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FOOD VALUES OF POI, TARO, AND LIMU

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INTRODUCTION

Hawaii offers an unusual opportunity for the study of the effect of the nutritive value of food upon stature and physical well being of the human race.

While no attempt is made to deny the influence of heredity upon the stature and build of a people, students of nutrition have found convincing proof of the effect of food upon the physical development of people, asserting that fine stature in a race or unmixed group is due to the use of good food over a long period of time, and conversely that uniformly poor physique may be due to food inadequate in quantity or quality for many generations.

Centuries of life on isolated tropical islands had taught the Polynesians which of the available foods would satisfy their needs, and on their long journeys the Hawaiians brought the necessary food plants in their outrigger canoes, and were still cultivating the plants when the islands were discovered by Captain Cooke in 1778. As the animal food would vary little, it follows that the diet of the Hawaiians at that time had been maintained practically unchanged for at least 1500 years.

Unlike most peoples of fine stature, the Hawaiian race had no grains and no milk, yet it compares most favorably with other races in both stature and physical development. It is therefore desirable to evaluate the constituents of their diet in order to determine what the foods contributed.

Captain Cook (7)[1] describes the diet as follows:

> . . . . the food of the lower class of people consists principally of fish and vegetables, such as yams, sweet potatoes, taro, plantains, sugar-canes and breadfruit. To these, the people of higher rank add the flesh of hogs and dogs, dressed in the same manner as at the Society Islands.

Ellis (4), a reliable early writer, who travelled in the islands in 1822 and 1823, says that the natives subsisted principally on taro, sweet potato, and yams. Malo (9) gives a list of 138 edible fish, 31 fowl and birds, and a number of shell fish that were used by the Hawaiians. Foods less frequently used were the fruit of the hala (*Pandanus*); the ti root (*Cordyline terminalis*); the base of the leaf stem, the young shoots, and leaves of some ferns; the coconut; eight or nine wild berries; the mountain apple (*Eugenia malaccensis*); and pia (*Tacca pinnatifida*). Foods

[1] The numbers in parentheses refer to Bibliography (p. 25).

of lesser importance were used occasionally and during famine. Malo states that the food staple most desired in Hawaii was the taro, of which not only the thick root stock was used, but the young and tender leaves were cooked and eaten as greens, likewise the stems (*haha*).

Modern investigations by Hess (6) and by Steenbock, Hart and Jones (19) have shown the importance of wave lengths less than 4000 Angstrom units in the solar spectrum to health, growth, and bone formation. While no studies have yet been made of the ultra violet rays in the sunshine in Hawaii, there is no doubt from the marked burning and tanning effect of sunshine that exposure means subjection to these rays. According to information from the Weather Bureau of Honolulu (23), during the period 1905 to 1924, the average annual hours of sunshine were 2797. The Hawaiians, like most primitive people when the climate allows, wore little or no clothing, constantly exposing themselves to the sun's rays. What Ellis (4) says of the Tahitians no doubt applies equally to the Hawaiians:

> At the time of birth, the complexion of Tahitian infants is but little if any darker than that of European children, and the skin only assumes the bronze or brown hue as they grow up under repeated or constant exposure to the sun. Those least exposed are lightest, those most exposed (fishermen) darkest. Darkness of color was generally considered an indication of strength; and fairness of complexion, the contrary. Hence, the men were not solicitous either to cover their persons, or avoid the sun's rays, from any apprehension of the effect it would produce on the skin. When they searched the field of battle for the bones of the slain, to use them in the manufacture of chisels, gimlets, or fish hooks, they always selected those whose skins were dark, as they supposed their bones were strongest. When I have seen the natives looking at a very dark man, I have sometimes heard them say, "The man, how dark, good bones are his."

This would appear to show an appreciation of the value of the sun's rays in bone calcification centuries before it was recognized by modern science.

For making this study a Bishop Museum Fellowship was awarded by Yale University. Additional financial aid was rendered by Mr. and Mrs. George Carter and the Ii Estate. The assistance of the following is also gratefully acknowledged: Miss Marie Neal, for identifying the limu; Dr. Paul Kirkpatrick, for a study of the "lab-arc" and for making X-ray pictures; Dr. Nils P. Larsen, Queen's Hospital, Honolulu, for analyzing pictures; Mrs. Gwendolyn Waldron, for studying the micro-organisms in poi; Mr. David Kanuha Aiona, poi inspector for Honolulu, for information regarding ancient Hawaiian food habits.

The research was conducted at the University of Hawaii, 1925-1926.

Analyses in this paper were made according to the methods recommended by the Association of Official Agricultural Chemists (1). In the tables the weights are designated by grams.

TARO AND POI

CULTIVATION AND USE

Taro (*kalo*) and the poi made from it were the staff of life of the Hawaiian people. In those localities where taro could not be raised, the sweet potato or breadfruit was substituted. The propagation and cultivation of taro had been perfected to a remarkable degree. The taro of Hawaii, called by the early travelers *Arum esculentum* but by modern botanists *Colocasia antiquorum* var. *esculenta,* is now raised in the southern United States and is there commonly called the dasheen.

According to Wilder the old Hawaiians cultivated many varieties (25):

> For more than a century before the advent of the foreigner to these Islands, the Hawaiians had under cultivation some 200 varieties of wet-land and dry-land kalos. Gradually, however, the cultivation of the rarer varieties has decreased year by year, and the average Hawaiian of today knows little about any kalos excepting those that are grown for commercial purposes. The reason why this is so is due to the fact that about the year 1870 the Chinese entered into competition with the Hawaiians and began growing kalo on a large scale, always selecting the varieties that were heavy producers and that matured early.

Taro requires eight to sixteen months to mature, according to the variety.

Neither the root nor the stems and leaves of the taro are eaten raw as they are very irritating to the mucous membranes of the mouth and esophagus. This irritation is commonly attributed to an acrid substance that is destroyed by heating, but according to studies reported by Safford (13, p. 69) it is caused by the minute needle-like crystals of calcium oxalate which exist in capsule-like form and which are expelled with great force when the tissue of the capsule is subjected to pressure such as would result from chewing and swallowing the material. Cooking for considerable time is necessary to cause the capsules to lose their activity and thus destroy the irritating quality of the crystals.

No analyses of cooked Hawaiian taro being available, a mixed sample of steamed taro such as was used in the vitamin experiments (pp. 10-15) was analyzed with the following result:

ANALYSIS OF STEAMED TARO

Water	64.0
Protein (N x 6. 25)	1.18
Fat (ether extract)	0.169
Starch (acid hydrolysis)	29.31
Starch (saliva hydrolysis)	24.56
Sucrose	1.40
Reducing sugars	0.391
Ash	0.588
Calcium	0.0263
Phosphorus	0.0612

This analysis shows the protein and fat content of taro to be almost negligible so that it is essentially a carbohydrate food high in water. For comparison, the following analysis of dasheen, published by Young (26) is given:

ANALYSIS OF DASHEEN

Water	62.77
Protein	3.03
Carbohydrate	
starch	26.09
soluble sugars	1.75
pentosans	1.24
Ether extract	0.16
Ash	1.30
Crude fiber	0.71
Undetermined	2.95

These analyses for steamed taro and dasheen do not differ essentially though the dasheen shows a higher protein and ash content. Figures obtained from Mr. M. B. Bairos, Food Commissioner for Honolulu, show that the moisture content of Hawaiian taro ranges from 58 to 68 per cent.

Mr. David Kanuha Ainoa, who has an extensive knowledge of taro and poi making, gave me much of the following information regarding poi.

The old Hawaiians ate very little taro as cooked taro, practically all being eaten in the form of poi. The early travelers to the islands spoke of poi as a taro pudding. It is made by pounding the steamed, peeled taro to a smooth paste with the addition of a small amount of water, then straining it to remove any minute lumps and coarse particles of fiber. Nearly all poi now used in the islands is made by machinery. The mixture may vary in thickness but the Hawaiians prefer a poi of such consistency that it has approximately 20 per cent solids. It may be eaten freshly made or allowed to stand until fermentation takes place, which gives it an agreeable sour taste. Most Hawaiians prefer poi at least two or three days old when some acidity has developed. Good poi made as the old Hawaiians prepared it will remain in good condition for as long as two weeks. Tests made in the laboratory seemed to indicate that poi reaches a maximum acidity in eight or nine days, beyond which it ordinarly does not progress.

Stewart (21) writing of Hawaii in 1823 says:

> Hard or dry poi is kalo [taro] baked and beaten in the manner described, but not moistened with water. It is not much eaten in this state; but is packed in small bundles, and bound in leaves, to be diluted and formed into soft poi at pleasure. In this manner it will keep without injury for months; and makes a principal article in the sea stores of the native vessels.

Stewart refers to *paiai* which according to Mr. Aiona was not pounded but was the cooked taro pressed together in a sticky mass and wrapped in ti leaves in which state it would last a month or more. The Hawaiians usually ate it in the thick state as *paiai* rather than thinning it with water to the consistency of poi.

FERMENTATION OF POI

The organic acids formed in poi during the process of fermentation have not been determined. Lactic acid is probably the predominating one.

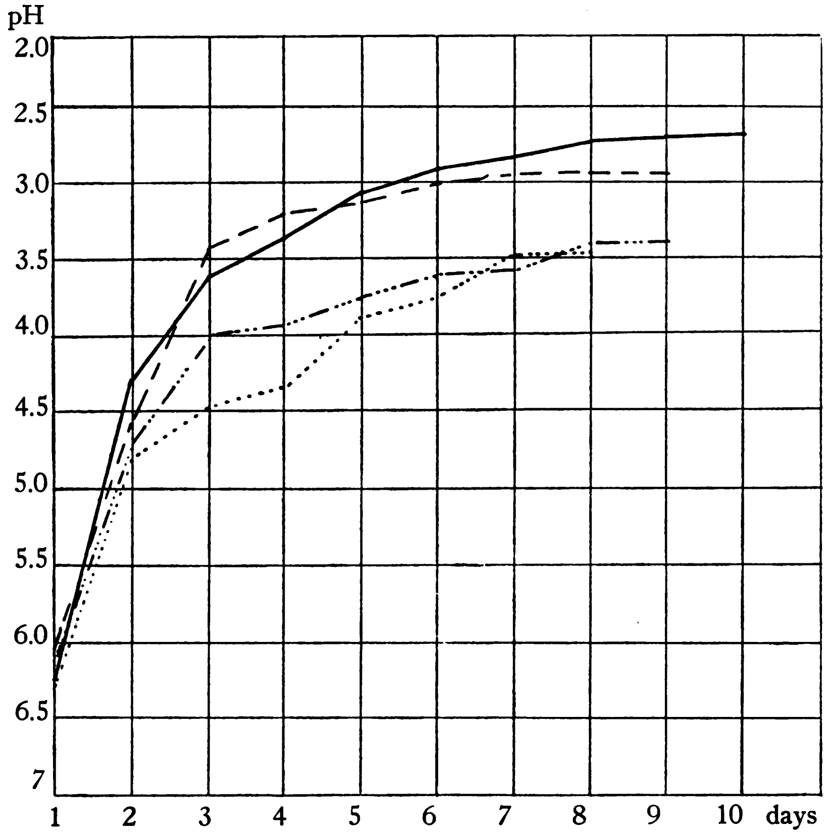

FIGURE 1.—Graph showing increase in acidity of poi, as the result of natural souring. The four curves refer to four different lots of poi.

Poi used to study the changes in the degree of acidity and in the form of carbohydrate was made in the laboratory in order to follow the changes beginning with freshly made and controlled material. As shown in figure 1, the initial acidity is usually a little greater than pH 6.0 by the second or third day it was pH 4.0 and by the fourth or fifth day between pH 3.0 and 4.0; while by the seventh or eighth day it may be as acid as pH 2.75 without showing any sign of spoilage. This souring process acts like the souring of milk in preventing the development of undesirable bacteria and produces a food that will keep without refrigeration for several weeks. The natural acidity of tomatoes is pH 4.3, of pineapple and other acid fruits from pH 3.5 to pH 4.0. Poi therefore must have furnished the organic acids to the diet of the Hawaiians as fruit furnishes it in the diet of other peoples. Though the organisms causing this change in acidity have not been fully studied, preliminary work indicates that yeast and bacteria are both concerned in the changes that take place during the souring of poi. The experiments show that the initial temperature determines the type of fermentation. At room temperature both bacteria and yeasts play a part; at ice box temperature and above 40° C the bacteria grow while the yeasts remain dormant. Yeasts ordinarily do not produce acids but rather alcohol which is further changed by their enzymes to carbon dioxide and water, which would account for the gas formation and for the slight thinning of the poi as it sours. The bacteria on the other hand may produce acids and are doubtless the organisms responsible for the production of the organic acids of poi.

The stimulating effect upon the appetite of organic acids of fruits and vegetables is well known. That organic acids of poi have a similar effect is indicated by the records of food consumption of rats when fed supplementary amounts of fresh poi and sour poi. See Tables 1 and 2.

TABLE 1. RESULTS OF FEEDING FRESH AND SOUR POI FOR VITAMIN A DURING A PERIOD OF SIX WEEKS

RAT	LOT	WEIGHT OF POI FED	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	FOOD CONSUMPTION
SOUR POI						
93 ♂	17	7	55	68	119	242
97 ♀	17	7	50	64	107	242
100 ♂	18	7	51	60	118	250
102 ♀	18	7	51	60	115	250
FRESH POI						
92 ♂	17	7	57	74	113	207
94 ♀	17	7	50	64	105	207
106 ♀	18	7	45	59	94	221
107 ♀	18	7	40	53	95	221

TABLE 2. RESULTS OF FEEDING FRESH AND SOUR POI FOR VITAMIN B, DURING A PERIOD OF EIGHT WEEKS

Rat	Lot	WEIGHT OF POI FED	INITIAL WEIGHT OF RAT	FINAL WEIGHT	FOOD CONSUMPTION
Sour Poi					
113♂	20	7	52	115	253
117♀	20	7	51	110	253
119♂	21	7	50	127	251
123♀	21	7	49	83	247
Fresh Poi					
114♂	20	7	49	96	224
118♀	20	7	45	107	224
121♂	21	7	47	121	211
125♀	21	7	43	90	211

Tables 1 and 2 show that when equal weights of sour and fresh poi were fed to rats from the same litter, sour poi caused a greater consumption of the basal diet. This did not always cause a greater gain in weight as the vitamin content of sour poi and fresh poi, which is the most important limiting factor, is apparently the same.

Considerable change takes place in the thickness, odor, color, and appearance of poi during the souring process, yet very little change in the carbohydrate content is shown by analyses. Poi was made fresh in the laboratory and one cubic centimeter of sour poi (pH 4.0) was added to effect a more rapid souring than is ordinarily obtained when fresh poi sours naturally. This mixture was placed in three flasks and the carbohydrate and moisture content of the fresh poi determined immediately. A second flask of the same poi which had reached an acidity of pH 3.50 by the second morning was then analyzed. The third flask of poi was allowed to stand until the fourth day when the pH was 3.00 and final carbohydrate and moisture determinations were made.

The results are sumarized in Table 3.

TABLE 3. CHANGES IN STARCH AND SUGAR CONTENT OF POI DURING FERMENTATION

	STARCH ACID HYDROLYSIS PER CENT	STARCH SALIVA HYDROLYSIS PER CENT	REDUCING SUGARS PER CENT	SUCROSE PER CENT
Fresh Poi	10.52	9.70	0.218	0.901
Sour Poi pH 3.5	10.01	9.66	0.1685	0.0725
Sour Poi pH 3.0	9.93	9.60	0.1825	0.0159

The reducing sugars and sucrose are first attacked by the bacteria and yeasts and broken down. A more complete series of tests on the change in carbohydrate during souring with a study of the organic acids and a quantitative test for the presence of alcohol should be made.

VITAMIN CONTENT OF TARO AND POI

Little or no work had previously been done on the vitamins of taro or poi. Steenbock and Gross (18) reported the dasheen to be a fair source of vitamin B but devoid of vitamin A. They fed raw dasheen to rats, which must have been very uncomfortable for them because of the calcium oxalate crystals—ordinarily animals cannot be induced to eat any part of the raw taro plant. In their experiments the dasheen was sliced without peeling, dried at room temperature, then ground to a fine powder and incorporated in the ration. No difficulty in consumption was observed; the taro was incorporated in the diet and the rats were forced to eat it in order to get any food at all. The technique of determining vitamins in food has been greatly improved since the experiments of Steenbock and Gross were made.

Vitamin A Content of Taro and Poi

The mothers of all rats used in the vitamin A experiments had a diet of the following mixture: One thousand grams whole ground wheat, 500 grams whole milk powder, 20 grams of common salt, and 100 grams of soy bean meal. The soy bean meal was made by cooking yellow soy beans in a pressure cooker for one hour at 15 to 20 pounds pressure, drying them in the oven, and grinding fine.

Young rats weaned at the age of four weeks were placed on the following diet:

	Per cent
Meat residue (extracted)	20.0
Starch	60.0
Yeast (Fleischmann, dry)	5.0
Sodium chloride c.p.	1.0
Salt mixture	4.0
Crisco	10.0

For this diet the meat residue and the salt mixture were prepared as described by Osborne (10, p. 37 and 11, p. 572). The prepared meat residue was extracted three times with hot 95 per cent alcohol following Sherman and Munsell's (16) recommendation for the extraction of casein.

The technique recommended by Sherman and Munsell (16) for making the vitamin A determinations as nearly quantitative as possible was used. When the weight of the rats had been stationary or declining for a week on this diet, weighed amounts of steamed taro were fed daily. The results of a preliminary test using varying amounts of taro and using irradiation on one-half the rats indicated that the amount of food needed to cause a gain of 25 grams in 8 weeks, or average gain of 3 grams a week, was about 1.5 grams daily. (See Table 4.) The results of feeding 1.5 grams daily are shown in Table 5.

TABLE 4. RESULTS OF FEEDING VARYING AMOUNTS OF TARO TO RATS FOR A PERIOD OF EIGHT WEEKS

RAT	LOT	WEIGHT OF TARO FED	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	IRRADIATION
375 ♂	60	1	57	77	84	7	Non-irradiated
376 ♂	60	1	51	75	91	16	Irradiated
382 ♀	60	2	46	61	100	39	Non-irradiated
379 ♂	60	2	46	82	120	38	Irradiated
380 ♀	60	3	51	73	104	31	Non-irradiated
381 ♀	60	3	50	67	119	52	Irradiated
377 ♂	60	4	48	67	135	68	Non-irradiated
378 ♀	60	4	48	68	166	98	Irradiated

TABLE 5. RESULTS OF FEEDING 1.5 GRAMS OF TARO DAILY FOR VITAMIN A, FOR A PERIOD OF EIGHT WEEKS

RAT	LOT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	IRRADIATION
427 ♀	66	54	62	67	5	Non-irradiated
425 ♀	66	58	70	79	9	Non-irradiated
421 ♂	66	56	63	60	—3	Non-irradiated
423 ♂	66	53	58	82	24	Non-irradiated
428 ♀	66	51	60	77	17	Irradiated
426 ♀	66	55	53	70	17	Irradiated
422 ♂	66	56	71	62	—9	Irradiated
424 ♂	66	52	71	83	12	Irradiated

As the results of the experiments recorded in Tables 4 and 5 were not very satisfactory, 2 grams of taro were fed daily for 8 weeks, with the results indicated in Table 6.

TABLE 6. RESULTS OF FEEDING 2 GRAMS OF TARO DAILY FOR VITAMIN A, FOR A PERIOD OF EIGHT WEEKS.

RAT	LOT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	IRRADIATION
483 ♂	75	53	82	96	14	Non-irradiated
486 ♀	75	52	64	107	43	Non-irradiated
481 ♂	75	54	70	75	5	Non-irradiated
484 ♂	75	52	63	91	28	Irradiated
482 ♂	75	54	71	94	23	Irradiated
485 ♀	75	54	74	103	29	Irradiated

The somewhat erratic results shown in Table 6 are difficult to explain as all the rats always ate the taro readily, but may in part be explained by the fact that the rats showing losses or poor gains in weight had lower food consumption records. It may be concluded that it takes about 2.0 grams of taro daily to cause a gain of 25 grams in 8 weeks.

All taro used in the feeding experiments was steamed for three-quarters of an hour in a tight fitting steamer, the taro being about four or five inches above the boiling water.

Commercial poi containing 70 per cent of water and 30 per cent of solids as it comes from the stores was fed to rats. The results of a preliminary test using varying amounts of poi and using irradiation on one half of the rats indicated that the amount of poi needed to cause a gain of 25 grams in 8 weeks was about 3.0 grams daily. (See Table 7.)

TABLE 7. RESULTS OF FEEDING VARYING AMOUNTS OF POI TO RATS FOR A PERIOD OF EIGHT WEEKS.

RAT	LOT	WEIGHT OF POI FED	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	IRRADIATION
398 ♀	62	1	57	95	89	—6	Non-irradiated
399 ♀	62	1	55	71	73	2	Irradiated
393 ♂	62	2	62	94	95	1	Non-irradiated
394 ♂	62	2	60	95	112	17	Irradiated
391 ♂	62	3	64	91	127	36	Non-irradiated
392 ♂	62	3	62	89	117	28	Irradiated
395 ♂	62	4	59	95	147	52	Non-irradiated
397 ♀	62	4	59	79	105	26	Irradiated

Table 8 shows that it takes less than 3.0 grams of poi daily to cause a gain of 25 grams in 8 weeks. Comparing this with taro on the basis of solids in each, no destruction of vitamin A is evident as a result of the souring process.

TABLE 8. RESULTS OF FEEDING 3 GRAMS OF POI DAILY FOR VITAMIN A, FOR A PERIOD OF EIGHT WEEKS.

RAT	LOT	INITIAL WEIGHT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	IRRADIATION
465 ♂	73	61	67	121	54	Non-irradiated
465 ♂	73	55	67	77	10	Non-irradiated
469 ♀	73	57	62	96	34	Non-irradiated
472 ♀	73	52	61	94	33	Non-irradiated
466 ♂	73	57	69	106	37	Irradiated
468 ♂	73	53	67	116	49	Irradiated
470 ♀	73	55	66	108	42	Irradiated
473 ♀	73	51	60	107	47	Irradiated

Sherman and Munsell (10) believe that using the technique they recommend, the irradiation of food to supply vitamin D or irradiation of the animals themselves is unnecessary. Steenbock, Nelson, and Black (20) recommend the irradiation of the animals or food to assure furnishing vitamin D. In the procedure here followed, the animals were exposed for ten minutes daily at a distance of 16 inches from a Cooper-Hewitt quartz-mercury "lab-arc." Indecisive but suggestive results were obtained. In the groups of 8 rats, 4 irradiated and 4 non-irradiated, 3 of the 4 irradiated ones usually made decidedly better gains than the average for the 4 non-irradiated rats. Post-mortem examination of the ribs of rats treated both ways showed no abnormalities. The feeding of 6 rats was continued through the twelfth week, usuing 3 non-irradiated rats that had made poor gains and 3 irradiated rats that had made good gains. X-ray pictures of these 6 rats showed no detectable differences or abnormalities. Light furnished by the "lab-arc", therefore, seems to have had some stimulating effect on growth, but was unnecessary for proper calcification of bone.

A study of the radiant output of the "lab-arc," under the direction of Dr. Paul Kirkpatrick of the University of Hawaii, led to the conclusion that the intensity of radiation of wave length less than 3,700 Angstrom units incident upon the animal at a distance of 16 inches from the source, is approximately 0.006 watts per square centimeter of surface normal to the direction of radiation. Taking Dorno's (3) values for the proportion of solar energy in the ultra violet region to be about one per cent and assuming a total incident solar energy at sea level of one calorie per square centimeter per minute, it is deduced that the energies of sunlight and of the "lab-arc" used are approximately equivalent in total energy below 3,700 Angstrom units.

The results of experiments here reported do not justify any conclusion as to the vitamin D content of poi and taro. However, inasmuch as this factor was so amply supplied to the Hawaiians by their exposure to sunlight it is not of vital importance if the anti-rachitic factor was or was not supplied in the food.

Vitamin B Content of Taro and Poi

The mothers of rats used in the vitamin B experiments received the same diet as the mothers of those used for vitamin A experiments. The young weaned at 4 weeks were placed on the following diet for 1 week (with one lot for 2 weeks) before taro feeding was begun:

	Per cent
Meat residue	20
Starch	63
Sodium chloride c. p.	1
Salt mixture	4
Cod liver oil	2
Butter	10

For this diet the meat residue was prepared as directed by Osborne (10, p. 37), but was not extracted with alcohol; the salt mixture was prepared as directed by Osborne (11, p. 572). The rats were kept in round wire cages, the wire mesh bottoms of which were raised above the floors of the cages one inch to reduce consumption of feces to the minimum.

Trial experiments in feeding indicated that the amount of taro necessary to cause the desired gain of 25 grams in eight weeks is about 2.5 grams.

TABLE 9. RESULTS OF FEEDING VARYING AMOUNTS OF TARO FOR VITAMIN B, FOR A PERIOD OF EIGHT WEEKS

RAT	LOT	WEIGHT OF TARO FED	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT
400 ♂	63	1	62	62	57	—5
401 ♀	63	1	57	57	54	—3
402 ♀	63	2	54	54	74	20
404 ♀	63	2	51	51	64	13
405 ♀	63	3	51	51	89	38
406 ♀	63	3	50	50	88	38

Table 10 shows that it took 2.5 grams of taro to cause a gain of about 25 grams in 8 weeks, 2 of the five rats showing somewhat smaller gains.

TABLE 10. RESULTS OF FEEDING 2.5 GRAMS OF TARO DAILY FOR VITAMIN B, FOR A PERIOD OF EIGHT WEEKS.

RAT	LOT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT
455 ♀	71	50	53	72	19
456 ♀	71	50	59	79	20
453 ♀	71	56	64	87	23
454 ♀	71	54	57	69	12
451 ♂	71	54	62	89	27

The results of preliminary trials in feeding poi, of the composition and character used in experiments for vitamin A (p. 12) are shown in Table 11.

TABLE 11. RESULTS OF FEEDING VARYING AMOUNTS OF POI FOR VITAMIN B, FOR A PERIOD OF EIGHT WEEKS.

RAT	LOT	WEIGHT OF POI FED	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT
407 ♂	64	1	55	55	55	0
411 ♀	64	1	50	50	50	0
409 ♂	64	2	51	51	67	16
412 ♀	64	2	49	49	61	12
410 ♂	64	3	50	50	76	26
413 ♀	64	3	48	48	82	34

The final results of feeding 3 grams of poi daily to a group of rats for 8 weeks are summarized in Table 12. The gains shown are a little irregular but the average gain of the 5 rats for 8 weeks is 21 grams, which indicates that a little more than 3 grams should have been fed.

TABLE 12. RESULTS OF FEEDING 3.0 GRAMS OF POI DAILY FOR VITAMIN B, FOR A PERIOD OF EIGHT WEEKS

RAT	LOT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT
494 ♀	76	48	52	73	21
493 ♂	76	46	49	87	38
492 ♂	76	50	50	68	18
488 ♂	76	54	57	70	13
490 ♂	76	60	60	76	16

Vitamin C Content of Taro and Poi

For feeding experiments designed to determine the vitamin C content of taro and poi, guinea pigs raised especially for feeding experiments were used, and the procedure recommended by Sherman and Smith (17) was followed. Guinea pigs weighing 300 grams to 350 grams and 6 to 8 weeks old, were placed on the following diet plus fresh alfalfa:

	Per cent
Whole oats ground as needed	59
Skimmed milk powder (Klim heated in open trays at 110° for 2½ hours)	30
Butter fat	10
Sodium chloride	1

When alfalfa was withdrawn, the weights went down, then up, then down again at the onset of scurvy. The results of feeding 10 grams of taro daily to 6 guinea pigs are summarized in Table 13, which shows that the antiscorbutic value of taro is low. But undoubtedly there is some vitamin C present or the guinea pigs would not have survived 10 and 12 weeks instead of the usual 4 or 5 weeks on the basal diet alone. After feeding of the taro was begun the guinea pigs gained for 1 week or even as long as 6 weeks and then the weights declined slowly until the guinea pigs succumbed.

TABLE 13. RESULTS OF FEEDING TARO FOR VITAMIN C

GUINEA PIG	INITIAL WEIGHT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	SURVIVAL AFTER FEEDING BEGAN—WEEKS
109 ♂	339	328	248	10
105 ♂	345	354	246	10
103 ♂	360	308	244	10
112 ♀	352	303	214	12
110 ♀	318	270	214	12
107 ♂	363	350	228	10

It has been shown (8) that the fermentation process taking place in sauerkraut and silage destroys the vitamin C of the original material. That vitamin C is not destroyed in poi as fed to guinea pigs is shown by the fact that two animals survived for 11 weeks, one for 9 and one for 8 weeks though they showed marked signs of scurvy.

The results of feeding 15 grams of commercial poi (30 per cent solids) daily to 4 guinea pigs are shown in Table 14.

TABLE 14. RESULTS OF FEEDING POI FOR VITAMIN C

GUINEA PIG	INITIAL WEIGHT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	SURVIVAL AFTER FEEDING BEGAN—WEEKS
117 ♂	356	351	222	8
120 ♀	344	329	207	9
119 ♂	350	348	235	11
118 ♀	324	294	246	11

In conducting the experiment recorded in Table 14 considerable difficulty was experienced in inducing the animals to eat the poi for the first week or two. This means that scurvy grew rapidly worse and when they finally did eat the poi there was not enough vitamin C to protect them, though there was sufficient to prolong their lives for a number of weeks. An examination of the cleaned and dried jaw bones of all the guinea pigs used in these experiments showed those from the guinea pigs fed with poi to be in no worse condition than those fed with taro.

As the exact amount of vitamin C necessary to protect an adult human being from scurvy is not known, it is impossible to state that a diet composed largely of poi would prevent scurvy. Undoubtedly it would when supplemented with raw fish and small amounts of other foods containing vitamin C.

The methods for the determination of the vitamin content of foods now permit of approximate quantitative comparisons. On the basis of the method suggested by Sherman (15) it may be stated that steamed taro contains twice as much vitamin A as baked white potato, an amount equal to that furnished by cabbage, baked beans and grapes, but about one-tenth the amount contained in tomatoes. Wheat and rolled oats have too little vitamin A to be measured by present methods.

Taro does not have its vitamin A content reduced by being made into poi, although poi contains relatively less than taro as it is thinned with water.

Using Sherman's methods for comparison, taro has about half as much vitamin B as the whole grains (including the embryo) and two times as much as milk.

Though taro and poi are poor antiscorbutics, they might prevent human scurvy, if furnishing the bulk of the diet.

CALCIUM AND PHOSPHORUS CONTENT OF POI

Minerals for building bone and teeth as well as supplying the daily metabolic need must come from our foods. Sherman (15) has shown that in the modern American diet the minerals which are liable to fall below the dietary standard set by him as a result of much study are phosphorus, calcium and iron.

From the analyses of steamed taro (p. 5) it is possible to estimate what part of the daily calcium and phosphorus requirement would be supplied by poi when eaten in large quantities. It is difficult to estimate the consumption of poi by the old Hawaiians. Mr. Aiano states that an amount equal to 5 pounds of the commercial poi as sold today (30 per cent solids) would be an average amount for a man or woman, but that the old Hawaiians might eat 10 or 15 pounds of such poi a day depending on the work they were doing and the abundance of the supply. Calculating the amount of calcium in poi of this composition from the figures given for cooked taro and supposing an arbitrary standard for the Hawaiians based on Sherman's figures be used (0.68 grams of calcium daily) 5 pounds of commercial poi with a calcium content of 0.0219 per cent would supply 0.497 grams of calcium or 73 per cent of the daily requirement. If the Hawaiians ate 10 pounds of poi (30 per cent solids) 0.994 grams of calcium would be supplied or 0.3 grams more than the daily requirement. Supposing the lower figure to be an average, a fish eaten whole and a little limu would easily care for the calcium need.

Sherman suggests a phosphorus standard of 1.32 grams a day for a man weighing 70 kilograms (about 154 pounds). Calculating from the phosphorus content of steamed taro, commercial poi would have 0.051 per cent phosphorus and 5 pounds of poi would supply 1.15 grams of phosphorus a day. Consumption of more than 5 pounds would more than supply the daily need of phosphorus as calculated by modern standards.

Five pounds of commercial poi would yield approximately 2,110 calories. This would certainly not meet the caloric need of a large man or woman at moderately heavy work, so that an additional amount of poi to bring the caloric supply to about 3,000 would mean that poi alone would supply the calcium and phosphorus need for the day, even though the mineral requirement of a large person might be greater than has been estimated in the figures given.

That a staple food should supply to such an extent the mineral and vitamin needs of the individual is greatly in its favor.

LIMU

USE AND COMPOSITION

Limu (fresh water, or salt water edible algae) is undoubtedly one of the ancient foods of the Hawaiians. Although no mention of it is made in any of the writings of the early explorers, its ancient use is indicated by references in a number of the folk tales (24). Today it is used in small quantities and may be purchased in the Honolulu markets.

Handy (5) tells me that limu is eaten by the natives in the Marquesas, the Society, and the Tuamotu islands. In the Tuamotus, in the absence of greens, limu is eaten in larger amounts than in any of the other islands he has visited. The Tuamotuans are of fine stature. Their diet consists of coconut, fish, limu, and hala fruit.

Reed (12), who made an excellent study of the seaweeds used by the Hawaiians, says:

> Before the coming of the white man to these islands the diet of the poorer Hawaiians was largely poi, fish and limu. Even poi was scarce in times of war or famine, and then the poorer fishermen contented themselves with only fish and limu. Sometimes for weeks no other vegetable food could be obtained but limu, which can be gathered all the year, except during very severe storms. . . Almost every kind of seaweed that could possibly be eaten was used for food by some Hawaiians, while certain of the more attractive algae were universally used wherever and whenever it was possible to secure them from the sea. The people living in the mountain valleys used, in addition to marine algae, several kinds of the soft green fresh water algae from the streams and ponds.
>
> There are over seventy distinct species of algae or limu used for food by the Hawaiians. Of these seventy species not more than forty are in general use. The other thirty or thirty-five are used only by a few people in certain small areas where they are found in limited quantities. . . . Each edible limu has its own special appellation besides the generic name limu with which it is combined either as a descriptive adjective or as a suffix.
>
> Immediately after gathering the limu it is very carefully washed, either in salt or fresh water, to remove all sand, mud, or clinging mollusks and crustaceans. . . After cleaning, the seaweed is always salted and usually broken, pounded, or chopped into small pieces, and usually it is eaten uncooked as a relish with poi, meats or fish.

Reed gives considerable detail of the various ways in which limu were prepared and states that the three limu in general use by the natives on all the Hawaiian islands are *limu eleele, limu kohu,* and *limu lipoa.* In attempting analyses of these three, and using them in feeding experiments with animals, it was found impossible to procure *limu kohu* in an unsalted state for a period sufficient to carry out experiments, therefore only *limu eleele* (the Hawaiian name for all species of *Enteromorpha*) and *limu lipoa* (*Haliseris plagiogramma*) were used. The same species of *Entermorpha* was not always obtainable, but the two species used in these experiments showed no difference in their vitamin content.

The composition of these two algae was found to be as follows:

	LIMU ELEELE PER CENT	LIMU LIPOA PER CENT
Water	90.34	84.68
Protein (N x 6.25)	2.82	1.64
Fat (ether extract)	0.0485	0.0287
Ash	1.59	2.56
Calcium	0.17	0.584
Phosphorus	0.0336	0.0156

Two other samples of each of these did not show any essential difference in composition.

Schwartz (14) made a detailed study of the carbohydrate content of algae which in their fresh state had been reported to contain as much as 14 per cent of carbohydrate. Among other algae, she studied eight limu sent her from Hawaii by Reed. She found that *limu lipoa* and *limu eleele* yielded little or no carbohydrate. She also demonstrated that when algae contain carbohydrates they are chiefly pentosans and galactans; hemicelluloses yielding pentoses and galactose on hydrolysis. As we have no enzymes that can break down these polysaccharides, they are not digested by man.

Considerable difficulty was experienced in procuring a continuous and uniform supply of limu for feeding purposes and further difficulty in feeding it to the rats. As limu must be kept moist if it is to be fed fresh, the water content may vary greatly. Moreover the keeping qualities of fresh limu without salt are poor. The limu were therefore dried and fed in small accurately weighed amounts. Even when the dry material was moistened with water, the animals refused to eat an amount sufficient to cause growth. It was therefore necessary that the fresh material with its varying moisture content be fed to new sets of rats and even then after many trials the results were far from satisfactory.

Vitamin A Content

In determining the vitamin content of limu, the diet and procedure for the experimental animals were the same as used for vitamin determination of taro (p. 10). The most satisfactory of the preliminary experiments for *limu eleele* (the green *Enteromorpha*), are for rats numbered 448, 449, and 445, in Table 15. When 5 grams were fed daily for 2 weeks the gains were negligible, but when 7 grams were fed, the gains were excessive. The data for rats numbered 475, 479, 474, 478, which were fed five grams daily for the usual eight weeks' period, are probably the most significant. One rat gained much in excess of the predicted 25 grams, while the other three failed to reach that figure. Probably 5 or 6 grams is necessary for the standard gain.

TABLE 15. RESULTS OF FEEDING LIMU ELEELE FOR VITAMIN A

RAT	LOT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	AMOUNT FED	PERIOD FED —WEEKS
448 ♂	70	54	79	152	73	5 7	2 8
449 ♀	70	63	76	134	58	5 7	2 8
445 ♂	70	64	82	124	42	5 7	2 8
475 ♂	74	52	73	91	18	5	8
479 ♀	74	48	59	96	37	5	8
474 ♂	74	59	89	101	12	5	8
478 ♀	74	48	66	82	16	5	8

Attempts at feeding the dried *lipoa* (brown *Haliseris*), were even more discouraging than those for *limu eleele.* The records of rats Nos. 434 and 447 in Table 16 are indicative of the results with preliminary trials. Rat No. 476 ate the 5 grams fed nearly every day and showed a gain of 17 grams in 8 weeks, but No. 477, though fed 5 grams daily for 8 weeks, rarely could be induced to eat up its daily portion.

TABLE 16. RESULTS OF FEEDING LIMU LIPOA FOR VITAMIN A

RAT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL FEEDING	GAIN IN WEIGHT	AMOUNT FED	PERIOD FED
434 ♀	48	56	54	-2	2 5	2 4
447 ♂	63	92	118	26	5 7	4 7
476 ♀	52	62	79	17	5	8
477 ♀	51	67	59	-8	5	8

Were the rats to eat the *limu lipoa* consistently, a daily supplement of 7 to 8 grams would probably cause the desired gain of 25 grams in 8 weeks. Coward and Drummond (2) show that two green seaweeds (*Ulva* and *Cladophora*) contain vitamin A while a red seaweed (*Polysiphonia*) has no appreciable amount of vitamin A.

The results reported here do not indicate that *limu lipoa* is devoid of vitamin A.

Limu eleele has less than half the vitamin A of taro, and *limu lipoa,* still less.

VITAMIN B CONTENT

In determining the vitamin B content of limu, the diets and procedure were the same as that given for taro and poi (p. 13). Feeding the dried material was unsuccessful. The results of feeding fresh *limu eleele* for vitamin B are shown in Table 17.

TABLE 17. RESULTS OF FEEDING LIMU ELEELE FOR VITAMIN B FOR EIGHT WEEKS

RAT	LOT	INITIAL WEIGHT OF RAT	WEIGHT WHEN FEEDING BEGAN	FINAL WEIGHT	GAIN IN WEIGHT	AMOUNT FED
495 ♀	76	45	48	63	11	5
491 ♂	76	51	55	80	25	5
496 ♀	76	45	48	72	24	5
489 ♂	76	52	56	69	13	5

Rat No. 495 daily failed to eat all the limu, which probably accounts for the poor gain. Two rats showed the expected gain of 25 grams, while rat No. 489 failed to do so. Of fresh *limu eleele,* 5 grams is probably about the amount for inducing the desired gain of 3 grams a week.

Compared with taro, *limu eleele* has one-fourth as much vitamin B, while *limu lipoa* has about one-sixth as much.

Feeding the dried *limu lipoa* was unsuccessful. One and two grams of fresh *limu lipoa* daily was not enough to prevent rapid loss in weight. Due to the difficulty encountered in inducing rats to eat the larger amounts, time and animals were not available for final experiments. The results obtained indicate that the vitamin B content of the *limu lipoa* is somewhat lower than that of *eleele.*

Vitamin C Content

The diet and procedure for the determination of the vitamin C of limu were the same as that reported for taro (p. 15). The results are summarized in Table 18.

TABLE 18. RESULTS OF FEEDING LIMU ELEELE FOR VITAMIN C

GUINEA PIG	AMOUNT FED DAILY	SURVIVAL AFTER FEEDING WAS BEGUN DAYS
104 ♀	2	7
106 ♀	3	6
93 ♂	4	16
114 ♀	5	26
116 ♀	5	25
95 ♂	5	24
101 ♂	5	32
108 ♀	5	26

Practically all guinea pigs whose records are given, showed severe hemorrhages of the ribs. Blood was observed in the bottom of the cages for a week or two before death. Intestinal hemorrhages were much more severe than ever observed before in experimental animals. Whether this was caused by something in the limu toxic to guinea pigs, the high mineral content, or merely the lack of vitamin C, is not known. The guinea pigs ate with apparent relish the entire weighed portion of *limu eleele* fed each day.

It seems that such fresh looking, green plant material as *limu eleele* should have some vitamin C, but it was impossible in these experiments to show its presence. No other records of experiments on vitamin C of algae or seaweeds are available.

The results of feeding fresh *limu lipoa* to guinea pigs are summarized in Table 19.

TABLE 19. RESULTS OF FEEDING LIMU LIPOA FOR VITAMIN C

GUINEA PIG	AMOUNT FED DAILY	SURVIVAL AFTER FEEDING WAS BEGUN DAYS
102♀	2	21
99♂	3	28
89♂	3	24
91♂	4	27

The four guinea pigs listed in Table 19 consistently ate the *limu lipoa,* but succumbed as quickly as guinea pigs on the basal diet alone and all showed severe intestinal hemorrhages. It must therefore be concluded that *limu lipoa* also is without anti-scorbutic value.

Mineral Content

These experiments show that limu are poor or inadequate sources of the vitamins and that their carbohydrate content is not utilizable by man; how well the mineral content is utilizable can be shown only by feeding experiments on man. Supposing, however, that the minerals are as well used as those in other foods their high content of calcium would be a valuable addition to the diet even though limu is consumed in small quantities. Mr. Ainoa estimates that when limu is available two tablespoonfuls or more of limu would be eaten in a day. One tablespoonful of fresh unsalted *eleele* weighs approximately 14 grams, therefore calculating from the calcium content given on page 19, two tablespoonfuls of *limu eleele* would supply 0.0476 grams of calcium, a not inconsiderate amount when added to that supplied by the other food. One tablespoonful of *limu lipoa,* which has a much higher content of calcium, weighs only approximately 5.0 grams, so that two tablespoonfuls would supply 0.05 grams of calcium a day.

Aside from the fact that the limu could contribute a small amount of calcium and an alkaline ash to the diet, its value in the old Hawaiian diet doubtless was one of adding variety. Its spicy aromatic flavor added greatly to the palatability of a somewhat monotonous diet. The limu may also have served a useful purpose in preventing constipation. Modern investigation has shown that the carbohydrates of the algae though not digested give bulk to the intestinal contents and thus assist the normal mechanical movements of the intestinal tract. The iodine content of the limu was not of importance considering that the Hawaiians lived so near the sea, ate large quantities of crude salt, and fish was their main protein food.

SUMMARY

When the Hawaiian islands were discovered, the natives were undoubtedly eating the same foods they had eaten for centuries. What foods they ate is known and many facts regarding their preparation. Scientists have given convincing proof of the effect of food on the physicial well being of people when that food is eaten for generations. As the Hawaiians were an unusually fine race physically, the nutritive value of their food offers a fertile field for investigation.

Steamed taro was analyzed for organic nutrients and for calcium and phosphorus. Low in fat and protein, it is essentially a carbohydrate food, and is a good source of vitamins A and B. Making taro into poi does not destroy the vitamin A or B content. The basal food consumption of rats given sour poi daily was greater than that of rats fed fresh poi. This was probably caused by the organic acids which are ordinarily a stimulus to appetite. The souring of poi does not materially change the carbohydrate content. Taro is a poor source of the antiscorbutic vitamin. Making taro into poi does not destroy the vitamin C though it appears to reduce it somewhat. It has been estimated that an average daily consumption of poi by the old Hawaiians was equivalent to five pounds of commercial poi (30 per cent solids). This would supply approximately 70 per cent of the calcium and almost the estimated phosphorus requirement. Poi was doubtless an excellent carbohydrate food.

Of the limu studied, *limu eleele* is a fairly good source of vitamin A and a less good source of vitamin B; *limu lipoa* is a poor source of vitamins A and B. The value of limu in the diet is its flavor and its tendency to prevent constipation. Neither *limu eleele* nor *limu lipoa* have antiscorbutic value.

The Hawaiians exposed constantly to the ultra violet rays of the sunshine, were undoubtedly furnished with an abundance of the antirachitic factor.

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