FOOD VALUES OF BREAD-FRUIT, TARO LEAVES, COCONUT, AND SUGAR CANE

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BULLETIN 64

HONOLULU, HAWAII
PUBLISHED BY THE MUSEUM
1929

KRAUS REPRINT CO.
New York
1971

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KRAUS REPRINT CO.
A U.S. Division of Kraus-Thomson Organization Limited

Printed in U.S.A.

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INTRODUCTION

In 1926 I began a detailed study of the nutritive value of foods used by the ancient Hawaiians. Some of these foods are used today by the Hawaiian and part-Hawaiian people but are commonly supplemented with varying quantities of local or imported American and oriental foods.

This study assumes unusual interest for the modern student of nutrition because of the lack of grains and milk in the diet. The fine physical development of the Hawaiians was undoubtedly influenced by their outdoor life but to an even greater degree by their food, which, it is estimated, had been essentially the same for at last 1,500 years before Hawaii was discovered by Captain Cook.

In a previous publication (18)[1], the nutritive values of poi, taro, and limu and the place of these foods in the diet of the ancient Hawaiians have been discussed. In a similar way this paper considers breadfruit, taro leaves (*luau*), coconut, and sugar cane.

This research was conducted at the University of Hawaii, 1927-1928, with university funds. The following assistance is gratefully acknowledged: information regarding ancient Hawaiian food habits, from Mrs. E. Lahilahi Webb, Mrs. Mary Pukui, and Mr. John Wise, all of Honolulu; Mr. and Mrs. C. C. Conradt of Wailuku, Maui. Miss Sylvia Dean, senior student at the University of Hawaii, 1927-1928, conducted the feeding experiments on coconut and analyzed the coconut milk and water for organic nutrients. I am indebted to Mr. G. R. Stewart, Chemist of the Experiment Station of the Hawaiian Sugar Planters' Association for the analyses of the sugar-cane juice.

Analyses in this paper were made according to the methods recommended by the Association of Official Agricultural Chemists (2).

[1] The numbers in parentheses refer to Bibliography (p. 23).

BREADFRUIT

CULTIVATION AND USE

Undoubtedly breadfruit (*Artocarpus incisa*) never occupied the important place in the diet of the ancient Hawaiians that it did in that of some of the south Pacific islanders, like the Marquesans and Tahitians. In some of the early writings are found conflicting statements in regard to the abundance of the breadfruit in the Hawaiian islands. This may be largely accounted for by the fact that the writers were discussing different islands or that some of them failed to see the finest breadfruit plantations.

In the account of Captain Cook's third voyage, Captain King (14) writes of Hawaii:

> The breadfruit trees thrive here, not in such abundance but produce double the quantity of fruit they do on the rich plains of Otaheite [Tahiti]. The trees are nearly of the same height, but the branches begin to strike out from the trunk much lower, and with greater luxuriance. . . . It is remarked by Captain Cook, that the breadfruit and yams appeared scarce amongst them, and were reckoned great rarities. We found this not to be the case on our second visit; and it is therefore most probable that as these vegetables were generally planted in the interior part of the country, the natives had not had time to bring them down to us, during the short stay we made in Wyoma Bay [Waimea Bay].

Menzies (17), who was with Vancouver's company in 1790 to 1794, gives an interesting account of an ascent of Mauna Loa. He describes in most glowing terms the industry and ingenuity of the natives in agriculture, remarks on the excellent state of cultivation of all their fields, their utilization of every bit of productive space, and their adaptation of the various crops to soil and altitude. Of the breadfruit in particular he states:

> On leaving this station we soon lost sight of the vessels, and entered their breadfruit plantations, the trees of which were a good distance apart, so as to give room to their boughs to spread out vigorously on all sides, which was not the case in the crowded groves of Otaheite [Tahiti], where the trees were drawn up tall and slender, and where we found them always planted on the low plains along the seaside; but here the size of the trees, the luxuriancy of their crop and foliage, sufficiently show that they thrive equally well on an elevated situation.

Stewart (22), writing of the Sandwich Islands in 1823-1825, states, "Their growth of the breadfruit here is confined to a few districts on one or two islands and where found yields a very partial supply of food at any season." He later tells of the run-down condition of the breadfruit trees and taro patches at Lahaina, indicating that in a period of about fifty years the fine agricultural methods of the ancient Hawaiians were rapidly deteriorating. Ellis (6, vol. 4), however, about the same date tells of passing through considerable groves of fine breadfruit trees near the town of Honaunau, Hawaii.

Wilder (24) states that in Kona and Hilo on Hawaii and in Lahaina, Maui, there were especially fine groves of breadfruit and that in moist val-

leys, or along streams or by springs on Oahu, Kauai, and Molokai breadfruit at one time thrived.

Hillebrand (10) states that the fruiting season of the breadfruit in Hawaii is short—from June to August. He must have had in mind one particular locality, for I was able to obtain breadfruit from the first of September until the last of December. It was rather difficult to obtain them during January and February.

From all that can be learned I would judge that breadfruit was never so important a basic foodstuff of the Hawaiians as taro, and probably was never so widely used as sweet potatoes.

Breadfruit was never eaten raw by any of the Polynesians, though it was fed to pigs in that state. The Hawaiians never ate their breadfruit in the unripe or starchy state as did the Tahitians and Samoans. They preferred it at least half ripe or ripe and cooked it in an *imu* (underground oven) or on hot coals. The overripe breadfruit was usually used in a pudding (*piele*), which was made by discarding the center and the outer skin and then cooking the pulp after softening with coconut milk. Mrs. Pukui thinks breadfruit poi is gaseous and not "so filling" as poi made from taro. Fruit in the half-ripe stage was used for poi and was preferred mixed with taro poi, which reduced its gaseous quality. Mrs. Conradt stated that breadfruit in the form of poi might be fed to babies at about the age of one year.

COMPOSITION

Analyses were made of cooked Hawaiian breadfruit such as that used in the feeding experiments. The average analyses of two different samples are summarized as follows:

ANALYSIS OF COOKED HAWAIIAN BREADFRUIT

	PER CENT
Water	67.8
Protein (N × 6.25)	1.34
Fat (ether extract)	0.31
Carbohydrate (by difference)	27.82
Fiber	1.5
Ash	1.23
Calcium	0.022
Phosphorus	0.062

The composition of cooked breadfruit is very similar to that of cooked taro. It is essentially a carbohydrate food low in protein and in fat.

According to this analysis, breadfruit is not a particularly good source of either calcium or phosphorus. Sherman (21) gives 0.084 per cent of calcium in breadfruit, the source of which is unknown. His figure would indicate that breadfruit is an excellent source of calcium, but my figure is only one-fourth as large as his. It would be desirable to analyze a larger number

of breadfruits from different localities in Hawaii to learn whether all of them are as low in this element as my figures indicate.

VITAMIN CONTENT

No data on the vitamin content of breadfruit are available. The Hawaiian variety called *ulu* was used in most of the experiments here reported, though the Samoan variety was used in a few.

All breadfruit used was baked on a shallow pan without water for one hour at a temperature of 375° to 400° Fahrenheit. The fruit was used as picked without peeling or removing the core. An effort was made to use fruit of uniform ripeness so that when cooked the breadfruit was always sweet to taste. Neither green nor overripe fruit was used.

VITAMIN A CONTENT

The diet of the mothers of the experimental rats and the diet used for the experimental animals have been described elswhere (18). The experimental procedure was also identical except that the food of the rats used for vitamin A experiments was irradiated in thin layers for 30 minutes at a distance of 16 inches from the arc, using a Cooper Hewitt Uviarc, 450 watt suspension type, run at 110 volts, 60 cycles, alternating current. The rats were therefore not irradiated.

Sherman's (21) recommendations for making the experiments as quantitatively accurate as possible were then followed. When the weights of the animals had become stationary or declined for one week, the weighed amounts of cooked breadfruit were fed daily (except Sundays) for 8 weeks, the aim being to feed an amount of breadfruit that would induce a gain of about 25 grams in 8 weeks. The results are summarized in Table 1.

Due to the difficulties of obtaining breadfruit over long periods, the final tests on the Hawaiian variety were started shortly after the preliminary ones when it appeared that 2 grams daily might be sufficient to obtain the desired gain, but 2 grams proved to be too little. Three grams of the Samoan variety fed later also failed to give the desired gain. This hardly can be said to indicate a less good vitamin content for the Samoan fruit, but owing to the lateness of the season may be due partially to the poor quality of fruit obtainable the last two weeks of feeding.

The weight of cooked ripe breadfruit (of either variety) containing one unit of vitamin A is probably very near to 3 grams. The breadfruit therefore appears to be only a fair source of vitamin A. Using the method of evaluation by units as suggested by Sherman it was found to have about 150 units of vitamin A a pound, whereas Sherman reports baked white potatoes as having 130 units a pound, yellow sweet potatoes about 3,000, and green peas 2,500 to 3,500 units to the pound.

TABLE 1. GAIN OR LOSS IN WEIGHT OF RATS RECEIVING VARIOUS AMOUNTS OF COOKED BREADFRUIT AS SOLE SOURCE OF VITAMIN A, FOR A PERIOD OF 8 WEEKS.

Source of Vitamin A	Number of rats	Weight of breadfruit fed daily (grams)	Gain (+) or loss (—) in weight (grams)
Preliminary tests			
Cooked Hawaiian breadfruit	2	1	—11
Cooked Hawaiian breadfruit	2	2	+ 8
Cooked Hawaiian breadfruit	2	3	+36
Final tests			
Cooked Hawaiian breadfruit	7	2	+ 6
Cooked Samoan Breadfruit	6	3	+16

VITAMIN B CONTENT

The diet for the vitamin B experiments has been reported elsewhere (18). Standard rats at 28 or 29 days of age were put on the vitamin B free diet, and the breadfruit in weighed amounts was fed at once daily (except Sundays).

The results, which are summarized in Table 2, indicate that the weight of breadfruit containing one unit of vitamin B lies between 1.5 and 2 grams. There is probably no difference in the vitamin content of the two varieties. Again using Sherman's method of evaluation, breadfruit appears to be a good source of vitamin B, containing 225 to 300 units a pound as compared with 130 units a pound for potatoes, 120 to 140 for carrots, 150 for raw string beans, and 1,000 for raw peas.

TABLE 2. GAIN OR LOSS IN WEIGHT OF RATS RECEIVING VARIOUS AMOUNTS OF COOKED BREADFRUIT AS SOLE SOURCE OF VITAMIN B.

Source of Vitamin B	Number of of rats	Weight of breadfruit fed daily (grams)	Gain (+) or loss (—) in weight (grams)	Duration of test (weeks)
Preliminary tests				
Cooked Hawaiian breadfruit	2	1	— 4	7
Cooked Hawaiian breadfruit	4	2	+ 5	8
Cooked Hawaiian breadfruit	2	3	+35	8
Final tests				
Cooked Hawaiian breadfruit	4	1	— 6	8
Cooked Hawaiian breadfruit	3	2	+ 9	8
Cooked Samoan breadfruit	3	1.5	— 2	8

Vitamin C Content

The diet and experimental procedure using guinea pigs for the determination of vitamin C has also been described elsewhere (18) and is essentially that used by Sherman (21).

As difficulty was experienced in getting the guinea pigs to eat the breadfruit readily, the method of allowing scurvy to develop and then adding the food as a curative was abandoned. Instead, the breadfruit feeding was begun as soon as alfalfa was removed from the diet. The final results after eight preliminary experiments, not here recorded, are shown in Table 3. It is obvious that cooked breadfruit is a rather poor source of vitamin C; it contains only 30 units a pound compared to the citrus-fruit juices and tomatoes, which have 150 to 300 units a pound. It compares favorably, however, with cooked potatoes that have 25 to 75 units a pound, and its use in rather large quantities would undoubtedly prevent human scurvy.

TABLE 3. WEIGHT AND POST MORTEM CONDITION OF GUINEA PIGS RECEIVING 15 GRAMS OF COOKED BREADFRUIT AS SOLE SOURCE OF VITAMIN C

Laboratory number of animal	Duration of test (weeks)	At beginning (grams)	At end (grams)	Gain (+) or loss (—) (grams)	Post mortem condition
♂ 157	10	324	280	— 44	No hemorrhages on ribs Very mild scurvy
♀ 152	9	317	223	— 94	No hemorrhages on ribs Very mild scurvy
♀ 158	14	317	435	+ 118	No scurvy
♀ 156	14	280	340	+ 60	No scurvy

GREENS

KINDS AND CULTIVATION

In the accounts of the early voyagers I find no mention of the various greens used by the Hawaiians. Possibly this is due to the fact that the British of that period would have considered greens as food fit only for animals. From other sources I find that the Hawaiians used many kinds of greens.

La Pérouse (15), telling of the food of the natives of Easter Island, states, "They likewise cultivate the *Solanum* or night shade, but I am ignorant to what use they apply it." He apparently refers to *Solanum nigrum* Linnaeus, which the Hawaiians call *popolo*. This is a common plant in Hawaii and is cultivated by Hawaiians today and considered by them an excellent green.

Thrum (23) quotes from a legend of Punahou Spring in which the "tender shoots of the *popolo, aheahea, pakai, laulele,* and potato vines" were said to have been eaten by two children while waiting for a patch of potatoes to develop. (The plant *aheahea* is *Chenopodium sandwicheum,* an excellent potherb, called by Hillebrand, *aweoweo.*) These were cooked by rolling hot stones around among them in a covered gourd, a method of cooking called by the Hawaiians *hakui,* and described by Mrs. Pukui as follows:

> Greens are put in a large clean calabash with some water. Several stones that have been heated until fiery red are dropped in and the calabash is covered. If this does not cook the food, the first stones may be replaced with other hot ones. When done only a little water remains which is eaten with the greens. Salt is added after the greens are cooked.

Greens were also baked in the *imu* and in hot askes.

My Hawaiian informants gave the native names of a number of greens used by them. It was not possible to identify all of them at this time but Degener and Wiebke (4) have verified the following ones:

HOIO. A fern, *Asplenium arnottii* Baker.

POPOLO. *Solanum nigrum* Linnaeus.

AKUAKU. *Cyanea rollandioides* Rock.

AKU. *Cyanea tritomantha* Gray. Rock (20) states ". . . the leaves of *Cyanea augustifolia, Cyanea tritomantha* (*aku*) and *Cyanea rollandioides* (*akuaku*) were cooked and eaten like cabbage."

KIKAWEO. *Aspidium cyatheoides* Kaulfuss. Of this Hillebrand (10) states, "common in the lower woods and gulches; the *kikawaeo* of the natives, who eat the young shoots as a vegetable, cooked with meat and taro."

PALA. *Marattia douglasii* Baker. Of this Hillebrand (10) states, "rather common in forests of medium elevation; the *pala* of the natives. The thick fleshy auricles abound in starch and mucilage and furnish to the islanders not only a palatable food when baked in hot ashes, but also a useful remedy against bronchial and intestinal catarrhs. Slices of the same soaked in cold water soon part with their mucilage and form a pleasant diet drink."

PALULA. Leaves of the sweet potato, *Ipomoea batatas* (Linneaus) Lamarck.

HAPUU III, or HEII. *Cibotium menziesii* Hooker.

HAPUU. *Cibotium chamissoi* Kaulfuss. Hillebrand (10) says that the young stems of *hapuu iii* and *hapuu* "are farinaceous and used to be eaten by the natives in times of scarcity. Baked in ashes they are by no means unpalatable."

Doubtless many other plants were used as greens by the ancient Hawaiians. No information on the nutritive value of these is available. It seems especially desirable to know something of the young fern shoots, a number of which were used.

Limu (seaweeds) did not take the place of vegetables in the diet of the Hawaiians and other Polynesian people as I have heard some Caucasians suggest. The Hawaiians with whom I have talked agree that limu was always used more as a relish, like pickles, than as a salad. The carbohydrates of limu are not utilizable by the body. Experiments conducted on the vitamin content of *limu lipoa* and *limu eleele* (18), two of the important limu of the Hawaiians, indicate that they are low in vitamins as compared with such salad foods as lettuce, cabbage, and tomatoes. As sources of minerals, limu may be more logically compared with common vegetables.

TARO LEAVES

USE, COMPOSITION, AND MINERAL CONTENT

The favorite green and the one in most common use was undoubtedly *luau,* the young leaves of taro (*Colocasia antiquorum* var. *esculenta*). The market supply was used for the experiments here reported, though the leaves may not always have been so young and tender as those preferred by the Hawaiians.

The cooked taro leaves were analyzed for the organic nutrients, calcium, and phosphorus. The average of analyses of two different samples are summarized as follows:

ANALYSIS OF COOKED TARO LEAVES

Water	87.8
Protein (N × 6.25)	4.1
Fat (ether extract)	0.47
Carbohydrate (by difference)	2.05
Ash	1.48
Calcium	0.107
Phosphorus	0.079

This analysis indicates a composition similar to that of other greens, like spinach and dandelion.

The calcium content of 0.107 per cent for taro leaves is higher than Sherman (21) gives for spinach (0.067), but about that of dandelion (0.105). Probably a large part of the calcium in taro leaves is in the form of calcium oxalate. Some doubt has been expressed as to the utilization of calcium in this form; but McLaughlin (16), as a result of human digestion experiments using spinach, concluded that the calcium of spinach showed excellent utilization notwithstanding its rather high oxalate content.

VITAMIN CONTENT

For determining vitamin content of taro leaves, a method of cooking was used which would imitate that of the *imu* cooking. The leaves were placed in a pan without water on a rack one inch above the bottom of an 11-quart pressure cooker that contained a small amount of water. The cover was put in place with pet cock open, but without screwing down the clamps. Any air was quickly expelled by the steam, thus reducing the oxidation to the minimum, a condition which would probably obtain in an *imu*. Two bunches of taro leaves were thus steamed for one hour.

Taro leaves, like taro, are never eaten raw, due to the irritation caused by the calcium oxalate crystals (18). Some people now advocate cooking the taro leaves in a large amount of water or changing the water several times to "get rid of the sting." This would of course mean a loss of minerals and vitamins which would never occur in the old Hawaiian method of cooking. I have been told that taking out the midrib, peeling the skin from the petiole, or picking off the tip of the leaf would lessen the sting. None of these theories was found to be true in cooking the taro leaves that may now be purchased at the market. I also gathered taro leaves of different stages of maturity, from the very young tightly rolled to the large mature ones, and examined them microscopically for the capsules of calcium oxalate crystals. I found the capsules of crystals in all parts of the leaves in all stages of growth. Heat must be applied long enough to cause disintegration of the capsules containing the crystals, thus eliminating their stinging quality.

VITAMIN A CONTENT

The diet and procedure for determining vitamin A content in taro leaves were the same as described for breadfruit. The results of feeding *luau* for vitamin A content are summarized in Table 4. The amount of cooked taro leaves containing one unit of vitamin A is about 3.5 grams, making 130 units per pound.

TABLE 4. RESULTS OF FEEDING RATS VARIOUS AMOUNTS OF COOKED TARO LEAVES AS SOLE SOURCE OF VITAMIN A FOR A PERIOD OF 8 WEEKS

Number of rats	Weight of cooked taro leaves fed daily (grams)	Gain in weight (grams)
Preliminary tests		
1	2	9
2	3	12
2	4	45
Final tests		
8	3.5	23

Vitamin B Content

For determining vitamin B content of taro leaves the diet and procedure were the same as that described for breadfruit. The results of feeding *luau* for vitamin B content are summarized in Table 5. The amount of cooked taro leaves containing one unit of vitamin B is 2 grams, or about 225 units a pound.

TABLE 5. RESULTS OF FEEDING RATS VARIOUS AMOUNTS OF COOKED TARO LEAVES AS SOLE SOURCE OF VITAMIN B.

Number of rats	Weight of taro leaves fed daily (grams)	Gain (+) or loss (—) in weight (grams)	Duration of test (weeks)
Preliminary tests			
2	0.5	—8	7
2	1.0	—5	7
2	2.0	—1	8
Final tests			
5	2.0	+ 5	8
2	2.5	+ 8	8

Vitamin C Content

Only two guinea pigs were fed the taro leaves. It was not anticipated that there would be much evidence of vitamin C after one hour's cooking, but due apparently to the method used whereby oxidation was greatly reduced considerable vitamin C remained. The guinea pigs were fed 10 grams of cooked taro leaves daily, except Sunday. One was killed after 13 weeks of feeding. It weighed 355 grams at the beginning of the experiment and 380 grams at the end, but appeared in fine condition and showed no signs of scurvy. The other died after 11 weeks feeding. It weighed 339 grams when feeding began and 300 grams the day before death. Though the teeth were rather fragile, there was no other evidence of scurvy; it appeared that death was due to lung infection. This indicates a value of about 40 vitamin C units a pound—a rather low amount, but sufficient to be of value in the human diet in preventing scurvy.

COCONUTS

CULTIVATION AND USE

Hawaiians of today state that the ancient Hawaiians used the coconut in all stages of ripeness. Coconuts, like pork and bananas, were tapu to women and girls in ancient times. This custom, whose origin is lost in antiquity, was rigidly enforced up to the time of the coming of the missionaries. For breaking the tapu the penalty for the common people was death. A woman or girl of the chiefly class might escape death by having her eyes put out.

King (14) relates that members of Captain Cook's party drank coconut milk which was offered them when they went inland, and states that the villages on the island of Hawaii were interspersed with groves of coconut trees spreading along the seashore.

Coconuts did not occupy the important place in the diet of the Hawaiians that they did in that of the southern Polynesians, largely because the trees in Hawaii were not so abundant. Hillebrand (10) states that although in Hawaii "the coconut palm is on the northern boundary of its range in the Pacific and does not yield such abundant harvest of fruit as in more equatorial latitudes, it still thrives very well, as can be seen in the vigorous groves of Lahaina and southern Hawaii."

In an account of the foods of the more southern Polynesians, Ellis (6, vol. 1) states that coconut milk was used when the nuts were very young and without pulp, merely a soft white shell; also that the soft white pulp was eaten by the chiefs as a luxury. He says also that coconuts were formerly a considerable article of food among the common people, being used in profusion on every feast of the chiefs, but that at the time of his writing (1824-1830) the coconuts were allowed to ripen for oil preparation for exportation. He states also that the use of coconut milk was avoided by the missionaries because they "supposed, perhaps erroneously, the free use of it predisposed to certain dropsical complaints prevalent among the people."

Some of the Polynesians, like the Tahitians and Samoans, used the coconut, especially the expressed milk, in cooking. The ancient Hawaiians made little or no use of the coconut in this way. Such modern use as cooking expressed coconut milk with *luau* is of Samoan or Tahitian origin. Modern Hawaiians agree that the expressed coconut milk was not used to feed babies nor were they fed the very soft coconut instead of mother's milk as is sometimes done in some of the islands to the south.

COMPOSITION

As analyses of mature coconuts, of water of the mature nut, and of green coconuts with both soft and firm pulp were already available, for this

study analyses were made only of the expressed milk of firm, ripe, freshly picked coconuts and of the water from these nuts.

In this discussion the almost clear liquid from the cavity of the coconut is referred to as "coconut water," and the expressed juice, which has the appearance of milk, as "coconut milk." The coconut milk was prepared as follows: the firm white pulp with adhering brown skin was ground fine in a household meat grinder, placed in a thin muslin bag, and all the juice possible expressed in a 2-quart Griswold fruit and lard press. This product was fed to experimental rats and guinea pigs and was also analyzed. (See Table 6.) Neither coconut water nor coconut milk are comparable to cow's milk in organic nutrients or calcium and phosphorus content. It is rather surprising to find that coconut water has as high a calcium content as some of the common fruits and vegetables, even higher than some. The expressed coconut milk always contains a high percentage of fat. Several samples were tested by both the Babcock and Soxhlet methods. This white fat rises to the top when the milk is allowed to stand and the liquid below is more watery in appearance than cow's milk.

TABLE 6. ANALYSES OF COCONUTS

Form of Coconut	Water	Protein (N × 6.25)	Fat	Carbohydrate (by dif.)	Ash	Calcium	Phosphorus
Coconut water[a]	94.82	0.23	0.356	3.68	0.64	0.03	0.022
Coconut milk[a]	52.0	4.02	27.0	18.89	1.08	0.01	0.15
Coconut (mature[b])	14.1	5.7	50.6	27.9	1.7	0.024	0.074
Coconut water (mature[b])	92.7	0.4	1.5	4.6	0.8	0.02	0.01
Green coconut (pulp firm[c])	82.27	0.7	2.67	2.66	0.566		
Green coconut (pulp soft[c])	92.8	0.725	1.02	2.98	0.715		

[a]Analyses by Sylvia Dean and Carey D. Miller.
[b]Analyses recorded by H. C. Sherman in Food Products, New York, 1924.
[c]Analyses recorded in The Queen's Hospital Bulletin, vol. 1, No. 6, Honolulu, 1924.

VITAMIN CONTENT

Most of the previous work on the vitamin content of coconut has been done on coconut press cake. Johns, Finks, and Paul (13) report that press cake contains insufficient amounts of vitamin A but a sufficient amount of vitamin B to support growth in white rats fed press cake, salt mixture, and lard or butter. Jansen and Donath (12) also report the absence of vitamin A in press cake. Jansen (11) reports a lack of vitamin A in coconut oil; and Ghose (8) a very low vitamin A content of unrefined coconut oil. Embrey (7), working in Manila, found the expressed coconut milk deficient in vitamin C, as four guinea pigs fed 10 cubic cm. daily died in 2 to 4 weeks.

In our experiments the following forms of coconut were used for feed-

ing: (a) ripe, firm, white meat of fresh coconut; (b) water from the same coconuts; (c) expressed coconut milk; (d) immature coconut here called "spoon coconut." The spoon coconuts have only a little soft jelly-like pulp. It was difficult to obtain a continuous supply of this type of coconut, and for short periods, amounting in all to about a week, harder but immature coconut was fed. It was also difficult to procure coconuts of uniform ripeness for the feeding of the firm coconuts. The aim was to use fresh coconuts in which the white was hard and firm, but that were young enough to contain a good volume of water. Older coconuts contain little water and seem to have developed more oil.

Vitamin A Content

The diet and procedure for determining vitamin A content of coconut were the same as for the breadfruit experiments.

The results of feeding coconut for vitamin A are summarized in Table 7. Ripe coconuts appear to have very little vitamin A. The rats lost weight rapidly and did not live out the experimental period of 8 weeks. Severe xerophthalmia developed about two weeks before death. Coconut water has only a trace of vitamin A if any. Coconut milk from the ripe coconuts seemed to show greater evidence of vitamin A than the coconut itself, though severe xerophthalmia developed in all five rats. The soft spoon coconut showed greater evidence of vitamin A, as two of the rats fed 8 grams daily made an average gain of 5 grams in 8 weeks, while the other lost 14 grams. All three however developed xerophthalmia at about the sixth week of feeding. It is evident that in any stage of ripeness coconuts are a poor source of vitamin A.

TABLE 7. RESULTS OF FEEDING RATS VARIOUS AMOUNTS AND FORMS OF COCONUT AS SOLE SOURCE OF VITAMIN A

Source of Vitamin A	Number of rats	Amount of supplement fed daily	Gain (+) or loss (—) in weight (grams)	Duration of tests (weeks)
Ripe coconut	1	5 grams	—14	6⅔
Ripe coconut	1	6 grams	—21	7
Ripe coconut	1	10 grams	—22	7⅔
Coconut water	1	15 c.c.	—27	5⅔
Coconut milk	1	5 c.c.	—12	7
Coconut milk	2	7 c.c.	—15	8
Coconut milk	2	10 c.c.	—11	8
Spoon Coconut	2	8 grams	+ 5	8
Spoon Coconut	1	8 grams	—14	8

TABLE 8. RESULTS OF FEEDING RATS VARIOUS AMOUNTS AND FORMS OF COCONUT AS SOLE SOURCE OF VITAMIN B

Source of vitamin B	Number of of rats	Amount of supplement fed daily	Gain (+) or loss (—) in weight (grams)	Duration of tests (weeks)
Ripe coconut	6	2 grams	— 6	8
Ripe coconut	6	2.5 grams	+ 17	8
Ripe coconut	3	3 grams	+ 15	8
Coconut water	2	10 c.c.	— 6	7
Coconut water	2	15 c.c.	— 9	6
Coconut milk	1	4 c.c.	— 7	8
Coconut milk	4	5 c.c.	— 6	8
Coconut milk	4	7 c.c.	— 10	8

Vitamin B Content

The diet and procedure for determining vitamin B content of coconut were the same as for the breadfruit experiments. The results of feeding coconut for vitamin B are summarized in Table 8.

The amount of ripe coconut containing one unit of vitamin B is between 2 and 2.5 grams or about 200 to 225 units a pound. Two rats fed 4 grams daily failed to eat the coconut completely, so the results are not recorded.

Coconut water proved to be a very poor source of vitamin B. The expressed milk was not so good a source of B as the coconut itself, indicating that most of the vitamin remains in the residue when the juice is expressed.

Vitamin C Content

For determining vitamin C content of coconut, the diet and procedure were the same as described for breadfruit except that the butter fat of the basal diet was reduced from 10 to 5 per cent for the guinea pigs fed on the coconut milk due to their poor tolerance for fat.

Two guinea pigs fed 10 cubic centimeters of coconut milk died of scurvy 4 to 5 weeks after feeding began. This confirms Embrey's work. There is no evidence of vitamin C in coconut milk.

One guinea pig fed 15 cubic centimeters of coconut water from ripe coconuts daily, died of scurvy in 4 weeks; one fed 20 cubic centimeters died of scurvy after 7 weeks. A third guinea pig fed 20 cubic centimeters of water from mature coconuts was losing until it was fed water from immature coconuts, when it began to gain. Feeding of water from spoon coconuts or from slightly more mature nuts was continued, and the guinea

pig lived out the experimental period of 90 days and weighed 53 grams more than at the beginning of the experiment. It appeared in excellent condition when killed and the autopsy showed no sign of scurvy. Time was not available for further tests, which it is hoped may be carried out later. It would appear, however, that water from unripe coconuts—the stage preferred by the ancient as well as present-day Hawaiians—has considerable antiscorbutic value.

SUGAR CANE

CULTIVATION AND USE

Sugar cane was one of the plants found in Hawaii by Captain Cook. King (14) seemed impressed with the way in which the stones between the fields were entirely concealed by the "sugar canes" planted close on each side, making, as he says, "beautiful fences." He states that they were of a very unusual size. "One of them was brought to us at Atooi [Kauai] measuring eleven inches and a quarter in circumference; and having fourteen feet eatable."

In early writings regarding the cultivation and use of food plants conflicting statements are made, not only by different authorities, but by the same author. Ellis (6, vol. 4), writing about 1823, states, "Sugar cane is indigenous and grows to a large size, though it is not much cultivated"; whereas later in the same volume he tells of going through plantations on Hawaii where the sugar cane as well as other food plants grew "very luxuriantly."

One of the ways in which the Polynesians used sugar cane is related by Ellis (6, vol. 1) as follows:

> In a journey, the natives often carry a piece of sugar cane, which furnishes a sweet and nourishing juice, appeasing at once, to a certain degree, both thirst and hunger. . . . A native will sometimes travel, in the course of a day, thirty or forty miles, frequently over mountain and ravine, without taking any refreshment, except the juice from a piece of sugar cane, and apparently experience but little inconvenience from his excursion.

Ellis is here writing particularly of more southern Polynesians. I am told, however, that these statements would apply as well to the Hawaiians. This use of sugar cane is in accord with modern use of glucose by runners of Marathon races, recommended by Gordon and his co-workers (9) to prevent exhaustion, weakness, shock, and other symptoms of hypoglycemia following such prolonged physical effort.

Stewart (22) mentions that sugar cane is found on every plantation but that "the cane is used by the natives only as a fruit." I presume he means they did not make sugar from it.

The juice of sugar cane was much used by the Hawaiians in *apu*—medicinal concoctions made of ordinary foodstuffs combined with herbs, or of herbs alone, taken internally. Hawaiians tell of many *apu* containing sugar-cane juice. A publication on Hawaiian medicinal herbs (1) lists many remedies containing sugar cane, usually the white sugar cane (*kokea*) being specified. Mrs. Pukui thinks sugar cane was not an important food in the diet of the ancient Hawaiians, but that it was chewed for pleasure and was much used for *apu*. She states that *kokea* was the favorite variety used for medic-

inal purposes. It was also given to babies, for whom the sugar cane was put on a fire and heated, then pounded and the strained juice fed while it was yet warm. This might be given to babies only a few weeks old. Hawaiians believe that chewing sugar cane and squid aid in the development of teeth and jaws.

COMPOSITION OF SUGAR-CANE JUICE

The juice of sugar cane was expressed as indicated for the feeding experiments (p. 44). The analyses show low values for nitrogen, as would be expected, and a higher sugar content for the more mature cane than for the young. The calcium and phosphorus content of young and mature cane is very similar but is not sufficiently high to be of significant value in a food of limited use. Undoubtedly the food value of sugar cane, even in the primitive diet, lay in its relatively high content of readily assimilable carbohydrate.

COMPOSITION OF SUGAR-CANE JUICE

(Analyses by G. R. Stewart)

	Mature stalks (average of 2 lots)	Younger stalks (average of 2 lots)
Total solids by brix	16.87	12.48
Total sugars from brix	15.79	11.20
Ash	0.367	0.514
Calcium	0.0025	0.0033
Phosphorus	0.0248	0.0301
Nitrogen	0.015	0.020

VITAMINS OF SUGAR-CANE JUICE

It was not possible to obtain juice from any of the old Hawaiian canes of which Caum (3) states there are approximately fifty varieties. The variety used throughout the experiments was H109 mature, or nearly mature cane. The juice was extracted by means of a small, three roller cane mill at the Hawaiian Sugar Planters' Experiment Station on Monday morning. It was taken immediately to the University, strained through two thicknesses of cheese cloth, put in stoppered flasks, and kept very cold in an electric refrigerator for the remainder of the week. The pH of the juice varied between 5.4 and 5.2. It was found that the weekly samples did not change more than one-tenth by the end of the week.

No data on the vitamin A and B content of sugar-cane juice could be found in literature, though Nelson, Heller, and Fulmer (19) report crude cane molasses, known as "blackstrap," to be rather high in vitamin B. Fifteen per cent of blackstrap as the only source of vitamin B in the diet, furnished enough of that vitamin to support growth and reproduction to the fifth generation. These authors state that blackstrap furnished no de-

tectable amounts of vitamin A when included in the diet to the extent of 20 per cent.

Delf (5) reports work done in Africa on the vitamin C content of sugar-cane juice. She fed 3 guinea pigs on 10 cubic centimeters of sugar-cane juice; they developed scurvy in 43, 48, and 86 days, respectively. Three guinea pigs given fermented sugar-cane juice also developed scurvy. Her results on fresh sugar-cane juice were confirmed by the work here reported.

Vitamin A Content

In determining vitamin A content of sugar-cane juice, the diet and procedure were the same as reported for breadfruit. (See p. 6.) The results, which are summarized in Table 9, indicate that fresh cane juice, as well as molasses, is devoid of vitamin A. The rats would not take more than 10 cubic centimeters of fresh cane juice daily, and those fed on this amount succumbed as quickly as those fed on smaller amounts and with about the same loss in weight. None of them developed xerophthalmia.

Vitamin B Content

The diet and procedure for determining vitamin B content of sugar-cane juice were the same as for breadfruit. The results, which are summarized in Table 10, indicate an almost total lack of vitamin B, as the rats lived an average of 5 weeks on the basal diet alone. As vitamin B has been shown to be present in the crude molasses, it must be present in the sugar-cane juice, but in amounts too small to be demonstrated by feeding experiments, due to its great dilution.

Vitamin C Content

In determining vitamin C content of sugar-cane juice, the diet and procedure were the same as that reported for breadfruit. Six guinea pigs, each fed daily (except Sundays) 10 cubic centimeters of fresh sugar-cane juice, succumbed to scurvy, with losses in weight of from 13 to 116 grams. Five of them died four weeks after feeding began; one lived for eight weeks.

TABLE 9. RESULTS OF FEEDING RATS FRESH SUGAR-CANE JUICE AS SOLE SOURCE OF VITAMIN A

Number of rats	Amount fed daily (c.c.)	Loss in weight (grams)	Duration of tests (weeks)
2	6	—17	4½
2	8	—20	4
2	10	—19	4

TABLE 10. RESULTS OF FEEDING RATS FRESH SUGAR-CANE JUICE AS SOLE SOURCE OF VITAMIN B

Number of rats	Amount fed daily (c. c.)	Loss in weight (grams)	Duration of tests (weeks)
2	4	—15	5½
2	6	—10	6
2	8	— 8	6½
2	10	—10	5½

The results recorded in Tables 9 and 10 confirm Delf's work. It seems strange that fresh plant juice such as that of sugar cane should have no antiscorbutic value, but it is evident that the juice of mature cane is lacking in this factor. It may be possible that the juice from younger cane would show some vitamin C, as one week when juice was obtained from less mature cane than usual the losses in weight of the guinea pigs were less. It is of course possible that this was merely a coincidence.

SUMMARY

Experimental studies of the food value of breadfruit, taro leaves, coconut, and sugar cane lead to the following conclusions.

Cooked breadfruit is a fair source of vitamins A and C and a good source of vitamin B. Cooked taro leaves are a good source of A but a better source of B. Even after cooking for one hour there was evidence of a low vitamin C content. Coconut in any form is a very poor source of vitamin A, a good source of B. The water from within only the very young coconuts showed any antiscorbutic value. The methods used failed to show evidence of vitamins A, B, or C in sugar-cane juice.

Using Sherman's methods of evaluation by units, the results of the vitamin experiments here reported are summarized in Table 11.

TABLE 11. NUMBER OF UNITS TO A POUND OF FOOD, APPROXIMATED

Kind	Vitamin A	Vitamin B	Vitamin C
Cooked breadfruit	150	225 — 300	30
Cooked taro leaves	130	225	40
Ripe coconut	*a*	200 — 225	
Coconut water	*a*	*a*	20 (Immature nuts only)
Coconut milk	*a*	40 I (?)	*a*
Sugar-cane juice	*a*	*a*	*a*

a Too little to be measured by the methods used.

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