PARDI2

Breadfruit Compendium: Processing & Value-Adding

Module 4 gives an insight into how mature and ripe fruit can be processed into shelf-stable products, such as chips and other snacks, and other value-added products, expanding the use of breadfruit as a food and also creating marketing opportunities. Historically, processing has been confined to practices that will preserve foods, to reduce waste and to extend the period over which they can be eaten (shelf-life), particularly for foods with short seasons. Processing is also an activity in its own right to generate income and employment and to provide a food option out of season – that is - to add value. The longer-term market opportunities for processed breadfruit products (both for local consumption and for export) are expected to be far greater than for fresh breadfruit. These market opportunities are discussed in Module 5 (Markets and Marketing).

The second part of this section is a link to a spreadsheet for preparing simple financial analysis of the operation. The output from this spreadsheet is a printable financial projection to be included in your business plan document. It is important to research how much the various inputs will cost. The model will make some assumptions about how your operation will improve over time so you can enter increasingly higher-level estimates for revenues.

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About Us

Funded by the Australian Centre for International Agricultural Research and facilitated by a consortium of implementation partners, Pacific Agribusiness Research in Development 2 (PARDI2) seeks to promote sustainable livelihood outcomes for Pacific Islands households through research and innovation, catalysing and informing a more vibrant, diverse and viable agribusiness sector.

The project spans 2017-2021, placing a geographical focus on Fiji, Tonga and Vanuatu. For more information, please visit www.pardi.pacificfarmers.com

1.0 Introduction

Breadfruit is a significant dietary component in tropical countries where the trees are widely grown. As a food, carbohydrates make up the significant fraction of energy in breadfruit with 100g (about four ounce serving) providing 102 calories. Breadfruit is an energy-rich food, high in complex carbohydrates, low in fat, and a good source of fibre and minerals, such as iron, potassium and calcium. It is a nutritionally higher quality protein source than occurs in other staple foods, such as wheat, rice and potato. The fibre in breadfruit and the starch fractions among the carbohydrates maintain health in the digestive system. The starches are slow to digest leading to a sense of satisfaction for longer periods than when eating sugary foods, thereby reducing the desire for constant snacking and hence lowering the risks of diabetes and obesity.

At maturity the starch gives breadfruit its characteristic texture when cooked by the usual method of boiling. Breadfruit at full maturity is considered to be the most acceptable in todays' communities and markets. After full ripening the starch begins to break down into simple sugars, hence, ripe fruits are sweeter and have a pleasant custard aroma. However, these sugars are ideal targets for micro-organisms which convert the sugars to a range of unpleasant chemicals including lactic acid resulting in a breakdown of the texture of the breadfruit.

Maturing and attack by micro-organisms is part of the natural process. Most micro-organisms are harmless and simply change foods to an unacceptable degree, known as spoilage. Some micro-organisms will cause illness or death and are known as pathogenic bacteria. To keep breadfruit in a condition that is acceptable to eat, the growth of bacteria must be stopped, which is what preservation achieves.

In stopping the growth of micro-organisms, preservation can be used to extend a season so that the breadfruit in one form or another is available throughout the year. Preservation also provides an opportunity to use the excess breadfruit that is available at peak season, rather than have it rotting on the ground. Processing also adds value to the breadfruit and can be the basis of a commercial activity. Certain elements are required for a sustainable commercial processing enterprise:

- A consistent supply of raw material of the correct quality: processing is much easier with large volumes of raw material of the appropriate quality. Low volumes of product are more expensive to produce because high throughput rates have economies of scale. In addition, if crops are highly seasonal, such as from a single breadfruit variety, for much of the year production levels are low. This means that any enterprise/industry will not be profitable and therefore, not sustainable. A solution can be to process other food crops during the breadfruit offseason to ensure your labour and equipment is being utilised for an extended period.

- A suitable variety: all varieties can be processed since the quality is largely consistent throughout (Figs. 1a-c). However, during processing waste is less if the varieties chosen have large fruit. Both the Samoan ma'afala and the Fijian bale kana varieties are suitable for processing but because they are smaller than other varieties, the proportion of the fruit that is trimmed will be higher, which may increase costs. Fruit that is split or badly bruised can still be used for processing if trimmed and hence wastage in the field can be reduced.

Figure 1a: *Bale kana* is a variety of good eating and keeping quality – regarded as the best in Fiji. Fruits are small and oval, averaging around 1 kg in weight, which is somewhat small for efficient processing.

Figure 1b: *Uto dina* is a widely grown traditional variety in Fiji with good eating and processing properties. Fruits are oval in shape and are among the limited number of big-sized fruits which can weigh up to 2 – 3kg per fruit. Thus this variety is a good size for efficient processing.

Figure 1c: *Uto bucu* (or *vula*) is a very large variety weighing around 5 – 6 kg with good eating qualities. Processing wastage would be low.

The equipment necessary to process the product; the equipment required for processing depends on which method of processing is chosen (Figs. 2a-d). Food processing equipment can range from domestic kitchen appliances to highly sophisticated machines that affect all the operations necessary for production. For each of the processing methods described below, the basic equipment required has been included.

Figure 2a: Hand operated slicer in a village-based chip making enterprise in Samoa

Figure 2b: A mechanized electric chip slicing machine used at the Tutu Rural Training Centre

Figure 2c: Simple oven for deep frying at Samoan chip making enterprise

Figure 2d: Electric deep fryers installed at Tutu for breadfruit and other chips

- A market that is prepared to pay for the products produced.

Major consideration must also be given to packaging. Packaging must contain the product for sale and importantly protect it from physical, chemical and biological contamination. Packaging should contain and protect the product for at least as long as the stated shelf life. Other functions of packaging include light transmission or restriction depending on the product, insulation, moisture and gases transmission and micro-organisms.

Packaging controls the rate of moisture and gas transmission which determines the shelf life of many products - especially snack foods. The 'crisp mouth-feel' is part of the appeal of many snack foods; a loss of crispness occurs if the packaging is not sufficient to control moisture and gas transmission.

Intact packaging materials are barriers to micro-organisms but poor seals on packaging are a potential source of contamination. Packs that are folded, stapled or twist-wrapped are not truly sealed and constant abrasion on plastic films can cause packaging to wear and become permeable to gases, bacteria and moisture.

Packaging must also inform and attract. *Codex Alimentarius*[1] mandates the requirements of the label but the label must also attract the consumer and be instantly recognizable to help in developing 'brand loyalty'.

Packaging choices are many and varied and can be found described in detail in the processing manual. For each of the processing methods described in this module packaging recommendations are made. Export packaging will reference 'clean green' Pacific image and sustainability – i.e. your purchase is helping Pacific Island communities survive, adapt and cope with the existential threat of climate change. Local packaging best references health benefits of breadfruit flour and local jobs.

2.0 Preserving Breadfruit by Processing

2.1 Chilling

Refrigeration extends the shelf life of breadfruit, 12 to 13°C being optimal[2]. Domestic and home refrigerators are normally set to operate at 4oC, but the temperature can be adjusted to optimal if the sole/main purpose is breadfruit storage. At these temperatures the life of the breadfruit is doubled for every 10oC drop in temperature. If the harvest temperature is 35oC then at 25oC the breadfruit will last twice as long and at 15oC four times as long and so on. However below 8oC breadfruit suffers chill damage and deteriorates very rapidly. Shelf life can be further extended if the fruit is wrapped. Plastic can be used but there is the

[1] http://www.fao.org/fao-who-codexalimentarius/en/
[2] Ragone, D in Encyclopedia of Food Sciences and Nutrition, 2003

possibility that condensation would form on the inside of the plastic wrappers which would accelerate rot. Paper wrapping is a less risky and an environmentally-friendly alternative.

"Does chilling stop deterioration?"

Chilling/cooling only slows deterioration - it does not stop it. Therefore chilling is a procedure used to maintain fruit quality when there is a delay in delivering freshly harvested fruit to the customer. In recent work in Samoa, postharvest experiments have shown that the maximum storage life for the variety puou was 11 days and 16 days for ma'afala fruit based on 17°C cool storage. The only equipment needed for chilling is a large refrigerator.

2.2 Freezing

"What is involved if I want to sell frozen breadfruit?"

Freezing is an expensive process and it is important to remove inedible portions of the fruit. Hence before freezing, ripe breadfruits are washed, peeled and cut into convenient sections (often decided by the pack size or the market specifications) with any seeds removed. The breadfruit must be delivered to the processor in the best possible condition; any delays will see a breakdown in the breadfruit texture. The washed, peeled and cut breadfruit is then packaged and frozen (Figure 3). It is important to package frozen food in (at least) 50 micron polypropylene (your supplier will help). Packaging choice depends on the shelf expected shelf life of the product. If two days shelf life is required (say for the local school or a fete) then polythene will do. For up to 6-8 weeks 50 microns thickness of polypropylene is required. For shelf life beyond 8 weeks five component composite is required (as exemplified by the commercial crisp and snack food market). Foods dry out in the freezer and also some flavours can migrate from one food to another causing 'taint.' Domestic home freezers are suitable for small scale processing. Chest freezers are preferred because less ambient/warm air enters the freezer as they are opened and closed.

For formal markets and export the storage temperature must remain below minus 18^{o}C. Some SMEs are now freezing to the first stage and immediately transported to larger organisations to reach international standards which at a minimum are those mandated by Codex Alimentarius or national specifications such as Food Standards Australia and New Zealand (FSANZ)[3].

The quality of frozen foods once they are thawed depends on the rate at which they are frozen. It is important to cool through the range of temperature of minus 0.5°C to minus 5.5°C as quickly as possible since this causes least damage to the food structure. To achieve

[3] http://www.foodstandards.gov.au/Pages/default.aspx

this, blast freezers are used as they blow very cold air across the food at very high speed; commercial processing operations use large scale blast freezers. These freezers are very expensive and the cost can only be justified if there is a sufficient supply of breadfruit available, or other complementary products, to enable the freezers to operate for eight hours per day for five days a week.

Figure 3 Frozen breadfruit wedges ready for dispatch

Currently breadfruit supplies are unable to meet this requirement therefore processors use large-scale blast freezers for freezing all starchy staples and for breadfruit when supplies are available.

For successful marketing the frozen or cold chain must be in place from the point of manufacture to the point of sale. This means there must be refrigeration at minus 18°C at the processing point, during distribution (refrigerated trucks) and at the retail outlet. Instructions on labels must include 'Store at minus 18°C' and 'Do not refreeze after thawing.'

2.3 Drying

A large surface area is important for drying so slicing the breadfruit is the first step in the drying process; this enables the water to be removed through the surface more efficiently. Breadfruit pieces can be dried in the sun (Fig. 4), in a low temperature oven (50˚C) or in a dehydrator.

Several types of solar dryers exist, including active and passive dryers; tent, box or cabinet designs; and backup heating designs. The latter are often referred to as hybrid designs providing the option of fuelled heating (preferably a small wood-fired stove or else propane or kerosene heater) placed in the drying cabinet below the shelves of fruit. The moisture content of fresh breadfruit is approximately 20% (+/-2%) - the moisture content must be below 4% for stability drying resulting in a loss of 16%. The Trees that Feed Foundation[4] have calculated that using their hybrid solar dryer 50 kg of fresh fruit will yield approximately 15 kg of dried fruit in a day, or approximately 300 kg per month[5].

"If I live somewhere with high humidity, should I not consider drying?"

Drying efficiency depends on the relative humidity of the air around the slices. If the relative humidity is near 100% then condensation will settle on all surfaces. Air with a humidity of less than 40% is very suitable for sun drying. Without fans it is rarely possible to control air circulation around the breadfruit and if the humidity rises then the breadfruit will not dry sufficiently and mould will become a problem. Processors living in areas of high humidity must expect that drying will be prolonged (unless they have invested in efficient solar/biomass or electric driers) and sometimes difficult to achieve before the fruit supports mould growth. It is possible to dry in any climate but the cost is always higher in high humidity environments – the drier/leeward side of large Pacific islands and some low-rainfall atolls will better support efficient drying.

Where rainfall cannot be predicted, the process must be more controlled. In this case the drying chamber is enclosed and air that is not adequately dry for sufficient water removal, is heated (Fig. 5) Air with high humidity will expand during heating and thus its capacity to absorb water from the breadfruit is enhanced so heated air is commonly used for drying foods.

The moisture (water) content of drying chips should be monitored and should be below 7-8% at conclusion of the drying process. In the absence of moisture meters then you should aim for slices that are

[4] https://www.treesthatfeed.org/
[5] https://www.treesthatfeed.org/wp-content/uploads/2016/03/A-Hybrid-Solar-Dryer-for-Processing-Breadfruit-August-2015.pdf

brittle and crisp (Fig. 6). For packaging, polypropylene 50 microns thick would be sufficient to prevent softening of the dried breadfruit product provided that the product is stored in a cool dry place.

Figure 6 Dried slices of breadfruit

Figure 7: Restaurant size coffee grinder for producing flour

Figure 8: Breadfruit flour

Dried breadfruit slices have a number of uses, such as in soups, casseroles and in puddings. The final pulverising stage is very simple and just an add-on to what is a fairly complex drying procedure. For breadfruit 'flour,' the dried slices are simply ground up either by hand or using a mill ranging in size from a domestic coffee grinder (Fig. 7) to a large flour mill.

Some baked goods can be produced using 100% breadfruit flour (Fig. 10) however breadfruit flour (Fig. 8) does not contain gluten so it does not behave like wheat flour. It can be used as a partial replacement for wheat flour by adding up to 30% of the weight of breadfruit flour to wheat flour (Fig. 9).

The baked products so produced have a heavier but pleasant texture and have the advantage that the products satisfy hunger for longer periods.

Figure 9: Bread and buns made from 30% breadfruit flour (mixed with wheat flour) at the Tutu Rural Training Centre

Figure 10: 'Babakau' made from 100% Tutu breadfruit flour

Traditional sun drying is a long process and problematic in countries where there is consistently high humidity. A successful alternative is simply to use cooked, mashed breadfruit that can be added to dough. Successful bread has been made from two-thirds flour dough with one-third breadfruit mash. This sidesteps the need to dry the breadfruit into a powder.

The significant advantage that breadfruit flour has over other starch-based commodities is gelling properties. It disperses almost instantly in cold water and does not clump. It is a perfect gluten-free base of instant soups and sauces and is a direct gluten-free replacer for corn flour (Fig. 11). Breadfruit flour therefore has enormous potential as a gluten-free thickener in products such as blancmange, gravy thickener and instant pudding (Fig. 12), but this level of value-adding is still mostly in the research stage.

Figure 9: Bread and buns made from 30% breadfruit flour (mixed with wheat flour) at the Tutu Rural Training Centre

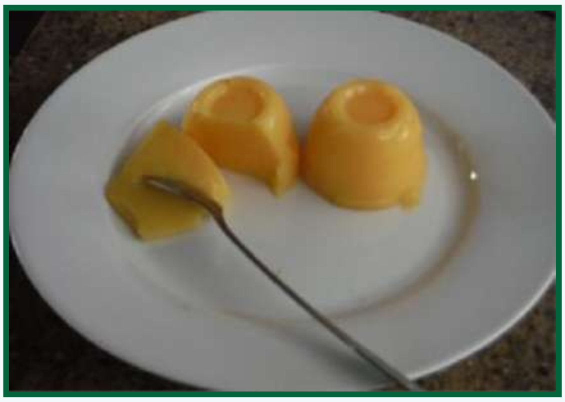

Figure 10: 'Babakau' made from 100% Tutu breadfruit flour

2.4 Frying

"I see breadfruit chips in the shops – are they easy to produce?"

Frying slices of breadfruit is another method by which moisture can be removed. Soybean or palm kernel oils are usually heated to approximately 150ºC to 180ºC. This temperature is above the temperature at which water boils so that the water boils off as the breadfruit slices sizzle. The breadfruit must be sliced thinly in order to remove sufficient water for the breadfruit to keep. Further, the chips should be cut as evenly as possible to avoid overcooking the thinner ones and leaving too much moisture in the thicker ones. A range of simple hand slicers are available to ensure slice consistency. High quality Swedish Hällde slicers are ideal for Pacific Islands' enterprises.

As the frying continues, the water is progressively removed and the sizzling stops and the slices become crisp. After frying the excess oil is removed by shaking and the chips are allowed to cool down.

The oil temperature needs to be high as the slices are removed from the oil. At high temperature, the oil is mobile and drains from the slices easily. At low temperature, the oil sticks to the slices which will increase costs. Fried snack foods with high oil contents are more prone to rancidity during storage, they are nutritionally less desirable and the mouth-feel is poor.

Oils used for cooking must be heated to temperatures a little below the smoke point and relatively small quantities of slices added to it, to prevent excessive cooling. Old oil should not be added to new oil but all used oil can be pooled and washed with water. The oil layer can be poured off the sludge that settles at the bottom of the container and re-used.

Packaging materials must be moisture-proof. The choice of packaging depends on the expected shelf life. If the breadfruit chips are to be sold locally then 50 micron polypropylene will give a shelf life of one month at tropical temperatures. If longer shelf life is required then more complicated, and therefore more expensive, composite packaging is required (see processing manual).

Breadfruit chips have universal appeal and are found not only in supermarkets but in small communities and school shops. The equipment and materials needed in the village to manufacture breadfruit chips include a suitable pot for frying, a hand slicer and oil for frying. Chips are an ideal scale product for a cottage industry scale processing enterprise (Fig. 13) given the relatively small initial capital investment required.

Figure 13: Cottage industry breadfruit chip manufactures in Samoa and Fiji



Key points to remember:

- *Frying time & temperature must be maintained as consistent as possible from batch to batch*
- *Chips should be allowed to cool after frying to ensure that no condensation forms on the inside of the plastic pouch after sealing. Condensation means that the chips will go soft and ultimately support mould growth.*
- *Chips that are not crispy are not sufficiently dry for long term storage.*

2.5 Alternative uses

Are there other products that could be made?

Apart from fresh consumption each Pacific Island nation produces a paste from starchy staples in which the cooked pounded cassava, breadfruit or taro is mixed with sugar and coconut cream (vakalolo in Fiji; puke in the Cook Islands; qalu in Kiribati; lu in Tonga; and poi in Hawaiʻi). These are traditional dishes normally eaten at the meal table because they have a short shelf life but some are exported to the diaspora in packaged frozen form. There is potential to include these items in the range of frozen foods for the tourism food service sector.

Kada chakka achaar is a breadfruit- based pickle, originally produced in Kerala but now produced in a number of countries. It is a highly spiced paste based on baked - therefore low moisture content - breadfruit. There are a range of products that can be made and sold from breadfruit as shown here in Figure 14.

Figure 14: Wide range of locally grown processed food products produced at the Tutu Rural Training Centre – including breadfruit chips and flour

3.0 Deciding on a product to develop and getting started

"Can I copy another product?"

Generating ideas for products that have a realistic chance of commercial success is one of the more challenging of the steps in the process of 'getting started'. Ideas tend to be generated based on experience (what do we, our families and friends like) or simply a good idea can 'pop up'. The abundant supply of a raw material can also stimulate new ideas (supply-driven product development). Copies or 'me too,' product development is simply a copy of an existing product. This approach is fine but there must be a market – the challenge is persuading existing consumers to change allegiance. One advantage of the 'copy' approach is that consumers are familiar with that type of product so less expenditure is required for launching and educating consumers than for an entirely new product.

When you first start and even if you are following a tried and tested recipe/formulation, it is very important that you record every step including quantities, time taken for each step (including any delays) and temperatures of heated mixture, methods of mixing etc. It is also important that you find out how acceptable your product is and the perfect way to do this is to get a group of consumers (taste panels) to assess your product. Taste panels commonly use what is known as the Hedonic Scale and complete a questionnaire (see Appendix 1). Taste panel scores that average above 6 are considered to be acceptable taking into account the comments included in the evaluation forms.

When taking your product to the market it is important to define and address the competition. A significant factor in overcoming the competition is to persuade consumers that they are getting value for money. As such price is an important (but not the only) motivator for market purchase. At each stage during the product development process a watchful eye must be kept on the final costs of production and hence the likely final price. One simple rule of thumb is to multiply the costs of all the raw materials by three and add on 10%. This will give an indication of the production costs but distribution and profit margins must be added.

4.0 Food Safety

Food safety is an essential consideration when breadfruit is prepared for others to eat; every effort must be made to ensure that the food is safe for human consumption. It is crucial therefore, that basic food handling techniques are observed. Appendix 2 contains the explanation and techniques that should be used in food preparation.

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What are the essential food safety conditions for processing?

- *Access to the proposed processing area should be limited to those engaged in food processing and who have received food handling training.*
- *Access by all animals and vermin (dogs, cats, birds, rats and insects) is prevented either by the use of curtains, shade cloth or permanent fixtures.*
- *Hand-washing facilities must be available*
- *An adequate supply of hygienic (potable) water must be available.*

In order to carry out these handling procedures it is necessary to have access to a dedicated food production facility. A stand-alone processing facility is preferable but if such a facility is not possible then it is possible to modify/upgrade an existing kitchen or village hall (Fig. 15). However, it must only be used by people who have undergone food processing training and it must be proofed against insects, birds, cockroaches, pets, rats and mice. Local health officials will require that minimum standards are observed but produce from breadfruit is rarely high risk. Most health authorities are supportive of new businesses and will work with entrepreneurs to ensure compliance with regulations.

Figure 15: Small Scale Processing Facility, Rabi Island, Fiji

The following conditions are necessary for establishing a long-term food processing facility such that at all times food safety and suitability is a priority. Where new premises are proposed, facilities must be located, designed and constructed to ensure that:

- Two self-closing doors exist between the toilet and the food handling area.
- Surfaces of walls, partitions and floors are made of impervious materials with no toxic effect in intended use;
- Walls and partitions have a smooth surface up to a height appropriate to the operation;
- Junctions at walls and floors are covered with inert material with a diameter of 0.6 cm – melamine is commonly used.
- Floors are constructed to allow adequate drainage and cleaning and there should be no pooling of water;
- Ceilings and overhead fixtures are constructed and finished to minimize the buildup of dirt and condensation, and the shedding of particles and all electrical fittings are water-proof so that the entire premises can be hosed;
- Windows are easy to clean and constructed to minimize the buildup of dirt and where necessary, are fitted with removable and cleanable insect-proof screens. Where necessary, windows must be fixed;
- Doors have smooth, non-absorbent surfaces, and are easy to clean and, where necessary, disinfect;
- Working surfaces that come into direct contact with food are in sound condition, durable and easy to clean, maintain and disinfect. They must be made of smooth, non-absorbent materials, and inert to the food, to detergents and disinfectants under normal operating conditions.
- Design and layout permit appropriate maintenance, cleaning and disinfections and minimize air-borne contamination;
- Surfaces and materials, in particular those in contact with food, are non-toxic in intended use and, where necessary, suitably durable, and easy to maintain and clean;
- There is effective protection against dust, fumes and smoke.

5.0 A small scale breadfruit processing financial model

Only limited data is currently available on the actual financial returns from processing breadfruit. The model presented below is based on information obtained from the experience of the Tutu Rural Training Centre (TRTC) on Taveuni, Fiji.[6]

The TRTC has established its own breadfruit orchard which is now coming into full production. Marcotted bale kana breadfruit seedlings were planted along the Tutu road system. Mature bale kana fruit weigh approximately 1.2 kg and have been used to produce breadfruit flour and chips at the TRTC.

The model presented in Table 1 covers 5 years of processing – commencing with 425 fruit being processed in year 1 and increasing to 1,800 fruit by year 4. It is assumed that 40% of the breadfruit is used for flour and 60% for chips. The TRTC found that there was significantly more demand for breadfruit chips than for breadfruit flour. Based on the experience of the TRTC, with the data supplied by Dr Richard Beyer, it is estimate that a mature bale kana bread fruit will yield approximately 380 gm of flour or 455 gm of chips. On this basis 65 kg of breadfruit flour is manufactured in the first year increasing to 274 kg by year 4 and for chips, 139 kg are produced in year 1, increasing to 590 kg by year 4 (as shown in Table 1). The breadfruit flour sells for FJD 5/kg which is considerably more than the price of wheat flour and thus the market for this product is very much a niche market. The breadfruit chips sell for FJD 1 for 85 gm packet which was found to be more than competitive with imported potato chips and other such snack items. The gross revenue from the breadfruit processing enterprise is nearly FJD 4,000 in the first year increasing to some FJD 16,500 by year 4.

The small-scale breadfruit processing model presented assumes that the breadfruit processing is part of an enterprise that produces a number of processed fruit and root crop products. The TRTC Processing Unit produces plantain and taro chips, a range of jams and sauces (including chilli sauce), frozen fruit and fruit juice – with all the raw material sourced from the TRTC's own land. The capital cost of the processing equipment and the labour utilized is therefore shared amongst these other products. It is unlikely that breadfruit processing alone on this scale would be viable – particularly considering how the seasonality of breadfruit affects availability.

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[6] McGregor and Stice, 2018, "Orchard and small-scale processing development: the case study of the Tutu Rural Training Centre" in: The Market and Marketing of Pacific Island Bread with a focus on Fiji and Samoa (Chapter 6).
https://pafpnet.spc.int/attachments/article/855/Pacific%20Island%20Breadfruit%20Market%20and%20Marketing%20Final%20Report%20(March%202018)_final.pdf

The fixed cost of the breadfruit processing enterprise is the cost of equipment and machinery which is based on the actual cost of importing this equipment from New Zealand. These costs depreciate over 5 years and are shared equally with the other processed products because they all use the same equipment. It is assumed that a suitable building for the processing is already in place – as was the case with the TRTC. If a building has to be constructed for the processing enterprise the economics change fundamentally and a far higher throughput would be necessary to ensure financial viability.

The variable costs are: i) the raw materials (breadfruit), labour, packaging materials (food grade bags), cartons, cooking oil etc.; and ii) energy.

The TRTC grows its own breadfruit and the processing enterprise doesn't incur any actual cost for the raw materials. However, the breadfruit processing financial model below has factored in an imputed value of 50c per breadfruit processed; labour costs are shared with the other processing activities.

The drying of breadfruit, with its high moisture content, is the main energy cost in processing breadfruit. According to the analysis conducted by Dr Richard Beyer, it requires approximately 2 kwh to dry 100 kg of breadfruit. In Fiji it costs approx. 40c/kwh to purchase this electricity from the grid. On this basis the energy cost for Year 1 of the financial model would be some FJD 400, increasing to over FJD 4,000 by Year 4. The TRTC is fortunate that it does not have these electricity costs, thanks to the previous investment in hydro and solar power. Thus, in this sense, the situation at the TRTC with regards to processing is seen as a special case.

The estimate gross margin (total revenue – total costs) for the small-scale breadfruit processing enterprise is negative (FJD 1,925) in Year 1 and becomes positive in Year 2 (FJD 1,377), increasing to FJD 7,621 in Year 4. If the enterprise is fortunate to have electricity available at no cost the estimated gross margin is negative (FJD 944) in Year 1 and becomes positive in Year 2 (FJD 3,441), increasing to FJD 11,749 in Year 4.

Table 1: A financial model for small scale breadfruit processing

	Year 1	Year 2	Year 3	Year 4	Year 5
Production					
No of breadfruit processed	425	900	1,300	1,800	1,800
Weight (kgs) @ an average weight 1.2 kgs per bale kana fruit	510	1,080	1,560	2,160	2,160
Flour					
Breadfruit (kgs) (40% of breadfruit)	170	360	520	720	720
Flour (kgs)*	65	137	198	274	274
Chips					
Breadfruit (kgs) (60% of the breadfruit)	306	648	936	1,296	1,296
Chips (kgs)**	139	295	426	590	590
Gross revenue (factory gate)					
Flour					
Kgs	65	137	198	274	274
Price unit (FJD/kg)	5	5	5	5	5
Total (FJD)	323	684	988	1,368	1,368
Chips					
Number of packets (85 gm pks)	3,600	7,624	11,012	15,247	15,247
Price unit (FJD/85 gm pkt)	1	1	1	1	1
Total (FJD)	3,600	7,624	11,012	15,247	15,247
Total gross revenue (FJD)	**3,923**	**8,308**	**12,000**	**16,615**	**16,615**
Costs					
Fixed costs					
Equipment/Machinery (depreciated over 5 years and shared with other processed items - eg vudi and taro chips)					
Worktop benches	1,438	1,438	1,438	1,438	1,438
Disc peeler	1,035	1,035	1,035	1,035	1,035
Slicer	931	931	931	931	931
Grinder	302	302	302	302	302
Electric deep frier	277	277	277	277	277
Other equipment	250	250	250	250	250
Equipment R&M (15% of purchase price)	635	635	635	635	635
Total fixed cost	4,867	4,867	4,867	4,867	4,867
Variable costs					
Raw material (breadfruit)					
Breadfruit purchased for flour (50c/kg farm gate)	85	180	260	360	360
Breadfruit purchased for chips (50c/kg farm gate)	128	270	390	540	540
Sub-total	213	450	650	900	900
Labour					
Labour input (days)***	4	8	12	16	16
wages per day ($)	30	30	30	30	30
Total labour cost	120	240	360	480	480
Materials					
Packaging					
Food grade plastic bags****					
Flour (1kg pkt) - number of bags	65	137	198	274	274
Cost @ 15c/bag	10	21	30	41	41
Chips (85 gm pks) - number bags	3,600	7,624	11,012	15,247	15,247
Cost @ 3c/bag	72	152	220	305	305
Sub total (FJD)	82	173	250	346	346
Cardboard cartons					
15 pks flour per carton @ $3.50/carton)	15	32	46	64	64
50 pks chips per carton @ $2/carton)	144	305	440	610	610
Sub-total (FJD)	159	337	487	674	674
Total packaging cost (FJD)	241	510	736	1,020	1,020
*Cooking oil (FJD) *******	468	991	1,432	1,982	1,982
Other materials (gloves, cleaning items etc.)	150	150	150	150	150
Sub-total materials (FJD)	859	1,651	2,318	3,152	3,152
Energy					
KWH of electricity used (@ 2 kwh per 100kg of breadfruit processed	1,020	2,160	3,120	4,320	4,320
Electricity cost @ 40c/kwh ($)	408	864	1,248	1,728	1,728
Total variable costs	**981**	**2,064**	**2,994**	**4,128**	**4,128**
Total cost	**5,848**	**6,930**	**7,861**	**8,994**	**8,994**
Gross Margin (total revenue - total costs)	- 1,925	1,377	4,139	7,621	7,621
Gross Margin if electricity available at no cost	- 944	3,441	7,133	11,749	11,749
*1 fresh breadfruit wil yield about 380g of flour.					
** 1 fresh breadfruit wil yield about 455g of chips.					
*** 4 days of labour process 500 breadfruit. The same labour also used tp process other items(vudi, taro chips, jams and sources, frozen fruit, fruit juice etc)					
**** 50 micron pp - expected shelf life 18 - 20 days					
***** $ 2,600 cooking oil required to produce 20,000 pks of chips					

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The following questions take into account what has been presented in this module. You should consider them carefully as the answers will provide the information you need for the business plan.

Questions	Answers
Do you or any family member have any processing experience – either with breadfruit or a starchy crop such as taro or cassava?	Y / N
Would you be able to put in place the food safety requirements as outlined in Module 4 in existing premises?	Y / N
Have you identified the processing equipment required? How much will the equipment cost and what volume of breadfruit do you need to process and sell to justify the cost.	Y / N
Would you be able to obtain sufficient volume of raw material to support a processing business?	Y / N
Have you identified a market for your processed product and the arrangements for marketing the product	Y / N
Can you incorporate other staple food crops into your processing business (if you are unable to initially access a sufficient volume of breadfruit) to help drive the business at the start?	Y / N

Appendix 1

Taste panels: hedonic scale and evaluation form

9-point Hedonic Scale

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like or dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Evaluation Form

Product............... Date.............. Variety............................

Appearance	Score		Taste	Score
Excellent			Excellent	
Very good			Very good	
Good			Good	
Moderately good			Moderately good	
Neither like or dislike			Neither like or dislike	
Moderately poor			Moderately poor	
Poor			Poor	
Very poor			Very poor	
Totally unacceptable			Totally unacceptable	
Aroma	**Score**		**Overall Acceptability**	**Score**
Excellent			Excellent	
Very good			Very good	
Good			Good	
Moderately good			Moderately good	
Neither like or dislike			Neither like or dislike	
Moderately poor			Moderately poor	
Poor			Poor	
Very poor			Very poor	
Totally unacceptable			Totally unacceptable	

Comments...

Appendix 2

1.0 Introduction

Most of the foods consumed in the Pacific Island Countries (PICs) spoil very quickly - especially at the high temperatures that are found in tropical countries. They spoil for two reasons:

- The life processes may continue so that fruits and vegetables continue to ripen and then over-ripen.
- They are attacked by life forms that are too small for us to see – **microorganisms, that is, bacteria, viruses or moulds**.

All life forms go through a period of growth, maturity and ultimately decay and death. Bananas are good examples. They grow on the tree, are commonly picked almost green, turn yellow as we keep them and eventually turn soft and black during tissue death. Breadfruits are the same – once they go past maturity they lose texture and sour as a result of bacterial activity.

These processes can be slowed or even stopped in some foods by chilling or by packing them in a special gas. Fruits that come from overseas are chilled as they are transported to their markets and the chilling slows down the life processes so that they are in good condition when they reach the consumer.

2.0 Attack by micro-organisms

All around us there are very small life forms, which are much too small to see. They are present in very large numbers and there are many different types. They are known as **microorganisms, that is, bacteria, viruses and fungi**.

These micro-organisms can be very adaptable, with some growing at high temperatures (some are so tough boiling water will not kill them), others at low temperatures, and some require air to grow whereas others can grow where air is absent.

Bacteria survive well in warm humid conditions and will grow during the day and night because light is not a requirement for their growth.

Where do we find bacteria?

- Soil
- Animal droppings
- Human droppings (faeces)

- Dirty water
- Rotten food
- Human nose and throat
- Hair and all body fluids
- All animals

If substances are exposed to any of these elements, they will become infected with bacteria even if they had no bacteria on them prior to the exposure which **highlights why it is important to take note of the conditions required for setting up a food processing facility**.

The speed at which foods spoil and rot is dependent on the number and types of bacteria present and the conditions under which the food is stored. It is the responsibility of the food processor and food handlers to make sure that the foods we prepare for others to eat have the lowest possible numbers of bacteria. Not only must we have a responsible attitude toward the welfare of others, but also if our food products cause illness the future of our food producing activities will be affected because others (consumers) will not eat our food again.

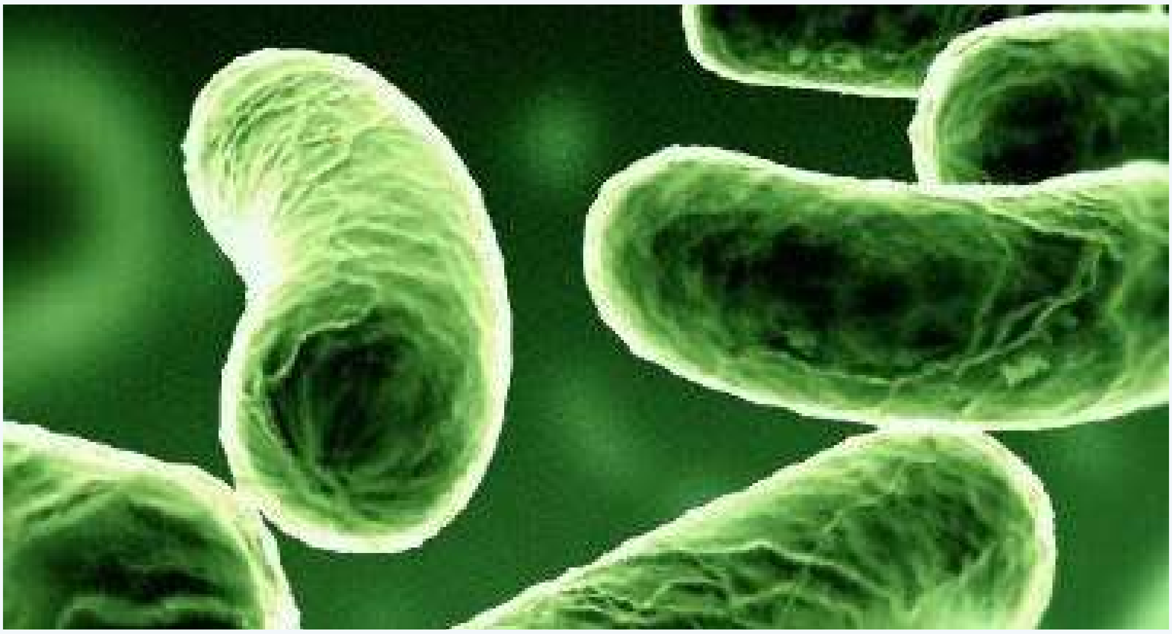


Figure 1 E coli - A Common Food Illness Bacterium; hundreds of thousands of bacteria can fit into a space the size of the period (full stop) at the end of a sentence.

3.0 Bacteria that can cause sickness

There are many ways in which food can become contaminated with dangerous bacteria.

3.1 Contamination from the equipment

Some foods are always **contaminated** because of the ways in which they are produced. All vegetables and fruits, such as melons and pineapples that are grown close to the ground are **contaminated** with **bacteria** from the soil. Some bacteria from the soil will cause sickness – these bacteria are known as pathogenic bacteria. Many pathogenic bacteria found in soil ultimately come from the droppings of animals but others are naturally present in soil. Fruits and tree crops are usually contaminated with bird droppings or from soil blown onto them as dust.

Your food products can become contaminated if they are placed on a board or table that has previously been used for other foods, such as meat (in particular, meat guts) or raw fruit. Obviously knives used to cut these foods can also be a source of contamination.

Shoes and feet can also bring bacteria into the food preparation area, during transport from the field or garden to your production area.

Being aware of all the sources of bacterial contamination is extremely important and to help in creating that awareness amongst any workers in the processing facility, the following rules must be observed.

Rule 1 Food arriving at the processing area must be washed before it enters the processing area. Any food that falls on the floor is contaminated and cannot be eaten without either washing carefully or reprocessing.

Foods (and peeling and trimmings) dropped on the floor also attract insects, birds, rats, mice and cockroaches (vermin) who will transfer bacteria from soil and droppings to the table and then to the food and your hands.

Rule 2 Food, peelings or trimmings that fall on the floor must be removed immediately so that vermin (rats, mice, birds, insects, cats or dogs) will not be attracted to the food production area.

Rule 3 Dirty areas, such as around the vegetable or fruit washing area and the production facility entrances, should be washed regularly.

Rule 4 Waste foods should be discarded at an area remote from the processing area so as not to attract vermin. (Wherever possible, vegetable waste should be composted).

Rule 5 Movement in and out of the production area must be restricted to staff who have undergone training in food hygiene and handling. Where possible all access doors should be self- closing to prevent vermin from entering the food processing area. Access to people not involved in food processing should be prohibited.

Rule 6 Food components including additives should be kept in sealable containers so that insects, birds, rats and mice will not be attracted to them.

3.2 Contamination from Handlers

Kitchen and food preparation staff will bring bacteria into the factory on their shoes and feet, and also on their hands because of everything we have touched. Many are naturally present on our bodies. Bacteria belonging to one person may cause sickness in another person and can be transferred to others by sneezing, when hair falls out and when we touch. There are many bacteria around our noses and throat. If we touch our nose or mouth then we will have bacteria on our hands, which can cause sickness in others. It is the custom in Pacific Island countries to shake hands regularly with friends and people we know. You can't be sure as to how clean their hands are so again caution is needed.

If we have just stroked a dog or cat then we will have many bacteria on our hands because all animals are heavily contaminated with bacteria. We may have been to the toilet and not washed our hands afterwards. Faeces and also the areas around our bodies close to the toilet areas are heavily contaminated with bacteria unless we take a shower every time we use the toilet, which is not possible. Bacteria can get through eight layers of toilet paper and so if we use the toilet we have many, many bacteria on our hands.

As we put food in our mouths or lick our fingers then bacteria in our nose or throat are moved to our fingers. It is important that we wash our hands after eating. Jewelry should be removed or taped using surgical protective tape to ensure that bacteria behind the item does not contaminate food and that it does not fall into food processing equipment.

Sneezing will spread bacteria from our nose over a wide area and if we feel that we are about to sneeze we should move away from the food production area quickly or catch the sneeze aerosol (spray) in a tissue or a handkerchief. The tissue must be discarded. Immediately after sneezing we must wash our hands before touching food or anything else.

Rule 7 Hands must be washed as you re-enter the food production area especially after smoking, using the toilet, eating or nose-blowing or sneezing into a handkerchief. If you sneeze into a tissue it must be thrown away immediately.

It is best to shake your hands dry after washing instead of using a towel which can be dirty; ideally taps should be foot or knee operated.

Hand washing and showering and foot baths assist in preventing contamination but protective clothing including mask, hairnets, gloves, clean overalls and foot-ware are now essential in many advanced food processing facilities.

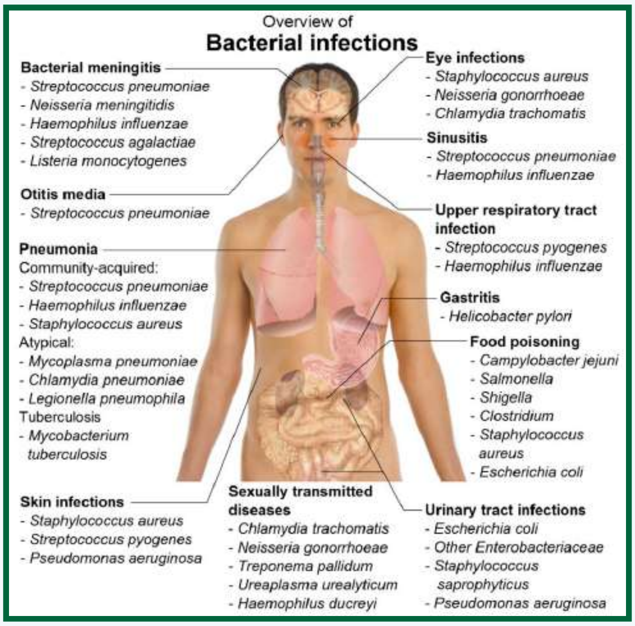
Rule 8 Hairnets, gloves coveralls and waterproof foot ware is mandatory in the processing area

Protective clothing should have pockets on the inside so that the contents of pockets (pens etc.) cannot drop into the food. If finances permit protective clothing should be provided that is changed and washed every day. Gloves and hair nets are essential.

Rule 9 Smoking, chewing, eating and spitting are not permitted in the processing area. When taste testing foods, utensils used for tasting must not be returned to the food under preparation.

Because we may spill food on the floor (see Rule 2) then we must never eat in the factory areas. Smoking is also not allowed in food factories because the bacteria from our noses and mouth are transferred onto our hands – again after smoking we must wash our hands. Cigarette ends are heavily contaminated with bacteria and they are unsightly.

The following diagram (Figure 2 Humans as a Source of Bacterial Infection) of the human body gives you an idea of just how many infectious bacteria we can carry:



Rule 10 Symptoms of illness, including colds, 'flu or boils or other skin lesions must be reported to the supervisor.

If we have a boil or sore on our bodies, it is full of bacteria, which will certainly cause illness in others. It must be covered with a dressing in such a way that it cannot leak. If this is not possible, then your tasks for the day must not be anywhere near food.

If you have a running tummy, then you should not enter the factory and you should stay at home. If it is only a mild case then you should tell your supervisor who will give you tasks away from food.

Rule 11 Staff incurring injuries that result in bleeding must be treated for emergency and removed from the processing area as quickly as possible consistent with safe First Aid practices.

4.0 Microorganisms that can Cause Damage to the Food Itself - Spoilage

When bacteria infect and use food they make chemicals which may give a sour taste and/or which may smell bad. If we leave meat, fish or milk out of the fridge it starts to smell very quickly. This process is called **spoilage**.

We can **stop spoilage** by any one of the following methods, some of which have been previously described:

- Freezing
- Packing in a can (or more recently heat-resistant plastic containers) and heating it so that all the bacteria are killed (canning, retort pouching)
- Drying

Foods preserved this way will keep for a long time – in some cases up to 2 years. We can **slow** down **spoilage** by:

- Cooling in the fridge – as described for breadfruit.
- Salting.
- Storing in vinegar (pickling).
- Adding sugar (jam, and crystallised fruits and ginger).
- Adding a preservative.

Foods preserved this way will keep for a short time only. The rate of spoilage slows to half for every 10ºC drop in temperature so foods kept at room temperature ~ 25ºC will spoil about four times more quickly than foods stored in the fridge at 5ºC.

The time that these foods keep will depend on how many bacteria are present at the time we finish processing them, therefore it is very important that we try very hard to keep bacteria out. This can be achieved by observing the food safety rules that have been stated

At the end of the day we must work on a cleaning system that makes sure that bacteria cannot grow overnight.

Diluted household bleach (eg Chlorox) (diluted 20 parts water to 1 part bleach), makes an excellent rinsing solution that can be used to sterilize hands after washing with soap and has been used a number of times in isolated food production areas. It can be used for surfaces and utensils after they have been washed properly with soap and other detergents. Tables can be rinsed with this solution and left to dry by itself. High risk items such as knives and chopping boards can be soaked in this solution overnight. If finances permit there is a range of specialised cleaning material that allows equipment to be cleaned without dismantling every time (so called, clean-in-place; CIP)[7]

[7] CIP is the automated cleaning of equipment with minimal dismantling of food production equipment prior to the cleaning and sanitizing operation.

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