to 0.88 g after only 5 days in the pit, increasing to a maximum of 1.29 g after 4 weeks, and declining to 0.56 g after 21 weeks. The strong characteristic smell emanating from the newly opened pit is due primarily to lactic acid and butyric acid that may be produced by secondary aerobic fermentation of the lactic acid. Analysis by gas chromatography of volatiles from breadfruit after extended fermentation showed the presence of a range of alcohols and organic acids, with ethanol the largest component at 34% (Whitney 1988). No ethanol was detected in samples of fresh breadfruit, while breadfruit boiled for 10minutes contained 16% (Iwaoka *et al.*1994).

Another type of preserved breadfruit, a breadfruit paste (*paka kuru*) from the Micronesian island of Kapingamarangi, was analyzed (Murai *et al.* 1958). The resulting paste is a concentrated, nutrient-rich food containing only 21% water, compared with the 60-70% water content of fresh or cooked fruits. It contained 68 g of carbohydrates, double the amount that the authors reported for fresh or cooked breadfruit. Protein and fat levels were substantially higher in the paste, with almost five times the average amount of protein and fat found in fresh or cooked breadfruit. Calcium and phosphorus levels were notably higher than that of fresh or cooked breadfruit. Iron, thiamin and riboflavin were the only nutrients with lower levels in the paste.

Commercial processing

Commercial processing of breadfruit is still in its initial stages. Slices canned in brine are produced in Jamaica for local and export markets (Thompson *et al*. 1974). Breadfruit flour and chips have been made on a limited basis, and the flour has been evaluated as a substitute for enriched wheat flour and as a base for instant baby food.

A preparation made with 25% breadfruit flour and 75% banana flour was comparable to the flavour and appearance of baby food made from commercial flour (Esparagoza and Tangonan 1993). In Brazil, Puerto Rico and Cameroon, the starch has been extracted and may find use in industrial applications such as textile manufacture (Roberts-Nkrumah 1993).

The dried fruit has been made into flour and improved methods have been explored in Barbados and Brazil with a view to substituting breadfruit in part for wheat flour in breadmaking

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Soft or overripe breadfruit is best for making chips and these are being manufactured commercially in Trinidad and Barbados. Some breadfruit is canned in Dominica and Trinidad for shipment to London and New York. Minor fruit in Guyana, with almost the entire production volume marketed domestically.

Experiments by technologists at the United States Department of Agriculture's Western Regional Research Laboratory in Berkeley, California, have demonstrated that breadfruit can be commercially dehydrated by tunnel drying or freeze-drying and the waste from these processes constitutes a highly-digestible stock feed.

Breadfruit's seasonal nature makes profitable processing difficult. food processing operations must operate extremely efficiently because competition keeps profit margins low. Idle time during processing is highly unprofitable because fixed costs accrue and production of finished products for sale diminishes. This is the driving force for mass production (Beyer 2007). Seasonal supply difficulties can be mitigated by:

1) bulk preservation (i.e., drying/freezing raw material at the height of the season);
2) dovetailing breadfruit processing with other products with different seasonal glut; and,
3) planting varieties with sequential seasons.

Development of products for local use to replace imported foodstuffs or products that are shipped via sea freight is the most cost effective and beneficial to local economies. The simplest, most cost- and energy-efficient means of processing breadfruit is to slice or shred raw fruit, dry the pieces using a solar dryer/dehydrator (electric dryers are more en- ergy intensive), and grind into a rough meal or flour. A traditional method of drying involves roasting whole fruit in a fire, cutting it into small pieces, and drying over a hot fire. These pieces (called *namba* in the Solomon Islands) have a pleasant, smoky flavor.

Consider using traditional methodology, such as fermentation, for product development, rather than concentrating all efforts on modern methodology

Value-added products

Processing breadfruit into a snack such as chips may be a useful value-adding preservation method of breadfruit.

In an experiment carried out, breadfruit chips were packed into metallized, commercial 75-gauge polypropylene / polyethylene bags and hermetically sealed in air. Packaged samples were stored at 2, 27 and 55°C and analyzed at 3-day intervals. Storage temperature clearly influenced the keeping quality of chips. Rancidity was detected in chips after 21 days at 27°C, and was comparable to plantain and banana chips at 24 days, after which rancidity in b re a d f ruit chips accelerated. Chips became rancid sooner at the higher storage t e m p e r a t u re while those stored at 2°C showed little change in quality for the duration of the study.

Flour is another potential commercial product that can be made from breadfruit. Imports of wheat flour can be decreased by substituting a locally grown foodstuff, such as breadfruit, for a portion of wheat flour used in making bread and other baked goods. Breadfruit flour was made from firm, mature breadfruit from Puerto Rico that was peeled, cored, cut into pieces and dried at 80°C for 24 hours (Nochera and Caldwell 1992). The flour contained 4.4% protein, 1.1% fat and 6.4% fiber and ash. It contained higher levels of two essential amino

acids, lysine and threonine, than wheat flour. A composite flour was made by substituting 5, 10, 15 or 20% of enriched white flour with breadfruit flour and 5 or 10% of white flour by soy protein, peanut meal or whey. The latter products were added to increase the protein content of the composite flour since enriched white flour has a higher protein content (10-12%) than breadfruit flour. Standard recipes were used to make breads and biscuits with the composite flour. Baked goods were evaluated for acceptability of colour, texture and flavour with breads made from 10% breadfruit and 5% whey preferred.

Breadfruit starch has been isolated and characterized. Starch was extracted from firm, mature breadfruit from Puerto Rico that were peeled, cored, cut into pieces and dried at 80°C for 24 hours and ground into flour (Loos *et al.* 1981). The starch was then freeze-dried for 24 hours and pulverized into a fine powder. The resulting starch was 90% pure and contained 18.2% amylose. Granules were spherical and segmented and appeared to be compound. The intrinsic viscosity of starch was higher than the reported values for wheat, cassava and arrowroot starches. At concentrations of 4-5% the viscosity held stable throughout a heating-cooling cycle. At higher starch concentrations (7-8%), the cooled gels exhibited a breakdown in viscosity during prolonged heating and stirring comparable to potato starch.

Reeve (1974) studied the commercial dehydration potential of breadfruit. Firm, mature breadfruits from Puerto Rico were peeled, cored and the edible pulp cut into small cubes or slices and tunnel-dried for 4 hours at 60°C or freeze-dried overnight. These were reconstituted and their textural qualities compared with that of freshly boiled, steamed and whole-baked breadfruit. No significant difference could be observed microscopically between freshly baked or boiled and the tunnel-dried breadfruit. There was little difference in colour slices that had been blanched for 3 minutes or treated with 3% sodium sulfite before tunnel drying, indicating that there is no need for sulfite treatment. Both forms reconstituted readily in cold or hot water and textural qualities were the same. Culinary qualities were very similar to those of freshly boiled or steamed samples.

Freeze-dried breadfruit was slightly greyish-white and chalky in appearance. It reconstituted quickly in cold water but raw texture was not fully restored. When reconstituted in hot or boiling water, the texture and flavour were very similar to the blanched or freshly cooked product. Keeping quality of both forms of dried breadfruit were good. No off-odour was detected in freeze-dried sections kept for 6 months at room temperature. When reconstituted in hot water, these made an excellent substitute for sliced potato in a scalloped-potato and cheese recipe. Both forms are suitable for grinding or crushing into flour. The practicality of producing dehydrated breadfruit flakes or granules, such as instant mashed potatoes, is limited because the textural characteristics of freshly cooked breadfruit are very different from white potato.

Cooked breadfruit can be frozen, and this storage method deserves greater attention as it may provide a simple, effective means to better utilize this crop, at least in areas where electricity and refrigeration facilities are available and affordable. Fruits of ‘ Yellow heart’ cultivar were peeled, quartered and cored and the edible pulp cut into small, wedge-shaped sections weighing approximately 15 g each (Passam *et al.*1981). These segments were boiled for differing lengths of time (ranging from 1 to 10 minutes), then air-cooled, wrapped in aluminium foil and frozen at -15°C. Segments which had been boiled for 2-5 minutes compared most favourably in flavour, colour and texture of fresh-cooked breadfruit. Segments that were frozen without pre-boiling discoloured on cooking after storage and had poor flavour. After 10 weeks in the freezer, there was no deterioration in quality and the

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

storage life of this product may be much longer. It may be possible to use this method to process and store larger segments, or even slices, which are preferable for boiling or roasting.

Dried breadfruit has been made into flour and improved methods have been explored in Barbados and Brazil with a view to substituting breadfruit in part for wheat flour in breadmaking. The combination has been found more nutritious than wheat flour alone. Breadfruit flour is much richer than wheat flour in lysine and other essential amino acids. In Jamaica, the flour is boiled, sweetened, and eaten as porridge for breakfast.

Soft or overripe breadfruit is best for making chips and these are being manufactured commercially in Trinidad and Barbados. Some breadfruit is canned in Dominica and Trinidad for shipment to London and New York.

Recommendations of 2007 Symposium:

The group of the 1st international breadfruit symposium report (April 16-19, 2007, Nadi, Fiji), identify desired products and production practices designed specifically to meet the demand for "a product." Develop packages of production practices for specific products which should be disseminated in a suitable form.
One of the major problems identified by all Symposium participants was the disinterest of youth in breadfruit. The group gave special consideration to this issue and felt that youth must be targeted. Increased consumption of non-traditional foods and the increasing consumption of "junk" foods were identified as common throughout the participating countries and a problem that was contributing significantly to the rise in lifestyle diseases.

Suggestions as to how the attitude of youth towards breadfruit could be influenced are:

- Endorsement by popular sporting icons (rugby-Fijian, soccer-Indians, NFLPolynesians), stressing breadfruit as caloric/energy food.
- Stress breadfruit as a food beneficial to health.
- Raise infants on breadfruit-based formulas. Produce cookbooks/manuals with traditional and modern recipes.

In line with promoting breadfruit, the group identified the need for new products, such as:

- A variety of convenient products with extended shelf life to replace imported less healthy staple foods and snack foods.
- Products using traditional methods (such as fermentation) as well as using modern methodology.
- Where applicable—use fermented breadfruit products as a replacement for traditional fermented products from starchy staples like cassava or taro.
- Alcoholic beverages using breadfruit.

Note: Appropriate machinery for industrial processing would have to be developed to support product innovation.

The Breadfruit destined for export is typically packed in strong, well-ventilated fiberboard cartons weighing either 9 kg or 18 kg (20 lb or 40 lb). Fruit are packed according to count (size). A single layer of uniformly sized and shaped fruit is put in each carton. Thin fiberboard dividers are used to separate the fruit within the carton in order to minimize surface abrasion and skin damage.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

An attractive label and packaging draws the consumer's attention to the product and helps with marketing. If certified organic by an independent, internationally recognized organization, the certifying organization's name and logo should appear on the label. Exporters should research and comply with the requirements of the importing country.

There are several promising specialty markets, including

- organic and natural foods
- bird, bee, and flying fox friendly (conservation twist)
- watershed protection
- sustainable agriculture, and
- potential carbon credits.

The historical importance of breadfruit and name recognition in many countries (based on its connection to *Mutiny on the Bounty*) could play a key factor in marketing. Specialty varieties identified by region could also be helpful in catering to expatriate markets.

Recommendations of 2007 Symposium:

The group of the 1st international breadfruit symposium report (April 16-19, 2007, Nadi, Fiji), identified an urgent need for a database to keep track of breadfruit products.
Papers presented at the Symposium revealed that there is significant information "out there" but it is not easily accessible and therefore not utilized. In discussing the products, an attempt was made to distinguish between the wide range of products available on the basis of whether they were still at the research and development stage or were good marketable products. For example, the role of breadfruit as a weaning food was considered to be still at the R&D stage, whereas minimal processing, although not yet being marketed, showed promise. In contrast, fresh fruit is generally the most marketable product.
In considering how best to support product development and marketing, the group focused on lessons learnt to determine the key problem areas, identified as:

- People's perception of breadfruit is poor and therefore there is an urgent need to increase awareness about its positive attributes.
- Lack of varieties for all-year-round production makes it difficult for R&D efforts.
- Limited R&D on extending the shelf life of breadfruit.
- Very poor documentation on all relevant information on breadfruit products.
- Limited range of products for targeting all age groups—infants, adolescents, and aged (geriatrics).

On the issue of marketing, and how to better market breadfruit, the group suggested the following approaches as options for making progress:

- Stress the sensory, health, cultural, food security, environmental, and fair trade aspects of breadfruit, and label appropriately.
- Organize promotional activities—cooking competitions, media activities (jingles, drama sketches, etc.).
- Appeal to patriotic instinct for local patronage.

The Product Development and Marketing group prioritized their recommendations as follows:

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

1. Trade agreements which promote and support export and import substitution policies are necessary to support the trade of breadfruit products.
2. Documentation is essential both as information for product development and to increase awareness.
3. A variety of convenient breadfruit products with extended shelf life are needed to replace imported less healthy staple foods and snack foods, and these should target all age groups.
4. Promotional activities are required to improve people's perception of breadfruit and to support marketing —youth need to be targeted in this campaign.
5. To improve marketing, different approaches (e.g., health, cultural, food security, environmental and fair trade) should be taken.

Uses of the fresh fruit

Bread fruit produces a highly nutritious, high-carbohydrate fruit that can be consumed at all stages of maturity. A high-quality starch can be easily extracted from the fruit. Breadnut yields low-fat, high-protein, edible seeds. These multipurpose trees are long-lived, producing for more than 50 years and providing nutritious fru i t s for human consumption, timber and feed for animals. They require little input of labour or materials and can be grown under a range of ecological conditions.

Fruit texture is an important attribute that affects cooking and processing. Seedless and few-seeded breadfruit both exhibits a wide range of textures at the mature stage. The pre f e r red fruits are those that are dense, smooth and creamy when cooked. T h e re are cultivars with mealy flesh, as well as ones with fibrous, stringy flesh, and spongy ones which are full of what appear to be fine threads of latex. Cooking and p rocessing are also affected by the amount of latex present in a mature fruit. There are many cultivars which exude little or no latex when cut, but others produce pro f u s e amounts of sticky latex from the fruit core and even the flesh itself. The latex oxidizes upon exposure to air and rapidly discolours. The latex is viscous and adheres and h a rdens onto knives, utensils, cooking pots and other surfaces that it touches.

The quality of cooked fruit also depends on the method of preparation: diff e re n t cultivars provide diff e rent results when boiled, roasted or baked. Some cultivars are suitable for roasting but become mushy and fall apart when boiled. The potential for wide-scale processing by freezing, canning or production of flour will be enhanced by selection of suitable cultivars. The presence or absence of seeds wills of course aff e c t how fruits are handled and processed. Fruits with seeds are probably inappro p r i a t e for large-scale canning or chip-making operations but are excellent for home use because the seeds are a good source of protein and make bre a d f ruit a more complete food. Since breadfruit is generally preferred while mature and still firm, nutritional studies, development of commercial products and research to extend shelf-life have focused on this stage. Ripe fruits generally go to waste or are used as animal food, and there has been little attention given to expanding the use of ripe fruits. A much greater proportion of the breadfruit crop could be utilized and marketed if food products incorporating ripe breadfruit, such as baby foods, baked goods and desserts, are developed.

Hundreds of traditional cultivars have been selected based on flavour, texture, size and cooking or storage qualities of the fruit, horticultural requirements, bearing season, yield and productivity.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Breadfruit is a versatile food and can be cooked and eaten at all stages of maturity, although it is most commonly harvested and consumed when mature, but still firm, and used as a starchy staple. The relatively bland fruit can form the basis for an array of dishes, and it takes on the flavour of other ingredients in the dish. Very small fruits, 2-6 cm or larger in diameter, can be boiled and have a flavour similar to that of artichoke hearts. These can be pickled or marinated. Mature and almost mature breadfruit can be boiled and substituted for potatoes in many recipes. Ripe fruits are very sweet and used to make pies, cakes and other desserts. Breadfruit is prepared boiled, steamed or roasted in the Caribbean and has lent itself to the creation of regional dishes such as ' oil down' which is popular in Trinidad and Tobago and Grenada (Leakey 1977; McIntoch and Manchew 1993). It is made with salt-cured meats, breadfruit, coconut milk and dasheen leaves. In the Philippines, breadfruit is eaten boiled and sliced with coconut and sugar as a sweet, and candied breadfruit made from mature breadfruit will keep for about 3 months (Coronel 1983).

The small, immature fruits of breadnut are sliced and cooked as vegetables, seeds and all (Brown 1943). Seeds are harvested from ripe fruits and boiled or roasted with salt. They are sometimes made into a puree in West Africa (Morton 1987). Breadfruit seeds are usually cooked with the raw breadfruit or are boiled or roasted. Seeded forms of breadfruit predominate on many atolls in Micronesia and seeds contribute to the daily diet. In the Marshall Islands, seeds are sometimes not cooked and eaten until they sprout (Murai *et al.* 1958).

The fruit can be cooked and eaten at all stages of maturity, is high in carbohydrates, and is a good source of minerals and vitamins. In addition to producing abundant, nutritious, tasty fruits, this multipurpose tree provides medicine, construction materials, and animal feed.

Most breadfruit is produced for subsistence purposes and small quantities are available for sale in town markets as fresh fruit or chips.

The breadfruit tree is much grown for shade in Yucatan. It is very common in the lowlands of Colombia, a popular food in the Cauca Valley, the Choco, and the San Andres Islands; mostly fed to live stock in other areas. In Guyana, in 1978, about 1,000 new breadfruit trees were being produced each year but not nearly enough to fill requests for plants. There and in Trinidad, because of many Asians in the population, both seeded and seedless breadfruits are much appreciated as a regular article of the diet; in some other areas of the Caribbean, breadfruit is regarded merely as a food for the poor for use only in emergencies. Nowadays, it is attracting the attention of gourmets and some islands are making small shipments to the United States, Canada and Europe for specialized ethnic markets. In the Palau Islands of the South Pacific, breadfruit is being outclassed by cassava and imported flour and rice.

The breadfruit may be eaten ripe as a fruit or underripe as a vegetable. For the latter purpose, it is picked while still starchy and is boiled or, in the traditional Pacific Island fashion, roasted in an underground oven on pre-heated rocks. Sometimes it is cored and stuffed with coconut before roasting. Malayans peel firm-ripe fruits, slice the pulp and fry it in sirup or palm sugar until it is crisp and brown. Filipinos enjoy the cooked fruit with coconut and sugar.

The dried fruit has been made into flour and improved methods have been explored in Barbados and Brazil with a view to substituting breadfruit in part for wheat flour in breadmaking. The combination has been found more nutritious than wheat flour alone. Breadfruit flour is much richer than wheat flour in lysine and other essential amino acids. In Jamaica, the flour is boiled, sweetened, and eaten as porridge for breakfast.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Soft or overripe breadfruit is best for making chips and these are being manufactured commercially in Trinidad and Barbados. Some breadfruit is canned in Dominica and Trinidad for shipment to London and New York.

Breadfruit is relatively free of pests and diseases. Snails and mealy bugs can be a problem on young plants and over-watering in the nursery can result in fungal dieback.

Breadfruit produces abundant, nutritious fruit (i.e., high in carbohydrates and a good source of fiber, vitamins, and minerals) that is typically cooked and consumed as a starchy staple when firm and mature. Ripe fruit can be eaten raw or cooked, processed into chips and other snacks, dried into flour or starch, and minimally processed or frozen. Breadfruit flour can be partially substituted for wheat flour in many bread, pastry, and snack products. Seeds, cooked in the fruit and eaten throughout the Pacific islands—but rarely in Polynesia—are high in protein, relatively low in fat and a good source of vitamins and minerals. Breadnut seeds tend to be larger and sweeter than breadfruit seeds and can be roasted or boiled. In Ghana, breadfruit and bread- nut seeds have been made into nutritious baby food. In the Philippines, immature fruit is sliced, cooked, and eaten as a vegetable.
Besides, breadfruit has a high starch content and is used as a vegetable when mature but not ripe, and as a dessert when ripe. During ripening, the starch turns to sugar and the fruit develops a sweet custard taste.
Furthermore, breadfruit flour can be used as a partial substitute for imported wheat flour in breads, cakes, and pastries, and is suitable for export. It can also supplement or replace imported crops such as rice or potatoes.

Nutritional value of fruit

Breadfruit is a nutritious, high-energy food with moderate glycemic index, rich in fi- ber, and a good source of vitamins B_1, B_2, and C, potassium, magnesium, and calcium, with small amounts of thiamin, riboflavin, niacin, and iron. Some cultivars contain small amounts of folic acid. Ripe fruit, especially yellow-fleshed varieties, can be a good source of provitamin-A carotenoids.

The composition of fruits from different cultivars from the Pacific Islands and Caribbean has been investigated. Analyses have been made of fresh and cooked breadfruit at various stages of development; products produced by traditional methods such as pit fermentation, dried, roasted breadfruit and sun-dried breadfruit paste; and products such as flour and chips produced by modern processing techniques. Breadfruit's carbohydrate content is as good as or better than other widely used major carbohydrate foods. Compared with other staple starch crops, it is a better source of protein than cassava and is comparable to sweet potato and banana (Graham and Negron de Bravo 1981). It is a relatively good source of iron, calcium, potassium, riboflavin and niacin. A comparison of nutrient composition of mature breadfruit prepared by various methods (boiling, baking/roasting, and preserved by pit fermentation or paste)

A detailed study of the nutritional composition of breadfruit determined nutrient levels for the pulp, skin, and stem and core of very immature, immature, mature and very mature fruits from Puerto Rico (Graham and Negron de Bravo 1981). Fruits were categorized as follows:

- A very immature fruit exudes a copious quantity of milky, gluey latex from the detached stem and when it is cut or pierced. The flesh rapidly discolours and darkens when cut and this stage is not ready (fit) for eating.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

- An immature fruit is larger, exudes less latex and does not discolour as severely.

- A mature fruit is comparatively larger. The skin, depending on the type, may show some yellowing and the pulp shows little or no discolouring when cut. Very little sap exudes from the detached stem.

- A very mature fruit may have a yellow skin which has 'cracks' or crevices. The pulp is usually quite yellow and soft. When roasted, it has a strong flavourful aroma and the pulp has a gummy, sweet, pleasant taste.

The nutritional composition of seven Samoan cultivars (*ulu maopo, ulu puou, ulu ma'afala, ulu talatala, ulu gutufagu, ulu ma'a, ulu avel*)*o olof a*breadfruit at various stages of maturity was determined (Wootton and Tumalii 1984). There were obvious differences between cultivars in terms of protein and carbohydrate levels for mature breadfruit, the stage most preferred for consumption. 'Ulu talatala' had a higher protein content than all other cultivars but had the lowest levels of carbohydrates.

Crude fat and fiber also varied among cultivars at the mature stage. Amylose levels of starch for each cultivar were determined and all but *ulu puou* (16.4%) had levels comparable to that observed for Puerto Rican breadfruit (18.2%). Four cultivars were sampled at the very mature or ripe stage, and there was no clear pattern of compositional change within cultivars save for a decrease in starch and increase in sugars between the mature and very mature stages. Changes in individual sugars during maturation were studied and fructose, glucose and sucrose were the major sugars, with only trace amounts of ribose and maltose. Fructose was the predominant sugar in less mature fruits, decreasing in comparison to glucose and sucrose as maturation progressed.

Even though crude fat levels were low (0.8-1.9%), fatty acid composition was determined for each cultivar because of the possibility of fat rancidity and poor storage life and/or acceptability of the product. Rancidity was not apparent in any of the flours after storage for 6 months at 5°C. Levels of iron, sodium and calcium were similar to those observed for Puerto Rican breadfruit although potassium was approximately half and phosphorus four times as great. These studies show that the nutritional composition of breadfruit varies among cultivars and should aid in selection of cultivars for different uses for fresh consumption and processed products.

The nutritional composition of 11 traditional cultivars from three island groups (Marshall Islands: *batakdak, bukdrol, mijiw*; *a*Cnhuuk: *atchapar, meichon, meikoch,na,par neisoso, sawan*: Samoa: *ma'afala, puou*) was studied (Murai *et al.* 1958). All were seedless cultivars except for *mijiwan* from the Marshall Islands. The fruits were sampled fresh, roasted, baked or boiled. The amount of waste and edible pulp varied with the cultivar and size of fruit; edible portion was greater than 70% for seedless cultivars. The total edible portion for the seeded cultivar varied from 46 to 60% including seeds with the pulp comprising less than half the weight of the fruit (43%).

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The table below indicates the food value per 100 g of Edible Portion

	Fruit (underripe, raw)	*Ripe (cooked)*	*Seeds (fresh)*	*Seeds (roasted)*	*Seeds (dried)*
Calories	105-109				
Moisture	62.7-89.16 g	67.8 g	35.08-56.80 g	43.80 g	
Protein	1.3-2.24 g	1.34 g	5.25-13.3 g	7.72 g	13.8-19.96 g
Fat	0.1-0.86 g	0.31 g	2.59-5.59 g	3.30 g	5.1-12.79 g
Carbohydrates	21.5 29.49 g	27.82 g	30.83-44.03 g	41.61 g	15.95 g
Fiber	1.08 2.1 g	1.5 g	1.34-2.14g	1.67 g	3.0-3.87 g
Ash	0.56-1.2 g	1.23 g	1.50-5.58 g	1.90 g	3.42-3.5 g
Calcium	0.05 mg	0.022 g	0.11 mg	40 mg	0.12 mg
Phosphorus	0.04 mg	0.062mg	0.35 mg	178 mg	0.37 mg
Iron	0.61-2.4 mg		3.78 mg	2.66 mg	
Carotene	0.004 mg (35-40 I.U.)				
Thiamine	0.08-0.085 mg		0.25 mg	0.32 mg	180 mcg
Riboflavin	0.033-0.07 mg		0.10 mg	0.10 mg	84 mcg
Niacin	0.506 0.92 mg		3.54 mg	2.94 mg	2.6 mg
Ascorbic Acid	15 33 mg		13.70 mg	14 mg	
Amino Acids	[N = 16 p. 100])				
Arginine	4.9		0.66		
Cystine	-		0.62		
Histidine	1.6		0.91		
Isoleucine	6.7		2.41		
Leucine	7.4		2.60		
Lysine	5.8				
Methionine	1.2		3.17		
Phenylalanine	8.3		1.05		
Threonine	6.8		0.78		
Tryptophan	7.0				
Valine	7.8				
Aspartic Acid	10.8				
Glutamic Acid	11.3		0.98		
Alanine	3.9		1.53		
Glycine	7.2		0.95		
Proline	6.5		0.72		
Serine	5.7		2.08		
Tyrosine			1.45		

It is seen from the above that the seedless breadfruit is low in protein, the seeds considerably higher, and therefore the seeded breadfruit is actually of more value as food.

Breadfruit flour contains 4.05% protein; 76.70% carbohydrates, and 331 calories, while cassava flour contains 1.16% protein, 83.83% carbobydrates, and 347 calories per 100 g.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Limitation

The major limitation on utilization of breadfruit is the highly perishable nature of the fruit and the seasonal nature of the crop. The keeping quality of breadfruit is limited by a rapid post-harvest rate of respiration with the fruits ripening and softening in just 1-3 days after harvest. Soft, ripe fruits are unacceptable for consumption and substantial losses are incurred during peak production periods.

The perishability of breadfruit restricts local marketing and greatly limits its export potential since fruits ripen before they reach their destination.

Most varieties of breadfruit are purgative if eaten raw. Some varieties are boiled twice and the water thrown away, to avoid unpleasant effects, while there are a few named cultivars that can be safely eaten without cooking.

The main drawbacks of breadfruit as a crop are:

- Fruit are perishable with limited shelf life.
- Seasonal production, especially if only a few varieties are grown.
- Challenging harvest and postharvest handling.
- Limited availability of planting material for good qual- ity varieties.
- Limited research and extension on agronomy, yields, pruning, and orchard management. Limited support for research and development and marketing of products.
- Lack of awareness about breadfruit.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

9. Markets/Export

Breadfruit seeds are a valued food in New Guinea and are widely collected. Gathered seeds are sold in village markets, providing an important source of income for women in some areas. The fruits, and to a lesser extent, seeds, are a major subsistence food in the eastern Solomon Islands and Vanuatu.

Actually, there is an increasing demand for fresh breadfruit in Hawaii by Hawaiians returning to traditional diets for health reasons and other Pacific islanders such as Samoans, Tongans and Marshall Islanders who reside in Hawaii. Development and increasing urbanization, especially on the island of Oahu, have greatly decreased the numbers of trees growing throughout the state. Fresh breadfruit is occasionally available in ethnic grocery stores and local farmers markets but demand far exceeds supply. There is interest in establishing commercial breadfruit plantings to provide fresh fruit and chips for the local market.
Besides, the fruit is produced and sold locally as chips in Fiji, Samoa, Guam, Hawaii, and other islands.
Breadfruit is also canned in brine and sold in the Caribbean and speciality markets in the United States, Europe, and Canada.
Usually, breadfruit is available for sale in markets throughout the Pacific and Caribbean islands. An estimated 100–300 tons of breadfruit is sold in Samoa annually, with 60–130 tons sold in the Fugalei Market in Apia.

Market data are hard to come by for most countries in the Pacific region. Fresh, cooked, and prepared fruit are generally available through markets, roadside stands, and other small vendors. Processed products, mainly chips, are sold at the same venues and by retailers. Breadfruit-based dishes are occasionally available at restaurants serving local foods. Samoa sells 100–300 MT (110–330 T) of fresh fruit annually, with 60–130 MT (66–143 T) sold in the Fugalei Market in Apia (McGregor 2002).

The current main export market is fresh fruit shipped by air freight. On a very small scale, traditional products are shipped internally, such as *namba* (from the Temotu Province to

Guadalcanal in the Solomon Islands) and a preserved fruit paste (from Kapingamarangi to Pohnpei Island, FSM).

In fact, a large potential market for fresh breadfruit and breadfruit products also exists in the communities of Pacific islanders who reside in Hawai‘i and on the U.S. mainland. In addition, markets can be created in the food service industry where new cuisines have developed in recent years, incorporating Asian/Pacific influences into themes such as Hawai‘i regional cuisine.

Breadfruit is being exported from the Pacific Islands, although a vast potential market for fresh breadfruit exists in the large communities of Pacific islanders living in urban areas such as Auckland, New Zealand, Honolulu, Hawaii and the west coast of the United States, if the constraints of perishability and short shelf-life can be overcome.
The 1980s saw the emergence of breadfruit as an export crop and today the Caribbean is the major supplier of breadfruit to Europe, the USA and Canada (Marte 1988). In 1985, 1025 tonnes were imported by the UK from St. Lucia and St. Vincent and the demand by 1987 was up almost 10-fold. Export figures for the six Windward Islands compiled for 1985-89 (Andrews 1990) are shown in Table 10.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The export of breadfruit (in tonnes) from the Caribbean Islands is given in the table below.

Island	1985	1986	1987	1988	1989
Barbados	25	n.a.†	65	66	123
Dominica	0	23	24	38	24
Grenada	n.a.	1415	1429	1400	n.a.
Saint Lucia	911	833	809	867	1137
St. Vincent	94	n.a.	n.a.	n.a.	n.a.
Trinidad	n.a.	n.a.	n.a.	n.a.	26

† n.a. = no information available.

In 1990, total exports of non-traditional crops from the Windward Islands totaled 10 058tonnes, of which breadfruit accounted for 10% (Roberts-Nkrumah 1993). The Caribbean currently provides more than 90% of the breadfruit for the United Kingdom market with the rest coming from Mauritius (Worrell 1994). Mauritius is the only other production area that produces and exports breadfruit for international trade.

Jamaica is one of the largest exporters of breadfruit, especially to the USA (Roberts-Nkrumah 1993). Haiti, Puerto Rico and the Dominican Republic also export to the USA. In 1985, approximately 15tonnes were exported to the USA and in 1988 a single importer was looking for reliable sources that could guarantee at least this amount weekly (Marte 1988). The USA imported 438.3 tonnes of fresh breadfruit from the Caribbean and 13.0 tonnes of frozen breadfruit from Asia in 1986 (Crane and Campbell 1990). Recent interest in propagation and the establishment of breadfruit orchards has arisen to support and expand the export market in the Caribbean (Roberts-Nkrumah 1993).

Besides, there is interest in establishing small-scale orchards to provide fresh fruits and chips for export from Pacific islands to New Zealand, the United States, and Canada. Fresh mature fruits, treated for fruit flies by hot forced air, are being exported to New Zealand from Fiji and Samoa. Furthermore, some breadfruit is canned in Dominica and Trinidad for shipment to London and New York.
Small amounts are also exported to Canada and the U.S. Breadfruit is a seedless breadnut, producing nearly spherical fruit with a diameter of 10 cm to 30 cm (4 in to 12 in) and a weight of 1 kg to 4 kg (2 lb to 9 lb).
Whole roasted fruit are occasionally air freighted from Ta- hiti and Hawai'i to Pacific islands, New Zealand, and the mainland United States. Commercial exports of fresh fruit in the Pacific region commenced in 2001 with shipments from Samoa and Fiji to New Zealand. Currently, New Zealand imports fresh fruit of 'Maopo', 'Ma'afala', and 'Puou' from Samoa and 'Uto dina' and 'Balekana' from Fiji. If supply and fruit quality constraints can be met, it is estimated that New Zealand markets could readily consume 4 MT (4.4 T) per week of fresh breadfruit with a market potential of 500–1,500 MT (550–1,650 T) per year (Stice et al. 2007).

Samoa exported 74 MT (81 T) in 2004–2006 (Tuivavalagi and Samuelu 2007). Annual exports from Fiji were 2 MT (2.2 T) in 2001, increasing to 12 MT (13 T) in 2005 (Stice et al. 2007). Up to 9 MT (10 T) per month of frozen bread- fruit pieces were exported from Fiji (Beyer 2007).

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

In 2007, 1–2 MT (1.1–2.2 T) per day were needed by a commercial processor to fill the demand for canned breadfruit shipped to Australia, New Zealand, and Canada (Fiji Times 2007). Fresh and cooked breadfruit imports to Australia from the Pacific are currently prohibited, although commercially produced peeled, seeded, and frozen pulp is permitted (Goebel 2007). The U.S. Department of Agriculture (Federal Register 2008) allowed the shipment of irradiated breadfruit to the U.S. mainland, opening the door for fresh fruit exports from Hawai'i.

Several Caribbean countries (Jamaica, St. Lucia, Dominica, St. Vincent, and the Dominican Republic) ship fresh fruit to the U.S., Canada, and Europe. Exports declined from 2,023 MT (2225 T) in 1998 to 1,203 MT (1,320 T) in 2005, even though demand remained high (Roberts-Nkrumah 2007). Jamaica is the largest exporter in the region, exporting 3,437 MT (3,780 T) during 2000–2004 (517–776 MT [570–850 T] per year) with a total value of approximately US$3 million (RADA 2003–2006). Mauritius exports breadfruit to Europe on a small scale of 0.4 MT (0.44 T) in 1996, 20 MT (22 T) in 1997 and 1.9 MT (2.1 T) in 2000 (MAFTNR 2003).

Mauritius

Mauritius exports breadfruit to Europe on a small scale of 0.4 MT (0.44 T) in 1996, 20 MT (22 T) in 1997 and 1.9 MT (2.1 T) in 2000 (MAFTNR 2003).

Aleki Sisifa, Director, SPC Land Resources Division, opened the proceedings of the 1st international breadfruit symposium report (April 16-19, 2007, Nadi, Fiji), with an excellent overview of breadfruit in the Pacific and how it has developed into an export commodity for some countries, such as Fiji and Samoa, yet remains an important food security crop especially for atoll countries

Moreover, important aspects such as development of trade agreements, promoting and supporting export and include import substitution policies, where necessary to support trade in breadfruit products were also reviewed by the group.

The group also recommended choosing innovative approaches for improving marketing—health, cultural, food security, environmental, or fair trade and produce a comprehensive production manual for export as well as simple leaflets for growing breadfruit in your backyard.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

10. Uses of Plant parts other than the fruit

Breadfruit and breadnut are nutritious sources of food for animals. Since only the pulp of mature breadfruit is consumed as a human food, at least 25% of the fruit is wasted. Dried, ground meal can also partially substitute for imported poultry and pig feed. The flesh, peel, core, and seeds, of both mature and ripe fruits are edible and are fed to pigs and other livestock. The leaves are also edible. . In India, they are fed to cattle and goats; in Guam, to cattle, horses and pigs. Horses are apt to eat the bark of young trees as well, so new plantings must be protected from them.

In fact, breadfruit is an important food source for flying foxes, native doves, and other birds in the Pacific islands. Moreover, it is used as a trellis tree for yam (*Dioscorea* spp.), especially in Pohnpei and honeybees visit male inflorescences and collect pollen, especially from fertile, seeded varieties. Bees also collect latex that oozes from the fruit surface.
Being an attractive, evergreen tree with large, striking leaves, breadfruit is used as an ornamental plant.

The non-edible portions are as high in carbohydrates, contain more protein than the pulp and are excellent sources of nutrients. The non-edible portion comprises approximately 26% of a mature fruit and contains 75.7% carbohydrate, 6.0% protein and 2.8% fat (Graham and Negron de Bravo 1981). The core and stem contained the highest levels of protein and this was attributed to the presence of several 'aborted' seeds attached to the core. The skin also contained higher levels of protein than the pulp which was attributed to the accumulation of latex on the surface of the skin which may trap minute amounts of nitrogen-containing materials from the air. Moreover, breadfruit cultivation does not depend on expensive petroleum-based fertilizers.
Breadfruit is a multipurpose tree species providing food, medicine, clothing material, construction materials and animal feed (Table 5). It is an important component of traditional agroforestry systems in the Pacific Islands, particularly the eastern Solomon Islands, Pohnpei and Kosrae (Yen 1974; Merlin *et. al*. 1992, 1993; Raynor and Fownes 1991). The trees are integrated into mixed cropping systems with yams and other root crops, *Piper methysticum*, bananas and some cash crops, especially black pepper and coffee.

In Jamaica, Puerto Rico and the South Pacific, fallen male flower spikes are boiled, peeled and eaten as vegetables or are candied by recooking, for 2-3 hours, in sirup; then rolled in powdered sugar and sun-dried. The seeds are boiled, steamed, roasted over a fire or in hot coals and eaten with salt.
In West Africa, they are sometimes made into a puree. In Costa Rica, the cooked seeds are sold by street vendors.
Underripe fruits are cooked for feeding to pigs. Soft-ripe fruits need not be cooked and constitute a large part of the animal feed in many breadfruit-growing areas of the Old and New World. Breadfruit has been investigated as potential material for chickfeed but has been found to produce less weight gain than cassava or maize despite higher intake, and it also causes delayed maturity.

Breadfruit is well suited for homegardens, providing beneficial shade and numerous nutritious fruits.

These multipurpose trees have a lightweight, easy-to-work timber well suited for carvings and handicrafts (statues, bowls, and other objects), canoes and house construction. The wood

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

is yellowish or yellow-gray with dark markings or orange speckles; light in weight; not very hard but strong, elastic and termite resistant (except for drywood termites) and is used for construction and furniture. In Samoa, it is the standard material for house-posts and for the rounded roof-ends of native houses. The wood of the Samoan variety 'Aveloloa' and ‘Maopo’ which has deeply cut leaves, is most preferred for house-building, but that of 'Puou', an ancient variety, is also utilized. In Guam and Puerto Rico the wood is used for interior partitions. Because of its lightness, the wood is in demand for surfboards. Traditional Hawaiian drums are made from sections of breadfruit trunks 2 ft (60 cm) long and 1 ft (30 cm) in width, and these are played with the palms of the hands during Hula dances. After seasoning by burying in mud, the wood is valued for making household articles. These are rough-sanded by coral and lava, but the final smoothing is accomplished with the dried stipules of the breadfruit tree itself.

Fiber from the bark is difficult to extract but highly durable. Malaysians fashioned it into clothing. Material for tape cloth is obtained from the inner bark of young trees and branches. In the Philippines, it is made into harnesses for water buffalo.

Throughout the Pacific, breadfruit is used as firewood but generally older, less productive trees are utilized and the large, flexible leaves are used to wrap foods for cooking in earth ovens. Moreover, the inner bark is used to make bark cloth (tapa), but this formerly widespread custom is now only practiced in the Marquesas. In Samoa, Micronesia, and the Philippines, the inner bast was traditionally used to make strong cordage used for fishing and animal harnesses.
Leaves, buds, latex, and bark all have medicinal uses. The sticky sap is widely used for glue and as a traditional caulk. The sticky white latex is used as a chewing gum and as an adhesive. Breadfruit latex has been used in the past as birdlime on the tips of posts to catch birds. After boiling with coconut oil, the latex serves for caulking boats and, mixed with colored earth, is used as paint for boats.
Besides, dried male flowers can be burned to repel mosquitoes and other flying insects. The male flower spike used to be blended with the fiber of the paper mulberry, *Broussonetia papyrifera* Vent. to make elegant loincloths. When thoroughly dry, the flower spikes also serve as tinder.

In the Pacific and Caribbean, all parts are used medicinally, especially the latex, leaf tips, and inner bark. The latex is massaged into the skin to treat broken bones and sprains and is bandaged on the spine to relieve sciatica. It is commonly used to treat skin ailments and fungus diseases such as “thrush,” which is also treated with crushed leaves. Diluted latex is taken internally to treat diarrhea, stomachaches, and dysentery. The sap from the crushed stems of leaves is used to treat ear infections or sore eyes. The root is astringent and used as a purgative; when macerated it is used as a poultice for skin ailments. The bark is also used to treat headaches in several islands. In the West Indies the yellowing leaf is brewed into tea and taken to reduce high blood pressure and relieve asthma. The tea is also thought to control diabetes.
In Trinidad and the Bahamas, a decoction of the breadfruit leaf is believed to lower blood pressure, and is also said to relieve asthma. Crushed leaves are applied on the tongue as a treatment for thrush. The leaf juice is employed as ear-drops. Ashes of burned leaves are used on skin infections. A powder of roasted leaves is employed as a remedy for enlarged spleen. The crushed fruit is poulticed on tumors to "ripen" them. Toasted flowers are rubbed on the gums around an aching tooth. The latex is used on skin diseases and is bandaged on the spine to relieve sciatica. Diluted latex is taken internally to overcome diarrhea.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

In the Pacific, breadfruit is a cultural icon. All parts are used medicinally, especially the latex, leaf tips, and inner bark. The wood is lightweight, flexible, and may resist termites. It is used for buildings and small canoes. The attractive wood is easily carved into statues, bowls, and other objects. Older, less productive trees are utilized as firewood throughout the region. The inner bark is used to make bark cloth (tapa, siapo), but this formerly widespread custom is now only practiced in the Marquesas. Large, flexible leaves are used to wrap foods for cooking in earth ovens. The sticky white latex is used as a chewing gum and adhesive and was formerly widely used to caulk canoes and as birdlime (to catch birds). Dried male flowers can be burned to repel mosquitoes and other flying insects.

Breadnut and breadfruit seeds are a good source of protein, potassium, calcium, phosphorus, and niacin, similar in flavor and texture to chestnuts. Seeds can be boiled, roasted, or ground into meal or flour. Breadnut seeds are generally sweeter and tastier than breadfruit seeds.

Uses of the breadfruit tree

Part of tree used	Uses
Tree	Agroforestry, shade
Timber	Construction of buildings, canoes, furniture and other objects, carvings, firewood
Latex	Adhesive, caulking for canoes, birdlime, medicine
Bark	Medicine
Bast (inner bark)	Cordage, clothing (bark cloth)
Leaves	Wrap food for cooking or serving, livestock feed, medicine, dried leaves and stipules used as a sanding cloth, fishing kites
Male inflorescences	Candied and eaten, dried and used as mosquito repellent, medicine
Fruit and seeds	Cooked fruits and seeds used for human consumption; uncooked for livestock feed.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

11. Consumer Preferences, Education & Products

Breadfruit in Society

Changing Pacific subsistence economies have had a major impact, one that is rapidly accelerating with population growth. As Pacific islanders become more westernized and shift from a traditional subsistence economy to a cash economy, more people migrate from the outer islands to population centres. There is increasing reliance on imported foods, and traditional, locally produced foods are being supplanted by introduced foods such as white rice and enriched-flour products.

Recommendations of 2007 Symposium

Participants considered key issues related to breadfruit conservation, research, and development, and made recommendations concerning projects and future priorities. The meeting was structured around five major themes:

1) Breadfruit in Society
2) Diversity and Conservation
3) Germplasm Exchange and Crop Improvement
4) Production and Production Constraints
5) Product Development and Marketing.

The Symposium provided a venue for sharing experiences and information related to breadfruit and looking at ways in which the future of breadfruit, both as a food security crop and as a marketable commodity (domestic and export), could be strengthened.

This report includes a priority list of recommendations which were discussed both by the entire gathering and in Working Groups:

1. The Symposium participants commended the significant work carried out by Dr Ragone and the NTBG in collecting and conserving breadfruit over the past three decades. They acknowledged that this work contributes globally to breadfruit research and development and that the security of this collection should be ensured "in perpetuity". The Symposium participants therefore recommended that the NTBG collection be part of the multilateral system (MLS) of the International Treaty as set out in Article 15, to facilitate the collection's continued conservation and use throughout the world.
2. Breadfruit for food security needs a higher profile at the national, regional, and international levels.
3. More funding is needed to support breadfruit conservation, research and development. Participants commented on the lack of interest given to breadfruit by donors. It was suggested that we work to educate donors about the value of breadfruit and its impact.
4. It is essential to get breadfruit on government agendas. Highlighting the role that breadfruit can play in food security, income generation, and other areas, such as livestock feed, marginal land use, and soil improvement, could be one way of getting increased governmental attention.
5. Engage forestry systems and programmes to work with breadfruit.
6. New ways to promote breadfruit are needed. An example would be featuring breadfruit in tourism programmes, such as the Jamaica breadfruit festivals. Such

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

festivals could involve chefs competing to create the most innovative, tasty breadfruit meal. In the UK and USA, the purchase and consumption of food products is raised significantly whenever "famous" chefs are involved in promoting the product.

7. There is widespread interest in dwarf (short-stature) varieties. These varieties need to be identified and targeted for conservation, distribution, research and development.
8. Identify potential funding sources and opportunities for breadfruit. Possibilities include: carbon offsetting, government agencies, international food companies, private foundations, and individuals. Different levels of funding need to be targeted, that is, national, regional, and international. For national funding countries would have to give breadfruit priority. Although regional funding involves different donors for different regions, we expect great benefits through combining efforts.
9. Include breadnut in R&D efforts since this tree is easy to propagate by seed and the tasty seeds are is a good source of protein.
10. There is a need to collect and document breadfruit knowledge, encompassing all aspects of breadfruit in society, from traditional beliefs to agronomic practices. This documentation should be useful for both product development and awareness campaigns which should use common information, materials, and themes to be effective.
11. Promote the uses of breadfruit, both for food (including livestock and disaster food products), and non-food through food fairs, breadfruit festivals, posters, media releases on health benefits and product development. Youth need to be targeted in this campaign.
12. Promote and strengthen the use of breadfruit in agro-forestry practices and programmes.
13. Promote the nutritional benefits of breadfruit. More analysis and information is needed on more varieties (both ripe and mature). Special attention should be given to carotenoids-rich varieties, omega-3 and omega-6 fatty acid content and antioxidants; this information could be used to create awareness on the importance of breadfruit and increase production and consumption.
14. Engage the support of government for breadfruit through the development of national policies/frameworks.
15. Produce information leaflets on how to prepare and cook breadfruit.
16. Consider and develop strategies for encouraging farmers to report on and conserve desirable naturally occurring diversity (*in situ* conservation).

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

Recommendations of 2007 Symposium:

The group agreed that breadfruit must remain central to the culture of a society, because it is an important element of sustainable livelihoods and food security. A number of key issues were highlighted as being crucial to ensuring that breadfruit remains culturally important, namely:

- Establish national policies to strengthen the importance of breadfruit in the culture.
- Conduct a baseline survey to document the importance of breadfruit in society.
- Promote breadfruit through various activities at the community level.
- Strengthen research and development activities and ensure results are disseminated to communities.
- Diversify the use of breadfruit in society (food, feed, medicine, woods, etc.).
- Establish regional policies/frameworks on breadfruit.

The role of breadfruit in society would be strengthened if it is recognized as a component of agro-forestry. Several suggestions were made as to how this could be achieved. Documentation of practices where breadfruit is already a component of agroforestry is very important, as well as the need to develop agroforestry practices/programmes involving breadfruit (based on different geographical areas, societal needs, etc.).

The group identified some possible project areas including:

- Develop a regional project to establish national inventories, including traditional knowledge.
- Assist governments in developing national policies for breadfruit conservation and utilization, incorporating nationwide breadfruit planting campaigns.
- Implement a global project on breadfruit planting material and management.
- Develop and evaluate outreach approaches to ensure community participation in any project.
- Develop breadfruit as a disaster relief food product (e.g., nambo as produced in Temotu Province in the Solomon Islands).
- Investigate the potential of breadfruit as livestock or poultry feed.

The major recommendations from the Breadfruit in Society group were:

1. Collect and document breadfruit knowledge, encompassing all aspects of breadfruit in society, from traditional beliefs to agronomic practices.

2. Promote the uses of breadfruit, both for food, (including livestock and also disaster food products) and non-food.
3. Promote and strengthen the use of breadfruit in agro-forestry practices and programmes.
4. Engage government support of breadfruit by developing national policies/frameworks.
5. Carry out research and development into commercial breadfruit production.

Information is key to developing any crop and the group discussed how better use of facts could help both backyard and commercial production. Documentation of material is essential both as a comprehensive production manual for export and simple leaflets are needed for growing breadfruit in your backyard. Extension officers need knowledge on breadfruit production and should also be excited about sharing it.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)

The Production and Production Constraints group identified a number of projects for potential funding:

- Develop suitable production guides and carries out "train the trainer" workshops. All information generated from this project must be disseminated to a wide range of Stakeholders—villagers, farmers, exporters, etc. The focus of this project would be "From tree to table".
- Establish national multi-purpose breadfruit collections, which would be multifunctional, serving as germplasm collection, semi-commercial orchard demonstration, agro-tourism, or information center.

The group felt that effective promotion of breadfruit has to be supported by national governments, and to achieve this each government should:

- Initiate trade agreements to promote export of value-added products.
- Establish an import substitution food policy.
- Promote breadfruit as a food that will assist in the achievement of Millennium
- Development Goals and poverty/hunger alleviation

- Fund R&D projects for product development.

Source 1; Breadfruit (Ragone, 1997); Source 2; *Artocarpus atilis* (Ragone, 2006); Source 3; . Breadfruit. Morton, J.1987; Source 4; Regeneration guidelines for breadfruit(Ragone 2008); Source 5; Postharvest handling Technical Bulletin(New Guyana Marketing Corporation, 2004) ; Source 6: Farm and Forestry Production and Marketing Profile for Breadfruit(Ragone,2011); Source 7; First International Symposium on Breadfruit Research and Development (Taylor.M & Ragone. D, 2007, Nadi, Fiji)