

## The Use of Pandanus Fruit As Food in Micronesia<sup>1</sup>

CAREY D. MILLER, MARY MURAI, and FLORENCE PEN<sup>2</sup>

THE PANDANUS, sometimes called screw pine, is widely distributed in Southeast Asia and all the tropical Pacific islands, but according to Dr. Harold St. John, Professor of Botany at the University of Hawaii, it is only in Kapingamarangi and the Marshall, Gilbert, and Ellice Islands that one finds the varieties with choice edible fruit. On the small and relatively dry low islands or atolls, pandanus and coconuts are the principal and sometimes the only vegetable foods.

Almost all parts of the pandanus plant are used by the inhabitants of these islands, the

leaves provide material for clothing and shelter, and for household use such as baskets and mats. The chief edible part is the fruit, especially the fleshy base of the keys.

There are two distinct sexes of trees for all varieties, male (staminate) and female (pistillate). The pistillate trees bear fruits of different sizes, varying from the inedible ones 3 or 4 inches in diameter, which weigh a pound or less, to the very large edible fruits weighing 20 to 30 pounds (see Fig. 1). A 30-pound fruit has approximately 50 keys and a core and stem weighing about 2 pounds.

Each fruit is made up of many small sections called keys (botanically a phalange), because though irregular in shape, they fit closely together to form a solid fruit. In a large fruit the keys are 3 to 4 inches long; at the outer end they are 1½ to 2 inches in diameter and at the inner end near the core ¾ to 1 inch (see Fig. 2). The rough outer surface may be green or yellow when ripe, but the inner edible end is always yellow-orange in color. The inedible varieties have fruits which, though smaller, look just like the edible types, but they are extremely astringent and bitter.

The chemical analyses and studies of the nutritive values of pandanus fruit reported in this paper were made on fruits from Micronesia: Majuro and Mille Atolls of the Marshall Islands and Kapingamarangi of the Caroline Islands.

<sup>1</sup> Published with the approval of the Director as Technical Paper No. 333, University of Hawaii Agricultural Experiment Station.

This work has been a joint project of, and financially supported by, three agencies:

The Pacific Science Board of the National Research Council provided a fellowship under which Mary Murai did the field work and made some of the analyses.

The United States Department of Agriculture, through a contract sponsored by the Human Nutrition Research Branch, Agricultural Research Service, provided the funds for most of the food analyses, which were made by Florence Pen.

The Foods and Nutrition Department of the University of Hawaii Agricultural Experiment Station furnished the laboratory, the equipment, and the necessary overhead, as well as the financial cost of the supervision for the analyses of the foods and the preparation of the manuscript by Carey D. Miller.

Pandanus was only one of the foods studied under this project. The complete publication will appear elsewhere.

<sup>2</sup> Department of Foods and Nutrition, University of Hawaii Agricultural Experiment Station. Manuscript received August 26, 1954.

## USE AS FOOD

The earliest account of the edible pandanus fruit and its use by the natives of the Marshall Islands is by Kotzebue (1821, 2: 8) who early in 1816, when he first touched at the Radak Island chain, observed "they had nothing with them except a few grains of pandanus, which they constantly chewed."

Kotzebue and Chamisso, the naturalist who accompanied the expedition, tell of being served "pandanus juice" which was pressed from the keys after they were bruised with a stone and which Kotzebue states, "had a sweet and spicy taste" (1821, 2: 10).

Discussing the abundant pandanus, Chamisso stated: "It is also diligently cultivated; numerous varieties, with improved fruits, which are to be ascribed to cultivation, are propagated by layers" (Kotzebue, 1821, 3: 150).

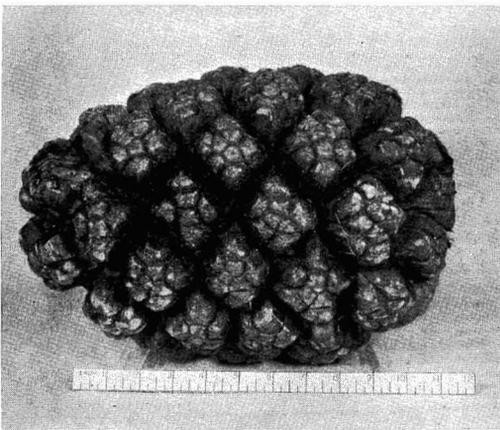


FIG. 1. Pandanus Fruit—Joibeb. From Ebon, Marshall Islands; weight 19¾ pounds.

Kotzebue (1821, 2: 75) opined that "the pandanus contains very little nourishment," but noted that the natives "enjoy extraordinary health, and attain to an advanced and cheerful old age." His picture of the teeth, however, is quite in contrast to that of some of the early voyagers who remarked on the fine teeth of the Polynesians (Cook, 1784, 1: 380; King, 1784, 3: 125; Ellis, 1832-36, 1: 81). Kotzebue states: "All the islanders are

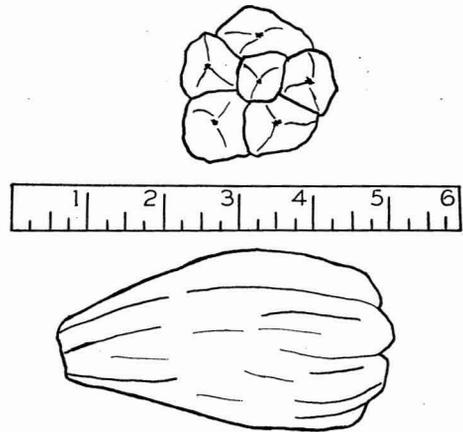


FIG. 2. A single key from a large Lojekerer, side and end views. Sketch by M. Higa.

great lovers of sweet things; and their chief food, which they draw from the sweet pandanus fruit, is probably the reason, that even children of 10 years old have not good teeth, and that they have generally lost them all in the prime of life" (1821, 2: 17).

Chamisso (Kotzebue, 1821, 3: 150) gives a rather detailed account of the making of pandanus paste (*mōkan*), which is essentially the same method used today. He also observed that the paste was "carefully preserved as a valuable stock for long voyages."

Pandanus has apparently always been an important food in the Marshall as well as the Gilbert Islands as it figures prominently in their folklore and is commonly considered to have come with their creation (Grimble, 1933-34, 54: 85, 97; James Milne, personal communication).

Selection and propagation must have been practiced by these isolated people for many years in order to have developed the fine edible varieties which are limited in their distribution.

No edible pandanus was in evidence when the dietary study was made in the Caroline Islands (Murai, 1954), but it was thought that it might have been out of season. Chamisso (Kotzebue, 1821, 3: 184) states that at the time of their visit (1817) that although

the pandanus grows on all the islands, "the fruit is neither eaten, nor ever used for an ornament. None of the improved kinds are found there."

In the Marshall Islands, each household owns some pandanus trees which may be near the house or at some distance from the dwelling. When ripe and ready for use, the large fruits are cut from the tree with a bush knife and the keys broken apart to be eaten raw or cooked.

Pandanus was in season in the Marshall Islands from January to the end of May, 1951, and at the time the dietary study was made in April both pandanus and breadfruit were being used (Murai, 1954: 14). On the low islands, pandanus is one of the important foods between breadfruit seasons, and, when breadfruit is abundant, pandanus may or may not be used.

The most common method of eating pandanus is to gnaw at the soft inner ends, leaving the long tough fibers attached to the keys. Children and adults seem to chew the keys almost continuously during their waking hours. People eat them much as Westerners might eat nuts or candy or smoke cigarettes. Chewing pandanus keys, talking and gossiping are an important part of their social life. Records of the amounts eaten and the nutrients furnished are given in the section on Composition and Nutritive Value.

The hard portion of the keys is used as fuel. The inedible ends also contain the seeds which can be removed only with great difficulty because they are enclosed in an unusually tough woody case and people rarely bother to extract them, although they are sometimes eaten.

In the raw state, the edible portion of the pandanus is merely a juice pressed from the cells embedded in coarse fibers. It is not a pulp but a liquid which when extracted in the laboratory has a small portion of solid material that settles to the bottom of a beaker. The juice is sweet and subacid with a pungent aromatic flavor. When cooked the starch

causes the juice to thicken and the edible portion becomes a soft pulp, resembling mashed sweet potatoes both in color and in texture. The flavor is similar to the raw juice.

If a good supply of other foods is available, the pandanus keys are more likely to be eaten in the raw state because people simply do not bother to cook them. But when the pandanus constitutes a large proportion of the diet (such as was observed in February, 1951, at Mejit Island, Mejit Atoll; Utirik Island, Utirik Atoll; and Ailuk Island, Ailuk Atoll; in the drier northern Marshall Islands), it is eaten cooked as well as raw, probably to add variety. It is also combined with other foods as listed below.

A glossary of the names of edible pandanus fruit, and products made from it, which were observed by one of us (M.M.) in the Marshall Islands in 1951 is as follows:

Bop—The pandanus tree or the whole fruit made up of many keys.

Kōbeo—Raw pandanus fruit.

Eroum—Boiled or baked pandanus.

Joanrong—Pandanus juice.

Mōkan—Cooked and preserved pandanus pulp (see below for preparation).

Beru—Soft pulp from boiled pandanus cooked with arrowroot flour to produce a sweet dessert.

Mokanrul—Pulp of cooked pandanus fruit mixed with grated coconut and baked.

Jakaka—Shredded fresh (uncooked) pandanus which is dried for almost one week and used as a confection.

The native people in most of the islands still make all the products from pandanus which their ancestors made. But where western influence is strong, or where more favorable conditions permit growing a greater variety of foods, they no longer preserve the pandanus, though they continue to enjoy it in the raw or freshly cooked state. Two products which we analyzed, that can be stored and used for emergency or as wanted, pandanus paste and pandanus flour, are described below.

*Pandanus Paste (Mōkan)*

Wherever the pandanus constituted an important native food in the fresh and cooked state pandanus paste was also made, and is still made in some areas.

Many reports of scientists in the 19th and 20th centuries tell of the preparation of pandanus paste which they also refer to as pandanus conserve or preserve (Kotzebue, 1821, 3: 150; Finsch, 1893: 142; Kramer, 1906: 427; Kurze, 1887; Wendler, 1911: 271).

Details of the process may vary slightly in different localities but in general the paste is made as follows: The separated pandanus keys are cooked in a deep earth oven with alternating layers of fruit and leaves for as long as 2 days, though one report states for 12 hours (Wendler, 1911: 271).

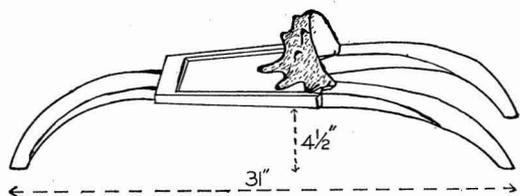


FIG. 3. Beka of traditional Marshallese type from Arno Atoll, Marshall Islands, collected in 1950 by Dr. Leonard Mason. Sketch by F. Pen.

The soft ends of the keys are rubbed against a scraper (formerly of shell, Fig. 3, but now more likely of metal) and the orange pulp is collected and dried on leaves. When it becomes a sticky mass, it is dried further over hot stones until it is thick and rather firm. The flat cakes are then rolled or pressed into a firm mass, wrapped in plaited pandanus leaves and firmly tied with coconut cord as shown in Figure 4.

These rolls are reported to have been of enormous size formerly—6 feet long and more than 1 foot in diameter (Finsch, 1893: 142; Kurze, 1887; Wendler, 1911: 271). Today they are more likely to be 12 to 15 inches long and 3 or 4 inches in diameter (Fig. 4). The model shown in Figure 5 is only 8 inches long.

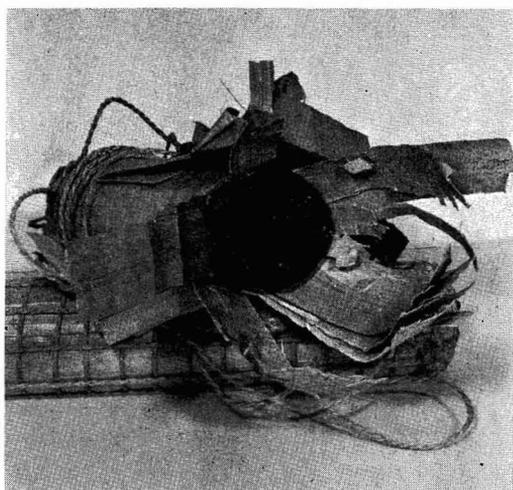


FIG. 4. Roll of pandanus paste in lauhala wrappings, collected at Mille Atoll by Dr. Kenneth P. Emory.

One account of the preparation of pandanus paste (Wendler, 1911: 272) calls attention to the unsanitary methods employed in making it, but probably they were no less sanitary than the handling of other foods.

The product is brown in color and tastes much like date or fig paste. It will keep a year or more and was formerly an important manner of preparing food for use on voyages and for storage in case of famine as well as for a regular food supply when the pandanus was not in season (see p. 4).

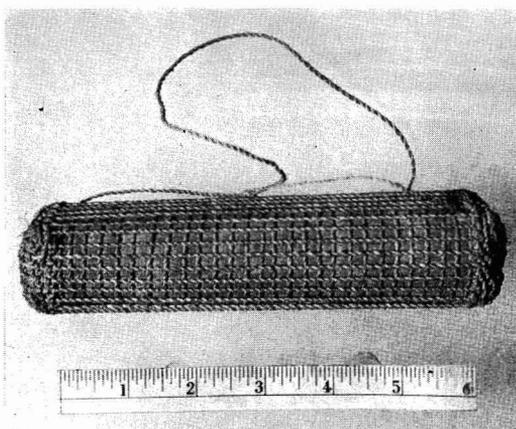


FIG. 5. Model roll of pandanus paste, collected at Majuro Atoll, by M. Murai.

*Pandanus Flour*

Although the accounts of anthropologists (Buck, 1950: 29; Grimble, 1933-34: 36) vary somewhat as to the method of making the dried product, referred to as "pandanus flour," they agree on the essential points which are here summarized.

The soft ends of the keys are cut off, placed in some type of coconut basket and cooked, usually by steaming in an earth oven until tender, about 1 hour. The cooked fruits are pounded to a paste which is made into large thick flat cakes, about 14 inches in diameter, which are dried (Buck, 1950: 29). In some places they are dried in the sun and finished over a grill of hot stones, and in other places they are dried over the hot stones first and then placed in the sun. The sun drying may take several days. They are usually given a final drying over hot stones and then the large crisp cakes are broken and pounded to a coarse flour-like consistency.

The product is dull yellow with a pleasant pungent odor. It can be stored in tubular containers made of plaited pandanus leaves and will keep for several years.

Grimble (1933-34: 39) reports that formerly pandanus flour and water were often the only food and drink taken on long voyages. The powder was simply mixed with water and drunk.

Dr. Katharine Luomala of the Department of Anthropology, University of Hawaii, who made observations in the Gilbert Islands in the latter half of 1948, especially on the Island of Tabiteuea, says that she saw both pandanus flour and pandanus paste being made (personal communication).

To our knowledge the pandanus is not made into a flour in the Marshall Islands as it is in the Gilberts and in Kapingamarangi.

## SAMPLES ANALYZED

The number of edible varieties of Pandanus in the Marshalls is uncertain, but St. John states that he has collected several score (personal communication).

One of us (M.M.), collected what were believed to be two native varieties of edible pandanus for chemical analyses, but St. John, who has examined the keys, believes them to be the same botanical species.

LOJEKERER (local name), *Pandanus pulposus* Martelli: This variety is the most common and widely distributed in the Radak chain. Four fruits on Majuro Island in April and May, 1951, had the following weights: 23, 32, 25, and 30 pounds. The keys are large, 3 to 4 inches long, 1½ to 2 inches in diameter, and weigh from about 3 to 7 ounces (100 to 200 grams) (Fig. 2). They are eaten both raw and cooked.

According to our informants this variety usually fruits but once a year. Our samples were obtained toward the end of the fruiting season.

JOIBEB (local name), *Pandanus pulposus* Martelli: This variety, which according to our informants, is also widely distributed, was thought to have originated on Jaluit of the Ralik chain. Four fruits on Majuro Island in April and May, 1951, had the following weights: 24, 30, 20, and 25 pounds. These fruits also had large keys.

We were informed that on Jaluit and Ebon, this variety usually fruits twice a year.

Under Composition and Nutritive Value, for clarity, we refer to the fresh pandanus by the two local names as if they were two horticultural varieties.

*Sample 1. Pandanus, Fresh*

1. Marshallese name—Lojekerer. *Pandanus pulposus* Martelli.
2. Date and place of collection: May 20, 1951. Uliga Island, Majuro Atoll.
3. Date vitamin assays begun: October 11, 1951. (Other analyses were made at a later date with repetition of moisture content to determine if there had been any loss as a result of freezer-storage.)

4. Preparation of sample after collection: Keys from three fruits, each from a different tree, were weighed, wrapped in groups of three in several thicknesses of wax paper, labeled, and placed in the freezer.
5. Transportation and storage: Frozen at 0° F. and held in Navy cold storage for 8 days. Kept frozen at 12° F. on a Navy vessel for 9 days enroute to Honolulu. Transferred to Foods and Nutrition Department, University of Hawaii Agricultural Experiment Station. The samples were examined and rewrapped in the same wax papers with an outer wrapping of aluminum foil. The keys were kept in freezer-storage at 0° to -5° F. until analyses were made.
6. Preparation for analyses: Samples were thawed in the refrigerator and then brought to room temperature. Total weights of keys and weights of edible portions were recorded. Edible portions were cut into small pieces and blended in the Waring Blendor without addition of liquid. The coarser fibers were removed by putting slurry through two thicknesses of cheesecloth to obtain a value more representative of the portion actually eaten. The juice so extracted was put into brown glass bottles filled with carbon dioxide, closed tightly with bakelite tops, labeled and held at 0° F. until all analyses had been made. Refuse, 59 per cent.

*Method of Crude Fiber Analyses:* To remove a large portion of the sugars from the pandanus samples to be analyzed for crude fiber, the samples were weighed, transferred quantitatively to filter paper in funnels, and extracted with distilled water in the refrigerator for almost 2 weeks. (Refrigeration was necessary to prevent the growth of molds.) The water extracted residues were dried on the filter papers for 48 hours, below 70° C., and then extracted with ether in the usual manner. The ether extracted residues and the attached filter paper were used for the crude fiber determinations. A blank of filter paper was

run simultaneously with each of the triplicate determinations of fiber.

*Sample 2, Pandanus, Boiled*

- 1, 2, and 3 same as sample 1.
4. Preparation of sample after collection: Keys from the same fruit as sample 1 were boiled without a cover in a large glass beaker of plain water for 30 minutes. The water was drained off and the keys cooled. Keys were weighed and labeled as stated for sample 1.
5. Transportation and storage: Same as sample 1.
6. Preparation for analyses: Same as sample 1, except that in addition to cutting off the soft ends, any soft juicy pulp remaining in the fibers was scraped out with a dull knife and added to the soft ends before mixing in the Waring Blendor. Refuse, 65 per cent.

*Sample 3, Pandanus, Fresh*

1. Marshallese name—Joibeb. *Pandanus pulpatus* Martelli.
2. Date and place of collection: May 15, 1951. Majuro Island, Majuro Atoll.
3. Date vitamin assays begun: October 11, 1951. Other analyses same as sample 1.
4. Preparation of sample after collection: Keys from three fruits from three different trees, prepared in the same manner as sample 1.
5. Transportation and storage: Same as sample 1, but product held in Navy cold storage for 13 days before shipping.
6. Preparation for analyses: Same as sample 1. Refuse, 66 per cent.

*Sample 4, Pandanus, Boiled*

- 1, 2, and 3 same as sample 3.
4. Preparation of sample after collection: Keys from same three fruits as sample 3 were boiled in plain water in a large glass beaker for 30 minutes without a cover. After cooling, the soft end of the keys was

scraped with a dull knife to remove the pulp that constitutes the edible portion. The following were mixed in a Waring Blendor: 164 grams of pulp, 90 milliliters of 1 per cent oxalic acid, and shortly before slurry was completely blended, 5 milliliters of chloroform and 3 drops of mixed tocopherols were added. The samples were transferred to brown glass bottles, the plastic caps screwed down tightly and sealed with paraffin wax. Refuse, 75 per cent.

5. Transportation and storage: Bottles were kept at 36° F. at Uliga, Marshall Islands, until shipped by plane on May 29, 1951. The bottles were packed in cartons and shipped by air without refrigeration. The flight took 2 hours to Kwajalein, bottles were refrigerated at 36° F. in a Navy reefer during a stopover of 20 hours at Kwajalein. The flight from Kwajalein to Honolulu took 9 hours during which time they were not refrigerated. Samples were transferred to the Foods and Nutrition Laboratory and kept at 36° F. until analyzed.

#### *Sample 5, Pandanus Paste*

1. Marshallese name—Mōkan.
2. Date and place of collection: Summer of 1949. Mille Atoll, Marshall Islands, by Dr. Emory.
3. Date vitamin assays begun: October 10, 1949, except carotene which was determined in January, 1951.
4. Preparation: Similar to method described on page 6, but exact times of cooking and drying are not known. Thin slices were made into a roll approximately 3 inches in diameter and 14 inches long, covered with plaited pandanus, and tied securely with sennet (see Fig. 4).
5. Transportation and storage: Transported by ship without refrigeration to Honolulu. Brought to the Foods and Nutrition Department in September, 1949. Kept at room

temperature until analyses were begun, samples were removed from wrappings and thereafter kept refrigerated in tightly closed bottles.

#### *Sample 6, Pandanus Flour*

1. Polynesian name: paku harahara.
2. Date and place of collection: July, 1947. Kapingamarangi Island, by Dr. Emory.
3. Date vitamin assays begun: Vitamin A feeding tests, July, 1948; other vitamins, August, 1948.
4. Preparation: Similar to method described on page 7.
5. Transportation: Transported by ship without refrigeration to Honolulu. Delivered to the Foods and Nutrition Department in September, 1947.
6. Storage: Stored in tightly closed bottles in the refrigerator until analyzed.

#### ANALYTICAL METHODS

The thiamine, riboflavin, and reduced ascorbic acid of pandanus fruits were assayed chemically and niacin was determined microbiologically by the methods outlined by the Association of Vitamin Chemists (1951). The carotene content was measured physically by the chromatographic method of the Association, except that the extraction procedure was facilitated by using a mixture of solvents (petroleum ether, acetone, and alcoholic KOH) in the Waring Blendor, followed by centrifugation.

The analytical methods used for moisture, fat, crude fiber, total ash, and phosphorus were essentially those recommended by the Association of Official Agricultural Chemists (1950). (Details of all methods used and modifications of A.O.A.C. methods are on file in this laboratory and will be furnished upon request.) Protein was determined by the Winkler boric acid modifications of the Kjeldahl method (Markley and Hann, 1925).

A modification of the McCrudden method for calcium as recommended by the Human

TABLE 1  
COMPOSITION OF PANDANUS FRUIT  
(100 grams, Edible portion)

SAMPLE	WATER	FOOD ENERGY CALORIES*	PROTEIN	FAT	CARBOHYDRATES		ASH	CALCIUM	PHOS- PHORUS	IRON
					TOTAL	FIBER				
1. Lojekerer, fresh.....	80.20	71	0.37	0.27	18.63	0.28	0.53	9.6	25.9	0.89
2. Lojekerer, boiled.....	83.74	58	0.22	0.20	15.42	0.08	0.42	13.3	19.6	0.39
3. Joibeb, fresh.....	84.17	56	0.38	0.27	14.55	0.30	0.63	16.4	33.0	0.58
5. Pandanus paste.....	17.83	293	2.23	1.38	76.14	3.28	2.42	134.4	108.2	5.74
6. Pandanus flour.....	10.80	196	2.94	1.25	80.71	14.95	4.30	797.0	114.0	1.73

\* Calories, with the exception of those in pandanus flour, were calculated by physiological energy factors recommended for fruit by the U.S.D.A. (Leung, Pecor, and Watt, 1952: 4). For pandanus flour, factors of 1.58, 8.37, and 2.24, respectively, were used for protein, fat, and total carbohydrate by difference. These factors, based on the heat of combustion values for fruit and the digestibility coefficients for wheat bran, were tentatively recommended for use in calculating the calories in pandanus flour by the Human Nutrition Research Branch, Agricultural Research Service (personal communication).

Nutrition Research Branch, Agricultural Research Service, United States Department of Agriculture, was used (personal communication).

Iron was estimated by the Saywell and Cunningham (1937) o-phenanthroline colorimetric method taking all possible precautions in the laboratory to prevent contamination with iron.

#### COMPOSITION AND NUTRITIVE VALUE

The pandanus products analyzed were: two varieties of fresh and cooked pandanus from the Marshall Islands (Majuro) collected in 1951, one sample of pandanus paste collected in 1949 by Dr. Emory at Mille Atoll, Marshall Islands, and one sample of pandanus flour from Kapingamarangi, also collected by Emory in 1947. The data on composition are summarized in Tables 1 and 2.

#### *Fresh, Raw, and Cooked Pandanus Fruit*

The fresh fruit contains but small amounts of protein and fat (less than 0.5 per cent), consequently its greatest food value may be ascribed to its carbohydrate, mineral, and vitamin contents.

The carbohydrate content (14 to 18 per cent) of the edible portion of the fresh pandanus is a little less than raw potatoes, somewhat greater than fresh fruits such as apricots and peaches, and about the same as apples and pears (Watt and Merrill, 1950). The moisture content of 80 to 84 per cent is also similar to these fruits. The edible portion of the fresh, raw pandanus fruit is juicy, whereas the cooked product has much the consistency of a moist, cooked, mashed sweet potato. The fresh samples of Lojekerer and Joibeb were examined and found to contain starch granules which were ruptured in the cooked product and which were easily stained blue with iodine. The starch granules of both varieties were round and relatively small, averaging 9 microns for the Lojekerer variety and 6 microns for Joibeb. The raw juice of the Joibeb

which we examined, obviously contained more starch than the Lojekerer and it also thickened to a greater degree when small samples of the extracted juice were cooked in the laboratory. Whether or not this difference may be explained on the basis of ripeness of the two samples or as a true varietal characteristic, can be determined only by additional tests. The thickening which takes place on cooking can be explained by the presence of the starch grains, but pectins, for which no tests were made, may also be present.

Pandanus fruit contains more calcium than do such temperate climate fruits as apples and peaches, and one sample had as much calcium as fresh apricots and almost as much as orange juice. Our fresh samples of pandanus were equal to or better than white potatoes as a source of calcium but they contained only about half as much calcium as average sweet potatoes. No determinations for oxalates were made and only digestion studies would determine whether or not the calcium is well utilized.

The phosphorus content of pandanus is about the same as that of the fresh fruits listed above but is much less than that of potatoes and sweet potatoes.

The iron content of our fresh samples varied but compares favorably with the fresh temperate climate fruits already mentioned and with potatoes and sweet potatoes.

Pandanus is a good source of provitamin A, the Lojekerer variety being superior to yellow peaches, but not so good as apricots or yellow sweet potatoes. Since the Marshallese, as well as some other island people (Murai, 1954: 14, 186; Spoehr, 1949: 153; Luomala, 1953: 15) consume little if any green and yellow fruits and vegetables, pandanus may constitute the most valuable source of provitamin A in their diet.

Pandanus is at least as good a source of thiamine, riboflavin, and niacin as are apples, peaches, apricots, and pears. It is a less good source of thiamine and riboflavin than potatoes and sweet potatoes. However, there may have been some loss during the period of transportation and storage prior to analysis. Pandanus contains less niacin than white potatoes but more than sweet potatoes, apples, and pears and about the same amount as apricots and peaches.

Both samples of the Joibeb contained approximately twice as much thiamine as the Lojekerer, but the differences in riboflavin and niacin content of the two varieties were small and not consistent for the samples analyzed.

The ascorbic acid content of the boiled sample of pandanus is about four times as great as that of the two fresh samples (Table 2). Possibly inactivation of the enzymes in the cooked sample prior to the long period of transportation and storage may account for

TABLE 2  
VITAMIN CONTENT AND pH OF PANDANUS FRUIT  
(100 grams, edible portion)

SAMPLE	CAROTENE*	THIAMINE	RIBOFLAVIN	NIACIN	ASCORBIC ACID	pH
	mcg.	mg.	mg.	mg.	mg.	
1 Lojekerer, fresh.....	1242	0.031	0.038	0.88	2.3	5.2
2 Lojekerer, boiled.....	847	0.024	0.034	0.71	8.9	5.1
3 Joibeb, fresh.....	184	0.052	0.025	0.95	2.6	4.9
4 Joibeb, boiled.....	291	0.059	0.042	0.73		
5 Pandanus paste.....	1078	0.037	0.062	2.47	(1.5)	5.6
6 Pandanus flour.....	1200 I.U.†	0.062	0.156	2.25		5.8

\* Total carotenes, chromatographic method.

† Biological determination of vitamin A value with rats.

this. Obviously additional studies are needed to determine the range and typical ascorbic acid values for this fruit.

To determine what proportion of the pandanus keys are usually eaten, 50 children at the Marshall Christian Training School at Ronron cooperated in a simple experiment. A single raw key was given to each student and his name and the weight of the key were recorded. They were asked to eat the pandanus in the usual way and the remaining inedible portion was again weighed.

The weights of single keys ranged from 130 to 200 grams, with an average of 156 grams. The weight of the edible portion ranged from 40 to 102 grams (mostly 60 to 90 grams), with an average of 75 grams. This figure for the weight of the edible portion of a single key has been used for all calculations in Table 3.

TABLE 3  
NUTRITIVE VALUE OF THE EDIBLE PORTION  
OF PANDANUS KEYS

NUTRIENTS	1 KEY 75 GMS.	20 KEYS 1500 GMS.
Calories.....	53	1060
Protein gm.....	.28	5.6
Fat gm.....	.20	4.0
Calcium mg.....	7.2	144
Phosphorus mg.....	19.4	388
Iron mg.....	.7	14
Carotene mcg.....	932	18,640
Thiamine mg.....	.02	.4
Riboflavin mg.....	.03	.6
Niacin mg.....	.7	14
Ascorbic acid mg.....	2	40

While this little study indicates that almost 50 per cent of the key is edible, when the keys were prepared for analyses in the laboratory, the waste was much greater and the edible portion was found to range from 25 to 40 per cent. The edible portion of the cooked product was somewhat greater than the raw. It is probably easier to suck or gnaw out the sweet juice or pulp than to obtain it by mechanical means, and the size and ripe-

ness of the fruit, as well as variety, may influence the proportion of waste.

The dietary study in the Marshall Islands (Murai, 1954) included weekly records of 324 people 1 year of age and over; of this number, 138 ate pandanus, some for only 1 day, others for 6 days out of 7, making a total of 293 days on which pandanus was recorded. The number of large keys consumed ranged from 1 to 25 for all ages. Many ate at least 10 keys and several ate 20, the highest recorded was 25. Children 1 year old ate as many as 10. Records for 18 different days for nine children, 2 and 3 years old, showed that they ate 2 to 10 keys with an average of 5 keys per day.

The nutrients obtainable from one and from 20 keys have been calculated on the basis of our figures for raw Lojekerer and are summarized in Table 3. The conservative value of 3 milligrams of ascorbic acid per 100 grams of edible portion has been used for the calculations in this table although it is highly probable that the value is greater when the pandanus is eaten fresh.

An estimate of the nutritive value of the fresh pandanus may be made by evaluating the contributions to the diet made by 20 keys, which is not at all an unusual quantity, even when a variety of other foods is available. Twenty keys would supply about half the calories needed per day by a small and not very active person, all of the provitamin A, niacin, and iron, about one-third the thiamine, almost half the riboflavin, and more than half the ascorbic acid, judging from the National Research Council's standards or "Recommended Daily Allowances" for all nutrients except calories which are in excess of what the island people would require (Food and Nutrition Board, 1953: 3). Twenty keys would provide little protein, calcium, or fat but would make a good contribution toward the phosphorus needs.

On the basis of our analyses, it is obvious that the greatest contributions of pandanus fruit to the diet are calories, provitamin A, and ascorbic acid. When large amounts are

eaten, the quantities of the three minerals (Ca, P, and Fe) obtained are not inconsiderable but the variety (or varieties) which we analyzed indicate that the edible portion is not an important source of calcium and phosphorus.

It should be emphasized that the groups studied on Uliga Island and Majuro Island, Majuro Atoll, had a rather varied diet and a number of other foods, but in the isolated islets where pandanus, coconut, and fish are often all that is available, half or more of the caloric needs are probably satisfied by pandanus. Coconuts would supply the fat needed and fish and shellfish would furnish not only protein but calcium and phosphorus, especially when small fish are eaten whole.

If the value of about 8 milligrams of ascorbic acid obtained for the cooked sample should prove to be typical of all fresh pandanus, then the fruit would constitute an important source of this vitamin. Even if the pandanus usually has only half this amount, the quantity of ascorbic acid obtained when large amounts are eaten would satisfy the daily needs.

#### *Pandanus Paste*

The composition of the pandanus paste may be compared with dried dates which it resembles. The pandanus paste has a little less moisture and therefore a greater energy value (293 calories per 100 grams). The total carbohydrate content is almost identical with dates and the crude fiber content about 1 per cent higher. The reducing sugars of pandanus paste were determined by the Munson-Walker method (Assoc. Off. Agr. Chem., 1950: 506) and found to be 50 per cent (calculated as glucose), which would indicate that about two-thirds of the carbohydrate is in the form of sugars and the remainder includes starch. The protein and fat contents of pandanus paste and dates are low and of little significance. The calcium content of the paste is almost twice that of dates and the phosphorus and iron contents exceed those

of dates, though it may well be that some of the iron in the paste is the result of contamination during preparation and drying. The pandanus paste has almost 20 times the vitamin A value of dates, about the same amount of niacin, and less thiamine and riboflavin. The period of storage prior to the determination of vitamin A was longer than that for the other vitamins as has been indicated. Doubtless all the vitamins were reduced as a result of storage, but since this is a preserved product used for emergencies, the figures which we obtained are probably typical for pandanus paste. Although by the dye titration method pandanus paste had about 1.5 milligrams of ascorbic acid per 100 grams, it may be due to other reducing substances than vitamin C. More work on the paste would be desirable to learn if other samples appear to contain ascorbic acid.

#### *Pandanus Flour*

The sample of pandanus flour from Kapingamarangi which was analyzed is probably typical of the dried products made in other islands judging from the description of its preparation given by Grimble (1933-34: 36, 37, 38) for the Gilbert Islands.

Because the entire soft end is cut off and dried as described earlier, no fibers are removed and the resulting "flour," which resembles fine sawdust, is high in crude fiber (15.0 per cent) and low in moisture (10.8 per cent). (The low moisture content is necessary to insure its good keeping quality.) If the crude fiber is calculated to a product containing 80 per cent of water (comparable to the fresh product), the crude fiber would be reduced to approximately 3.3 per cent, which is much greater than that of even our coarsest vegetables such as cabbage. This is in contrast to the pandanus paste which when recalculated to a fresh basis has less crude fiber than the fresh fruit from the Marshalls (Table 1).

Grimble (1933-34: 39), discussing pandanus flour, states that "the gently purgative qualities of the food are also recognized and

valued by the islander, who uses it freely as an aperient for his children." It is to be expected that a food with such a high fiber content would tend to absorb water and form gas, thus lending bulk to the fecal residues and giving it laxative properties. Just how seriously the fiber would interfere with the absorption of food nutrients is difficult to predict. Digestion experiments upon people accustomed to such a coarse diet would be necessary to determine this point. When the pandanus flour is eaten either with water or with concentrated coconut sap as described by Grimble (1933-34: 39), a much greater percentage of crude fiber would probably be ingested than when the fresh raw or freshly cooked pandanus is nibbled and the fibers are rejected or left clinging to the woody end of the keys.

The calcium content of 797 milligrams per 100 grams seems to be remarkably high and when calculated to 80 per cent moisture would still appear high (180 milligrams per 100 grams). Perhaps much of the calcium is in the fibrous portion, but there is also the possibility that a few grains of coral sand, blown into the pandanus flour in the process of making or drying, could raise the calcium to this high value. Additional analyses are desirable to check this figure. The phosphorus and iron contents when calculated to the fresh basis fall within the range for fresh fruit.

The vitamin A value for pandanus flour was determined in 1948 by rat feeding methods employed in our laboratory with standard vitamin A acetate fed to the controls (Miller, *et al.*, 1951: 106). Either the variety from which this sample was made is low in biologically active carotenoid pigments or as a result of oxidation and dessication the vitamin A value is greatly reduced.

The flour retained its riboflavin content remarkably well and appears to have twice as much of this vitamin as does the paste, on a comparable moisture basis. Riboflavin is sensitive to light and it would be expected that losses would be great when a food is dried

in the sun. Again the original variety of pandanus used in making the flour no doubt influenced the final product. Niacin, being more stable, appears to have been relatively well retained in the pandanus flour as in the paste.

#### *Pandanus Seeds*

By use of a hammer and chisel, a sufficient quantity of pandanus seeds were removed from their woody cases to permit determination of only the moisture, protein, and fat contents, which were 47.2 per cent, 10.1 per cent, and 24.7 per cent respectively. Since one seed weighs about half a gram, and the keys available to us had no more than three or four seeds, and often only one or two, more energy is probably required to extract the seeds than could be obtained from eating them.

#### SUMMARY AND CONCLUSIONS

In some Pacific islands, especially Kapin-gamarangi and the Marshall, Gilbert, and Ellice Islands, the pandanus fruit is an important seasonal food.

The soft ends of the keys which form the fruits contain a sweet spicy juice or pulp that is eaten in the raw or cooked state. The edible portion is also preserved in two ways—as a dried paste resembling dried dates and as a "flour."

The fresh raw or cooked pandanus contains 14 to 18 per cent carbohydrate in the form of starch and sugars, but has negligible amounts of protein and fat.

The calcium, phosphorus, and iron contents are comparable to temperate climate fruits such as peaches and apricots.

The carotenoid pigments which give the pandanus a rich yellow orange color may be the only source of provitamin A available to the people of these islands when there are few or no green or yellow vegetables in the diet.

Pandanus, like most fruits, is not a rich source of thiamine and riboflavin, though it makes a significant contribution of these fac-

tors in the diet when eaten in large amounts. This is especially true of riboflavin.

Pandanus is a poor source of ascorbic acid, if compared with fruits rich in vitamin C, but when eaten in relatively large amounts, it could meet the needs of the body for this vitamin.

The composition of pandanus paste and pandanus flour are discussed in relation to the fresh samples. Their special worth lies in their energy value as emergency rations or for long sea voyages.

Our work suggests that additional studies on different varieties, followed by selection and propagation by agriculturists, might be profitable. Planting and continued use of the varieties of highest nutritive value that suit particular areas could well be encouraged by all concerned with the health of the people living in the low dry islands of the Pacific. It is especially important to stress that the edible pandanus should not fall into disuse as the result of introducing "store foods" of low nutritive value.

#### *Acknowledgments*

The authors wish to thank a number of people for assistance during the course of this research: Dr. Bruce J. Cooil, Associate Plant Physiologist, Hawaii Agricultural Experiment Station, who assisted in the measurements of the starch grains of pandanus; Miss Helen Denning, former Junior Nutritionist, Hawaii Agricultural Experiment Station, who made most of the analyses for the pandanus paste and pandanus flour under the direction of the senior author; Dr. Kenneth P. Emory, Ethnologist, Bernice P. Bishop Museum, Honolulu, who provided the samples of pandanus paste and pandanus flour and the photograph of the paste in lauhala wrappings; Dr. Harold St. John, Professor of Botany, University of Hawaii, for identification of the pandanus varieties; Mr. Horace Clay, Assistant Specialist in Horticulture, Agricultural Extension Service, University of Hawaii, for collecting and transporting the pandanus

fruit shown in Figure 1, and Mr. Yoshihiko Kawano, Assistant in Chemistry, H.A.E.S., for taking the photograph; Dr. Leonard Mason, Professor of Anthropology, University of Hawaii, who loaned the beka shown in Figure 3.

#### REFERENCES

- ASSOCIATION OF VITAMIN CHEMISTS. 1951. *Methods of vitamin assay*. Ed. 2, 301 pp. Interscience Publishers, Inc., New York.
- ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. 1950. *Official methods of analysis*. Ed. 7, 910 pp., illus. Washington.
- BUCK, PETER H. 1950. Material culture of Kapingamarangi. *Bernice P. Bishop Mus., Bul.* 200: 1-291.
- COOK, JAMES. 1784. *A voyage to the Pacific Ocean*. Vol. 1. xcvi + 421 pp. G. Nicol & T. Cadell, London.
- ELLIS, WILLIAM. 1832. *Polynesian researches*. Ed. 2. Vol. 1. 414 pp. Fisher, Son and Jackson, London.
- FINSCH, OTTO. 1893. *Ethnologische Erfahrungen und Belegstücke aus der Südsee*. K. K. *Naturhist. Hofmus. Ann.* 8 (1): 19-89; 8 (2): 119-182.
- FOOD AND NUTRITION BOARD. 1953. *Recommended Dietary Allowances*. Revised ed. 36 pp. [Pub. 302.] National Academy of Sciences — National Research Council, Washington, D. C.
- GRIMBLE, ARTHUR. 1933-1934. The migrations of a pandanus people. 112 pp. *Polynesian Soc. [Jour.], Mem.* 12: 1-185.
- KING, JAMES. 1784. Volume 3 of Cook, J. *A voyage to the Pacific Ocean*. 558 pp. G. Nicol & T. Cadell, London.
- KOTZEBUE, OTTO VON. 1821. *A voyage of discovery, into the South Sea and Beering's Straits . . . undertaken in the year 1815-1818 . . . in the ship Rurick . . .* Vol. 3. 442 pp. Vol. 4. 220 pp. Longman, Hurst, Rees, Orme, and Brown, London.
- KRAMER, A. 1906. *Hawaii, Ostmikronesien und Samoa*. 585 pp. Strecker and Schroder, Stuttgart.

- KURZE, G. 1887. *Mikronesien und die Mission daselbst*. Pp. 5-6. [Original not seen. Taken from translation in the Univ. of Hawaii library.]
- LEUNG, WOOT-TSUEN WU, R. K. PECOT, and B. K. WATT. 1952. *Composition of foods used in far eastern countries*. 62 pp. [Agr. Hdbk. 34] U. S. Department of Agriculture, Washington.
- LUOMALA, KATHARINE. 1953. Ethnobotany of the Gilbert Islands. *Bernice P. Bishop Mus., Bul.* 213: 1-129.
- MARKLEY, K. S., and R. M. HANN. 1925. A comparative study of the Gunning-Arnold and the Winkler boric acid modifications of the Kjeldahl method for the determination of nitrogen. *Assoc. Off. Agr. Chem. Jour.* 8: 455-467.
- MILLER, CAREY D., H. DENNING, and A. BAUER. 1951. Food values of native foods from Pacific islands. *Hawaii Agr. Expt. Sta., Bien. Rpt.* 1948-50: 106-107.
- MURAI, MARY. 1954. Nutrition study in Micronesia. *U. S. Natl. Res. Council, Pacific Sci. Bd., Atoll Res. Bul.* 27: 1-239.
- SAYWELL, L. G., and R. B. CUNNINGHAM. 1937. Determination of iron: colorimetric o-phenanthroline method. *Indus. and Engin. Chem., Analyt. Ed.* 9: 67-69.
- SPOEHR, ALEXANDER. 1949. Majuro—A village in the Marshall Islands. *Chicago Nat. Hist. Mus., Fieldiana: Anthropology* 39: 1-266.
- WATT, BERNICE K., and A. L. MERRILL. 1950. *Composition of foods—raw, processed, prepared*. 147 pp. [Agr. Hdbk. 8] U. S. Department of Agriculture, Washington.
- WENDLER, P. J. 1911. Zur Feuer-und Nahrungsbereitung der Marshall-Insulaner. *Baessler-Archiv: Beiträge zur Völkerkunde* 1: 269-276.