I. THE NUTRITIVE VALUE OF PAPAYA¹

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THE papaya (*Carica papaya*), a delicious fruit found in most tropical and semi-tropical countries, thrives well in Hawaii at altitudes below 1200 feet. Pope [1930], who has studied the culture of papaya, states that there are no established varieties in Hawaii, though there are a number of different types.

Reports on the composition and vitamin value of papaya have appeared in the literature from time to time; most of the earlier ones are included in the bibliography of a brief article in this Journal [Miller, 1926], reporting the vitamin A, B and C values of papaya.

This paper contains new material on mineral, vitamin and acid-base balance values of papaya grown in Hawaii.

COMPOSITION OF PAPAYA

Methods of chemical analyses

The methods employed for the determination of the organic nutrients were those of the Association of Official Agricultural Chemists [1930], with the exceptions noted below. Good quality papayas of the long narrow type bought on the open market were used for the analyses which were made on the edible portion after the seeds, inner membranes and a peel of about $\frac{1}{4}$ inch thickness were discarded. The percentage refuse, determined on more than a dozen papayas, was found to range from 6.5 to 31.5 % according to the size of the papaya and the quantity of seeds. Refuse of the large and medium-sized papayas averaged 25 %.

Moisture was determined by a slight modification of the official method. A thin layer of the fresh edible material was weighed in a small, shallow weighing bottle (30 by 40 mm.), then dried in an electric oven for 3 days at 65°. Final traces of moisture were removed *in vacuo* over sulphuric acid for 3 days.

Calcium was determined by a slight modification of the McCrudden volumetric method [Sherman & MacLeod, 1925]; iron by the method of Elvehjem & Hart [1926]. All precautions were taken to prevent contamination by avoiding the use of iron utensils, by ashing the material without previous drying and by subtracting the iron value of a blank determination run simultaneously.

The method of Davidson & LeClerc [1935] was used for the determination of the acid-base balance of the papaya. Triplicate analyses were made on a composite sample representing equal quantities of the edible portion of eight ripe papayas of various types.

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Results of chemical analyses

The figures in Table I represent averages of triplicate determinations on a composite sample of three ripe papayas.

Table I. *Composition of Hawaiian-grown papayas*

Expressed as % of the fresh edible fruit

	%		%
Acid (as citric)	0.13	Ash	0.51
Water	85.6	Ca	0.019
Protein (N $\times$ 6.25)	0.5	P	0.013 *
Ether extract	0.3	Fe	0.00025
Crude fibre	0.8	Cl	0.132
Carbohydrate (by difference)	12.3		

Reports have come to the station laboratory that papaya grown near the sea often has an undesirable salty taste. A short series of analyses was run to note the variation in the chloride content (Table II).

Table II. *The total ash, calcium and chloride contents of papayas*

Expressed as % of the fresh edible fruit

Sample No.	Source of sample	Elevation ft.	Approx. distance from sea miles	Moisture %	Total ash	Ca	Cl
1	Wahiawa Vil., Oahu*	900	8	87.3	0.42	0.015	0.061
2	Kailua, Oahu*	300	3½	84.0	0.51	0.017	0.075
3	Kona, Hawaii†	1500	2	88.5	0.33	0.012	0.083
4	Kaneohe, Oahu‡	100	1	85.1	0.46	0.016	0.104
5	Kapaa Hts., Kauai	200	½	88.7	0.59	0.010	0.168
6	Damon Tract, Oahu*	15	½	85.6	0.51	0.019	0.188
7	Waiālae, Oahu	Sea level	½	87.3	0.63	0.018	0.223
8	Wailupe, Oahu*	Sea level	50 ft.	91.3	0.70	0.026	0.244
Average				87.2	0.52	0.017	0.143

* No fertilizer.

† Experiment Station land had been fertilized more than 6 months previously.

‡ Chicken manure used for fertilizer.

These results show that the chloride content of papaya varies but that even the highest values do not greatly exceed those reported for some other foods such as milk, bananas and dates [Sherman, 1932]. However, it was not possible to obtain papaya that had a distinctly salty taste; sample No. 7 had a very slight salty taste.

Rabinowitch [1932] has reported extreme variation in the chloride content of oranges from 0.009 % to 0.0052 %.

To evaluate papaya as a source of Ca, determinations were made on the same samples with the results shown in Table II. There is considerable variation in the Ca content of the eight samples of papaya, the quantity on the fresh basis ranging from 0.015 to 0.026 %. This variation is less than that reported by Rabinowitch [1932] for oranges (0.0131–0.038 %).

The results of analyses on a composite sample indicate that papayas have an acid-base balance value comparable with that of oranges. On the fresh basis papayas have a base balance value of 5.7 ml. of *N* alkali per 100 g. of fresh substance and 43.7 ml. of *N* alkali on the dry basis.

VITAMINS OF PAPAYA

Methods and results of vitamin determinations

All experimental animals were raised in the station laboratory. The mothers of all experimental rats received the following diet: whole wheat 960 g., whole milk powder 400 g., cooked soy bean meal 100 g., dried yeast 65 g., wheat germ 40 g., NaCl 10 g., salt mixture 10 g. The salt mixture was made up of nine parts CaCO_3 and one part ferric citrate.

All experimental animals were kept in individual cages with raised screen bottoms and were allowed distilled water and the basal diets *ad lib*.

Quantities of papaya greater than 2 g. were weighed on a torsion balance, 2 g. and less on a chainomatic balance. For the vitamin A experiments the supplements of papaya were fed three times a week and the carotene twice a week; these are reported on the basis of daily quantities. For the vitamin B experiments 0.01 g. of the international standard was fed three times a week (0.005 g. daily). All other supplements were fed daily. For all experiments daily feeding means every day except Sunday.

Vitamin A. For the vitamin A experiments young rats were weaned at 20–21 days of age and placed on the following experimental diet: extracted caseinogen [Sherman & Munsell, 1925] 18 %, dried yeast 10 %, salt mixture [Osborne & Mendel, 1919] 4 %, NaCl 1 %, corn-starch 57 %, crisco 10 %, viosterol to supply one part in 40,000 parts of diet.

For the first series of experiments, 26 rats averaging 43 g. in weight were used. The average time for depletion of vitamin A stores was 33 days, the rats then weighed an average of 123 g. Five rats were used as negative controls; the remainder were given daily feeding as follows: 9 rats, 4 units of carotene (1931 international standard) and 12 rats, 0.1 g. of papaya.

For the second series of experiments 26 rats were used which weighed on the average 38 g. The average time for depletion of vitamin stores was 30 days, when the rats averaged 123 g. Three rats were used as negative controls, 12 were fed daily 4 units of carotene, 11 were fed daily 0.2 g. of papaya.

All rats in our colony show slight to severe signs of xerophthalmia when the weight curves flatten or begin to drop. The mild cases become severe if the rats are continued on the basal diet only. Before death all controls show unsteady gait and inco-ordination of the hind legs.

Although the rats fed supplements of carotene or papaya grew well, 60–70 % of each group showed inco-ordination of the hind legs at the end of the 5-week feeding period. The majority of the rats had less yellow pigment in the incisor teeth than normal animals and the teeth of a few were chalky white. At autopsy, pus was found at the base of the tongue as follows: carotene, first series 2 rats, second series 1 rat; papaya, first series 2 rats, second series 3 rats. At autopsy, the female rats uniformly showed good sexual development with many large ripe follicles of the ovaries. The males showed poor sexual development; the testes were under-developed and microscopic examination showed few motile sperms in the cauda epididymis. One rat fed carotene had a bladder with thickened and hemorrhagic walls containing calculi.

The results summarized in Table III and Fig. 1 indicate that papaya contains 2500 units of vitamin A per 100 g., a high value for fruits. Morgan & Madsen [1933] have reported that apricots contain 3300 units of vitamin A or 2000 γ of carotene per 100 g. Yamamoto & Tin [1933] reported that papaya contains no carotene but a pigment which they called caricaxanthin and which like carotene

Table III. *Results of feeding various amounts of papaya to rats as the sole source of vitamins A, B₁ and B₂ (G)*

Vitamin studied and source	Number of rats	Weights of supplements fed daily g.	Average weights			Average gain in 5 weeks g.	Approximate units per 100 g. of papaya
			Initial g.	When supple- ment started g.	Final g.		
Vitamin A:							
Negative control	5	0.0	41	124*	90		2500
Carotene	9	4 units	48	126	206	80	(Inter-
Papaya	12	0.1	43	120	186	66	national
Negative control	3	0.0	41	134*	89		standard
Carotene	12	4 units	38	122	201	79	
Papaya	11	0.2	37	120	225	105	
Vitamin B ₁ :							
Negative control	5	0.0	38	68*	49		8
Standard†	9	0.005	40	70	130	60†	(Inter-
Papaya†	14	6.0	41	72	126	54†	national
Vitamin B ₂ (G):							
Negative control	5	0.0	40	47*	52	5	33
Autoclaved yeast	5	0.1	37	43	67	24	(Bourquin-
Papaya	8	2.0	51	58	66	8	Sherman
Papaya	16	3.0	44	50	67	17	standard)

* Weight at the end of the depletion period.

† All rats in this group fed 6 weeks.

Fig. 1.

Fig. 2.

Fig. 1. Average gain in weight of groups of young rats fed papaya and carotene as the sole source of vitamin A. S=4 units of International Standard carotene. The broken line indicates the occurrence of the first death in the group. The numbers in parenthesis show the number of rats used for each test.

Fig. 2. Average gain in weight of groups of young rats fed papaya and the vitamin B₁ standard as the sole source of vitamin B₁. S=0.005 g. of the International Standard. The broken line indicates the occurrence of the first death in the control group. The numbers in parentheses show the number of rats used for each test.

possesses growth-promoting properties. Karrer & Schlientz [1934] have confirmed the presence of caricaxanthin but point out that it is chemically identical with kryptoxanthin.

Vitamin B₁. For the vitamin B₁ experiments, 28 young rats were weaned at 21–22 days when they averaged 40 g. in weight. They were then placed on the diet recommended by Sherman [1932]. The average time for depletion was 24 days when the rats averaged 71 g. From each litter of rats one or more negative controls were continued on the basal diet only, and two or more positive controls were fed 0.005 g. of the 1931 international standard. Table III and Fig. 2 summarize the results of feeding tests and show that papaya is a poor source of vitamin B₁, containing approximately 8 international units per 100 g.

Vitamin B₂ (G). The method used was essentially that of Bourquin & Sherman [1931] which, according to Bisbey & Sherman [1935] and others [see Munsell, 1936] measures the flavin values. Instead of the alcoholic extract of whole wheat, however, an alcoholic extract of rice bran, or tikitiki, was used to supply vitamin B₁. Whether or not the tikitiki extract contains a factor essential for the rat, as does the alcoholic extract of wheat described by Booher *et al.* [1934], has not been determined.

Thirty-four young rats were placed on the experimental diet at 20–21 days of age when they averaged 44 g. in weight. The average time for depletion was 26 days and the rats then averaged 50 g. Vitamin B₁ was supplied in the form of an extract of tikitiki made in our laboratory (0.1 ml. fed daily: equivalent to 1 g. of rice bran) or 4 drops (0.12–0.13 g.) daily of tikitiki from the Bureau of Science, Manila. From each litter of rats were chosen two or more negative controls which were continued on the basal diet only and two or more positive controls which were fed daily 0.1 g. of autoclaved yeast.

During the experiment and at autopsy the rats showed no lesions or dermatitis, but more than half had some blood on the whiskers and at the base of the whisker follicles. A few had shorter fur than normal, giving a somewhat woolly appearance.

Fig. 3. Average gain in weight of groups of young rats fed papaya and autoclaved yeast as the sole source of vitamin B₂ (G). The numbers in parentheses show the number of rats used for each test. A.Y. = 0.1 g. autoclaved yeast.

Results of the feeding experiments summarized in Table III and Fig. 3 show that papaya is only a fair source of vitamin B₂ (G), containing approximately 33 Bourquin-Sherman units per 100 g.

Vitamin C (ascorbic acid): biological tests. Standard guinea-pigs raised in our laboratory were fed Sherman's [1932] scorbutic basal diet plus fresh alfalfa

plus the supplements until they ate the papaya readily. The alfalfa was then discontinued and the supplements fed to 21 guinea-pigs for 28 days. Two animals were used as negative controls and were fed only the basal diet for 21 days. At the end of the feeding experiments the method for the histological examination of the incisor teeth recommended by Höjer [1926] was employed. The results of the experiments are summarized in Table IV.

Table IV. *Results of feeding papaya to guinea-pigs as the sole source of vitamin C*

Guinea-pig no.	Weight of supple- ment fed daily g.	Period during which supple- ment was fed Days	Weights of animals		Net gain or loss g.	Gross scurvy at autopsy*	Histological examina- tion of teeth, Höjer's rating†
			When supple- ment started g.	At end of experi- ment g.			
323 M.	0	21	303	154	- 149	+++	—†
335 M.	0	21	323	336	13	++	0.0
286 F.	2	28	309	284	- 25	?	0.5
290 F.	2	28	301	397	96	—	1.0
296 F.	2	28	303	375	73	—	0.9
298 F.	2	28	301	331	30	—	0.7
300 F.	2	28	304	410	106	—	1.0
302 F.	2	28	305	375	70	—	0.5
329 M.	2	28	336	458	122	—	1.0
331 M.	2	28	310	401	91	—	1.0
333 M.	2	28	344	370	26	—	0.7
337 M.	2	28	316	411	95	—	0.8
339 M.	2	28	311	406	95	—	1.0
341 M.	2	28	313	397	84	—	1.0
282 F.	3	28	313	359	46	—	1.0
284 F.	3	28	303	340	37	—	0.7
288 M.	3	28	310	339	29	—	0.5
310 F.	3	28	303	344	41	—	0.8
312 F.	3	28	302	385	83	—	0.9
325 M.	3	28	326	462	136	—	1.0
327 M.	3	28	308	423	115	—	1.0
353 M.	3	28	308	279	- 29	—	0.8
355 M.	3	28	323	320	- 3	—	0.9

* Sherman and Smith [1931].

† Höjer [1926].

‡ Histological preparation unsatisfactory.

Of the 12 guinea-pigs fed 2 g. of papaya, only one showed signs of gross scurvy and that case was questionable. Not all the 8 animals fed 3 g. of papaya daily had the teeth completely protected from histological changes. The international standard ascorbic acid was not available when the feeding tests were made, but pure ascorbic acid has since been fed to 10 guinea-pigs in our colony. We find that 0.5 mg. of ascorbic acid per day does not usually protect from gross scurvy; 1.0 mg. always protects from gross scurvy and protects the teeth, according to the Höjer [1926] rating approximately 0.7, somewhat less than 2 g. of papaya. On this comparative basis, the results of the biological tests show an ascorbic acid value of approximately 0.6 mg. per g. of fruit or about 60 mg. per 100 g. of fresh edible papaya. Using the Sherman standard of protection from gross scurvy, it is calculated from the data shown in Table IV that papaya contains 70 Sherman units of vitamin C per 100 g. of fruit, indicating that papaya is an excellent source of vitamin C. Values obtained by chemical methods are given below.

Chemical tests. For the chemical tests ascorbic acid of papaya was determined by the 2:6-dichlorophenolindophenol method as described by Bessey & King

[1933] with slight modifications and the iodine method used by Lorenz *et al.* [1934]. Glass-redistilled water was used throughout, and blanks were run for all methods and modifications.

Both the iodine and 2:6-dichlorophenolindophenol solutions were daily standardized against a pure ascorbic acid solution (Merck Cebione). The stability of ascorbic acid solutions with and without the addition of various acids was determined. Table V shows that the recovery of ascorbic acid up to 3 hours was good if a few drops of glacial acetic acid were added to the solution. This confirms the work of Ahmad & Bashir [1935] and unpublished data of Collins [1936].

Table V. *Percentage recovery of ascorbic acid from redistilled water solutions*

Time hours	Redistilled water only %	Approx. 0.1 % acetic acid %	8 % acetic acid %	8 % tri- chloroacetic acid %
0	—	100.0	99.5	99.6
1	—	99.3	99.8	91.0
2	92.2	—	99.2	80.2
3	91.0	98.2	98.6	75.4
4	90.0	96.8	97.7	72.1
5	87.6	96.8	96.1	70.0
24	72.4	90.1	71.6	14.1

Both the choice of acid and the concentration of acid used for the extraction had definite effects on the quantity of vitamin C extracted from the papaya and its stability after extraction. Table VI shows that hot 8 % acetic acid gave more satisfactory results for the extraction of ascorbic acid than did hot or cold trichloroacetic acid.

Table VI. *Extraction of ascorbic acid from papaya using various acids.*
Titration with 2:6-dichlorophenolindophenol

Expressed as mg. per g. of fresh fruit*

Sample No.	Acid used for extraction	1st extraction mg.	2nd extraction mg.	Total mg.
1	8 % acetic acid (hot)	0.552	0.009	0.561
1	20 % trichloroacetic acid (cold)	0.381	0.135	0.516
1	5 % trichloroacetic acid (cold)	0.476	0.008	0.484
2	8 % acetic acid (hot)	0.569	0.004	0.573
2	20 % trichloroacetic acid (cold)	0.307	0.070	0.377
2	5 % trichloroacetic acid (cold)	0.355	0.019	0.374
2	8 % trichloroacetic acid (hot)	0.444	0.011	0.455

* None of the extracts was treated with H₂S and CO₂.

A number of tests were made to determine the value of treating the extracts with mercuric acetate [Emmerie & van Eekelen, 1934] and/or hydrogen sulphide [McHenry & Graham, 1935] in order to remove interfering substances and to have all the ascorbic acid in the reduced or titratable form [McHenry & Graham, 1935]. Table VII shows that there was a definite increase in titration values after treatment of the solution with hydrogen sulphide and removal with carbon dioxide. The results with mercuric acetate shown in Table VII are unsatisfactory and are similar to those of McHenry & Graham [1935]. Emmerie & van Eekelen [1934] recommend that the extract containing the ascorbic acid be kept overnight in the presence of H₂S but there was so much destruction of the vitamin, especially in trichloroacetic acid solution as illustrated in Sample 1, Table VII, that the subsequent determinations were carried out as stated in the method given below. It was decided to use hydrogen sulphide and carbon

Table VII. *Comparison of the ascorbic acid contents of samples of papaya extracts treated with mercuric acetate and/or hydrogen sulphide and carbon dioxide. Titration with 2:6-dichlorophenolindophenol*

Sample No.	Acid used for extraction	Expressed as mg. per g. of fresh fruit		Extract treated with HgAc ₂ and CO ₂ mg.
		Extract without further treatment mg.	Extract treated with H ₂ S and CO ₂ mg.	
1	10% CCl ₃ COOH (hot)	0.352	0.230*	0.348
	" "	0.367	0.170*	0.400
2	" "	0.463	0.495	0.475
	" "	0.466	0.509	0.483
3	" "	0.584	0.691	0.658
	" "	0.584	0.674	0.663
4	" "	0.472	0.608	0.550
	" "	0.425	0.541	0.530
5	" "	0.298	0.417	0.387
6	8% CH ₃ COOH (hot)	0.340	0.361	—
	" "	0.352	0.376	—
7	" "	0.422	0.435	—
	" "	0.401	0.413	—
8	" "	0.419	0.434	—

* Left overnight in presence of H₂S.

Table VIII. *Recovery of ascorbic acid when added to papaya pulp using various methods*

Extract and method of treatment	Expressed as mg. per g. of fresh fruit				
	Ascorbic acid in sample mg.	Ascorbic acid added mg.	Total ascorbic acid mg.	Ascorbic acid covered mg.	Recovery %
10% CCl ₃ COOH extract (hot) no further treatment	0.298	0.378	0.676	0.603	89.2
10% CCl ₃ COOH extract (hot) treated with H ₂ S and CO ₂	0.417	0.378	0.795	0.702	88.3
10% CCl ₃ COOH extract (hot) treated with HgAc ₂ , H ₂ S and CO ₂	0.387	0.378	0.765	0.682	89.1
10% CCl ₃ COOH extract (hot) no further treatment	0.298	0.378	0.676	0.590	87.2
10% CCl ₃ COOH extract (hot) treated with H ₂ S and CO ₂	0.417	0.378	0.795	0.713	89.7
8% CH ₃ COOH extract (hot) no further treatment	0.340	0.159	0.499	0.511	102.4
8% CH ₃ COOH extract (hot) treated with H ₂ S and CO ₂	0.361	0.159	0.529	0.534	101.0
8% CH ₃ COOH extract (hot) no further treatment	0.419	0.161	0.580	0.572	98.7
8% CH ₃ COOH extract (hot) treated with H ₂ S and CO ₂	0.434	0.161	0.595	0.581	97.6
8% CH ₃ COOH extract (cold) no further treatment	0.422	0.133	0.555	0.534	96.3
8% CH ₃ COOH extract (cold) treated with H ₂ S and CO ₂	0.435	0.133	0.568	0.545	96.0
8% CH ₃ COOH extract (hot) no further treatment	0.442	0.174	0.616	0.608	98.7
8% CH ₃ COOH extract (hot) no further treatment	0.425	0.174	0.599	0.588	98.1
8% CH ₃ COOH extract (hot) treated with H ₂ S and CO ₂	0.698	0.153	0.851	0.855	100.4

Table IX. *Ascorbic acid content of ripe papayas as shown by 2:6-dichlorophenol-indophenol and by iodine titrations using hot 8% acetic acid as extractant*

Expressed as mg. per g. of fresh fruit						
Sample No.	Dye method			Iodine method		
	Ascorbic acid mg.	Variation mg.	Ascorbic acid content average mg.	Ascorbic acid mg.	Variation mg.	Ascorbic acid content average mg.
1	1.164			1.270		
	1.150	0.014	1.157	1.270	0.000	1.270
2	1.072			1.235		
	1.071	0.001	1.072	1.218	0.017	1.227
3	1.027			0.911		
	1.053	0.026	1.040	0.963	0.052	0.937
4	1.008			1.151		
	1.000	0.008	1.004	1.116	0.035	1.134
5	0.922			1.020		
	0.932	0.010	0.927	0.963	0.057	0.992
6	0.790			0.898		
	0.783	0.007	0.787	0.876	0.022	0.887
7	0.763			0.845		
	0.770	0.007	0.767	0.863	0.018	0.854
8	0.760			0.854		
	0.760	0.000	0.760	0.854	0.000	0.854
9	0.745			0.841		
	0.741	0.004	0.743	0.845	0.004	0.843
10	0.698			0.736		
	0.698	0.000	0.698	0.723	0.013	0.730
11	0.656			0.745		
	0.676	0.020	0.666	0.788	0.043	0.767
12	0.659			0.744		
	0.675	0.016	0.667	0.779	0.035	0.762
13	0.660			0.753		
	0.659	0.001	0.660	0.745	0.008	0.749
14	0.648			0.788		
			0.648	0.788		0.788
15	0.635			0.788		
	0.632	0.003	0.634	0.788	0.000	0.788
16	0.616			0.678		
	0.619	0.003	0.618			0.678
17	0.559			0.683		
	0.543	0.016	0.551	0.644	0.039	0.664
18	0.520			0.670		
	0.513	0.007	0.517	0.666	0.004	0.668
19	0.436			0.517		
	0.417	0.019	0.427	0.491	0.026	0.504
20	0.361			0.438		
	0.376	0.015	0.369	0.455	0.017	0.447
Maximum			1.157			1.270
Minimum			0.369			0.447
Average			0.736			0.827
P.E.			0.0321			0.0318
Mean variation	±.005			±.011		

dioxide but not mercuric acetate in the routine determination of the vitamin C content of papayas.

Trichloroacetic acid was not satisfactory either as an extractant or as a preservative of the vitamin in solution (Tables VI and VIII). Because of the stability of ascorbic acid in acetic acid solution and because the recovery of added ascorbic acid from papaya pulp mixed with 8% hot acetic acid was 98% or better, 8% hot acetic acid solution in redistilled water was chosen as the extractant for the ascorbic acid of the papaya.

A representative section of a ripe papaya was mashed thoroughly with a silver fork. A sample of 20 g. was weighed out and quickly mixed with about 20 ml. of hot 8% acetic acid and filtered through glass wool in a funnel containing a small porcelain filter disc. (The glass wool was first washed with the hot acetic acid.) The pulp was washed with successive small quantities of acetic acid until the volume of the filtrate was 100 ml. The green papaya was chopped with a stainless steel knife and ground with acid-washed sand and small quantities of hot 8% acetic acid until the volume of the extract was 100 ml. Hydrogen sulphide was bubbled into 50 ml. of the extract for 10 min. The flask was stoppered tightly and left for $1\frac{1}{2}$ to 2 hours. The hydrogen sulphide was removed by passing washed carbon dioxide through the solution (1– $1\frac{1}{2}$ hours), after which the solution was made up to 100 ml. and aliquots were taken for the dye and iodine titrations. The dye was made up in a phosphate buffer solution of pH 7 [Bennett & Tarbert, 1933] and was standardized daily against pure ascorbic acid. The dye was made up every 4 days and filtered each day.

Table IX shows the quantity of ascorbic acid (vitamin C) in papayas. Except in one instance, the results obtained by the iodine method were higher than those by the dye method, and the differences between the two methods were greater after treatment with H_2S . By the dye method, which is probably the more accurate, the maximum and minimum values were 1.157 mg. per g. and 0.369 mg. per g. with an average of 0.736. Using the iodine method the maximum was 1.270 mg. per g. and the minimum 0.447 mg. per g. with an average of 0.827. The P.E. for the dye titration is 0.0321 and for the iodine, 0.0318. The mean variation between duplicate determinations for the dye method was ± 0.005 and for the iodine method ± 0.011 .

A short series of tests was made to see whether the vitamin C content increased with ripeness. The results shown in Table X for papayas obtained from a

Table X. *Ascorbic acid content of papayas at various stages of ripeness from a single tree*

Description	Expressed as mg. per g. of fresh fruit	
	Dye method mg.	Iodine method mg.
Very green (no yellow in flesh)	0.265	0.315
Green (slight yellow colour in flesh)	0.323	0.402
Slightly green (flesh yellow, but hard)	0.464	0.528
Ripe (flesh yellow and soft)	0.618	0.678

tree on the University campus are clear-cut and indicate that there is a gradual increase in the ascorbic acid as the fruit matures.

The average ascorbic acid value of ripe papaya may be considered to be 0.7 mg. per g. or 70 mg. per 100 g. of edible portion, a value somewhat higher than the biological tests indicate. However, as stated on p. 6, only a small group of guinea-pigs in our colony have been fed ascorbic acid and these were not fed simultaneously with the papaya experiments.

SUMMARY

1. Papayas grown in Hawaii have been analysed for organic nutrients, calcium, phosphorus, iron, chlorine and acid-base balance.
2. Papaya compares favourably with oranges as a source of calcium, basic ash and ascorbic acid.
3. The vitamin C content of papaya increases with ripeness.
4. Average papaya is estimated to contain per 100 g. of edible material, 2500 international units of vitamin A, 8 international units of vitamin B₁, 70 mg. of ascorbic acid (vitamin C) and 33 Bourquin-Sherman units of vitamin B₂ (G).

REFERENCES

- Ahmad & Bashir (1935). *Biochem. J.* **29**, 275.
Association of Official Agricultural Chemists (1930). Official and tentative Methods of Analysis, Ed. 3, 593. (Washington, D.C.)
Bennett & Tarbert (1933). *Biochem. J.* **27**, 1294.
Bessey & King (1933). *J. biol. Chem.* **103**, 687.
Bisbey & Sherman (1935). *J. biol. Chem.* **112**, 415.
Booher, Blodgett & Page (1934). *J. biol. Chem.* **107**, 599.
Bourquin & Sherman (1931). *J. Amer. chem. Soc.* **53**, 3501.
Collins (1936). Personal communication to the authors.
Davidson & LeClerc (1935). *J. biol. Chem.* **108**, 337.
Elvehjem & Hart (1926). *J. biol. Chem.* **67**, 43.
Emmerie & van Eekelen (1934). *Biochem. J.* **28**, 1153.
Höjer (1926). *Brit. J. exp. Path.* **7**, 350.
Karrer & Schlientz (1934). *Helv. chim. Acta*, **17**, 55.
Lorenz, Reynolds & Stevens (1934). "Modified iodine titration of ascorbic acid of citrus juices and its possible application to urine analysis." Calif. Fruit Growers Exchange Research Dept. Read before the food and nutrition section of the Amer. Pub. Health Assoc. at the sixty-third annual meeting in Pasadena, Calif., 6 September 1934.
McHenry & Graham (1935). *Biochem. J.* **29**, 2013.
Miller (1926). *Biochem. J.* **20**, 515.
Morgan & Madsen (1933). *J. Nutrit.* **6**, 83.
Munsell (1936). *J. Home Econ.* **28**, 320.
Osborne & Mendel (1919). *J. biol. Chem.* **37**, 557.
Pope (1930). *Hawaii agric. exp. Sta. Bull.* No. 61.
Rabinowitch (1932). Personal communication to the authors.
Sherman (1932). *Chemistry of Food and Nutrition*, Ed. 4. (New York.)
Sherman & MacLeod (1925). *J. biol. Chem.* **64**, 429.
Sherman & Munsell (1925). *J. Amer. chem. Soc.* **47**, 1639.
— & Smith (1931). *The Vitamins*, Ed. 2. (New York.)
Yamamoto & Tin (1933). *Bull. Inst. phys. chem. Res., Japan*, **12**, 354. Abs. in English with *Sci. Pap. Inst. phys. chem. Res., Tokyo*, **20**, 411.