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Original Article

Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals

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Abstract

Few Micronesian foods have been analyzed for nutrient content. Information is needed on locally grown, culturally acceptable foods that could be promoted to alleviate vitamin A deficiency in the Federated States of Micronesia. Using an ethnographic approach that included key informant interviews and observation, Micronesian cultivars with potential for high-carotenoid content according to their coloration were identified. These cultivars of banana, giant swamp taro, breadfruit and other foods were analyzed for α- and β-carotene using high-performance liquid chromatography (HPLC) and for nine minerals using inductively coupled plasma (ICP). A wide range of provitamin A carotenoid levels was found in banana, taro, and breadfruit cultivars, some containing very high levels (β-carotene content from 515 to 6360 μg/100 g in banana, 260 to 1651 μg/100 g in taro, and 295 to 868 μg/100 g in breadfruit, edible portion). Other cultivars contained moderate levels, but as they can be eaten in large quantities, they may contribute significantly to vitamin A status. The taro samples contained very high levels of zinc (mean 5.9 mg/100 g) and significant levels of other minerals (mean content of calcium was 120 mg/100 g). These staples with cultural acceptability and high availability potentially could play a role in vitamin A, micronutrient, and chronic disease programs in the Pacific.

Keywords: Banana; Taro; Breadfruit; Cultivars; α-carotene; β-carotene; Zinc; Minerals; Vitamin A deficiency; Micronesia; HPLC; ICP

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1. Introduction

Effective, culturally appropriate food-based strategies are essential for sustainable solutions to alleviating vitamin A deficiency (VAD) and micronutrient malnutrition (Kuhnlein & Pelto, 1997; Combs, Welch, Duxbury, Uphoff, & Nesheim, 1996). In addition to the likely economic benefits, advantages of such strategies include empowerment of individuals and households leading to family food production, wise food selection and preparation methods, provision of multiple nutrients simultaneously (Ruel, 2001) and an enhancement of cultural pride and identity. However, food composition data is needed to identify local foods to promote and preliminary community data is needed to determine the acceptability of those foods (Kuhnlein & Nieves, 1992).

VAD is a serious problem in the four island states of the Federated States of Micronesia (FSM): Chuuk, Kosrae, Pohnpei, and Yap (Centers for Disease Control and Prevention, 2001; Lloyd-Puryear, Humphrey, West, Aniol, Mahoney, & Keenum, 1989; Lloyd-Puryear et al., 1991), and in some other Pacific countries (Ross & Trowbridge, 1994; Schaumberg et al., 1995; Palafox, 1995). Vitamin A deficiency leads to disorders of growth, development, vision, immune systems, and severe cases may lead to blindness and death (McLaren & Frigg, 2001). At the same time, obesity and chronic disease are growing problems for FSM and other Pacific countries (Coyne, 2000), and there is increasing evidence of the role of carotenoids in protection against chronic disease (World Cancer Research Fund, 1997). A recent literature review describes the food and nutrition situation in FSM, where rice and other imported foods are increasingly replacing the consumption of locally grown foods (Englberger, Marks, & Fitzgerald, 2003b), and other recent papers (Englberger, 2001; Englberger, Schierle, Marks, & Fitzgerald, 2003c; Englberger, Aalbersberg, Fitzgerald, Marks, & Chand, 2003a) present initial data on analysis of Micronesian foods for carotenoid content.

The purpose of the study was to identify vitamin A-rich foods in FSM with high cultural acceptability and potential for increasing vitamin A status in the population and to help improve the effectiveness of a food-based VAD and micronutrient malnutrition prevention strategy. The focus was on banana, giant swamp taro and breadfruit, which are the most commonly eaten indigenous staple foods in FSM (Fischer & Fischer, 1957; Pollock, 1992).

Samples of foods were analyzed for β-carotene, the provitamin A carotenoid making the largest contribution to vitamin A activity in food (McLaren & Frigg, 2001); for α-carotene, another provitamin A carotenoid; and for nine selected minerals.

2. Methods

In selecting the foods for analysis, the study used an ethnographic approach including key informant interviews, selecting foods with the most potential for contributing to vitamin A status (Kuhnlein & Pelto, 1997; Blum, Pelto, Pelto, & Kuhnlein, 1997; Fitzgerald, 1997). Relevant documents were reviewed to aid in the search for cultivars. Ethnographic fieldwork and sample collection were carried out from September 2000 to February 2002 in Pohnpei and Kosrae.

2.1. Material

Most samples were collected in Kosrae and Pohnpei. As yellow/orange coloration is an indication of carotenoids (Rodriguez-Amaya, 1999), much of the focus of data collection was on yellow-colored food cultivars, those that had the greatest potential for carotenoid content. Due to limited resources and difficulties of sample collection, for cultivars that grew both in Kosrae and Pohnpei, one sample was collected from either Kosrae or Pohnpei. One banana sample was collected in Chuuk, and one ladyfinger banana sample that grows in Kosrae, Pohnpei, and Fiji was collected in Fiji due to the difficulties of transporting it to the laboratory. It was difficult to get some samples, as many food cultivars were rare, seasonal, not marketed, or very infrequently marketed. However, three fruits or corms per composite sample were obtained for almost all samples to provide a sample that represents the food under consideration.

There were no analytical facilities in the island country; thus, frozen samples were prepared and arrangements made for analysis in a laboratory overseas. There was no possibility for air freighting the samples to the laboratory as there were no direct overseas flights, and as samples had to be kept frozen, arrangements were made for hand-carrying samples to the laboratory. There were also considerable difficulties due to quarantine regulations. Thus, due to these logistical issues, and due to the resources available for this study, a single set of analyses of composite food samples was carried out for one time period.

High-quality ripe or mature foods were selected as samples and sample characteristics were documented. Samples were prepared raw or cooked, or both, according to the states in which the foods are normally eaten. The cooking method for the banana samples included boiling or steaming the samples unpeeled in a covered pot for 10 min, and the baked sample was baked 1 h in the traditional earth oven, unpeeled, wrapped in banana leaves. For all boiled samples, the amount of water used was just enough to cover food pieces. The taro samples were peeled, cut in pieces 3 cm thick and 10 cm in diameter depending on corm size, and boiled in a stainless-steel covered pot for 40 min. The raw and cooked breadfruit samples were taken from the same breadfruit, and the cooked samples were boiled unpeeled for 10 min with the lid on. For the seeded breadfruit, seeds were removed. Both raw and cooked seeded breadfruit samples were prepared as this cultivar is eaten raw, as well as cooked. Samples of seeded breadfruit were also prepared with or without the rind, as this cultivar may be eaten in both ways. The cassava was peeled, and fern greens were cut in 1-in lengths, and were boiled for 10 min with the lid on pot. Samples (which weighed 250–400 g per composite sample) were kept frozen in the freezer of a household refrigerator until transporting to the laboratory.

2.2. Sample allotments and transport to laboratory

Samples were sent to the Institute of Applied Sciences, University of the South Pacific (IAS/USP), Suva, Fiji for analysis by high-performance liquid chromatography (HPLC) for α- and β-carotene. As not all samples could be collected, prepared, and transported to the laboratory in the same time period, the samples were analyzed in six allotments from September 2000 to February 2002. Analytic procedures were the same for all allotments. The analysis results guided decisions about which additional food samples to analyze. Frozen samples were hand-carried (continuous

cold chain) to the laboratory. Required quarantine papers were obtained from both the Fiji and FSM quarantine authorities.

A separate set of samples was analyzed concurrently by Roche Vitamins Ltd., Basel, Switzerland (Englberger et al., 2003c). These analyses allowed verification of the carotenoid content by a second laboratory and the opportunity to analyze for other carotenoids. Not all samples prepared for analysis at IAS/USP and Roche Vitamins Ltd. were taken from the same banana bunch, taro corm, or breadfruit, and not all sample transport and storage conditions could be maintained; thus, they cannot be compared as replicate samples, although in many cases, the samples were quite similar.

Another sample set of two cultivars of banana and two cultivars of giant swamp taro were prepared, frozen, and transported (continuous cold chain) to the Atlanta Center for Nutrient Analysis, Food and Drug Administration, Atlanta, Georgia to analyze for nine minerals. The banana samples were steamed unpeeled in a covered pot for 10 min. The taro samples were peeled and boiled in a stainless-steel covered pot for 30 min.

2.3. Chemical analysis

The HPLC analyses, which were carried out by the Institute of Applied Sciences, University of the South Pacific, used standard methods for carotenoid content (AOAC, 1996). Most cultivar samples were composites of two to five fruits or corms. A portion of this composite (5–10 g) was blended for 5 min with 70 cm^3 acetone to which 1 g of magnesium carbonate and 20 g of sodium sulfate were added. The mixture was filtered through a sintered glass funnel. The residue was further extracted with acetone until there was no yellow/green color in the filtrate. The organic layer was evaporated at low temperature and pressure, using nitrogen gas to remove last traces of solvent. The extract was made to an appropriate volume (depending on expected concentration) in a volumetric flask with methanol and filtered through a 0.45 μm HPLC filter paper. An appropriate volume of sample (usually 25 μl) was injected onto a Novapak C18 (3.9 mm internal diameter × 300 mm length) stainless-steel column with C18 guard column. The mobile phase was methanol/tetrahydrofuran (90:10) flowing at 0.5 cm^3/min, using a Waters 510 Model pump. The ultraviolet detector (a Waters 461 spectrophotometer) was set at 450 nm, with α- and β-carotene eluting at about 30 and 32 min, respectively. The areas of HPLC peaks were compared with a series of injected standard concentrations. The concentration of standards was determined by measuring the absorbance of the β-carotene at 463 nm and using Beer's law with a molar absorptivity of 125 893. All analyses were carried out in duplicate with the mean reported (results must vary by less than 10%). Blanks and recovery samples were also run as a quality assurance measure. A set of analyses was accepted if recoveries were in the range 80–120%. The details of the carotenoid analyses are similar in detail to those reported in Englberger et al. (2003a).

The analytical method for mineral content was taken from Official Methods of Analysis (AOAC, 2000), 50.1.15 (984.27), Jarrell Ash ICAP 61E, inductively coupled plasma (ICP) and was carried out by the Atlanta Center for Nutrient Analysis, US Food and Drug Administration, October 2001. A portion of the composite, between 6–10 g, was digested in 50 ml $HNO_3/HClO_4$ (2 + 1) and elements determined by ICP emission spectroscopy. A sample amount was transferred into a 100 ml Kjeldahl flask, and 50 ml HNO_3:$HClO_4$ (2 + 1) with four glass boiling beads was added, and then left to sit overnight in acid. The samples were digested on a heating mantle until

after the reaction of sample with $HClO_4$ was completed. Each digested sample was transferred to a 50 ml volumetric flask and diluted to volume with H_2O. The final acid content of the samples was ca. 20% $HClO_4$. Elemental determination was accomplished by ICP emission spectroscopy. Calibration of instrument was done through the use of known calibration standards.

2.4. Comparison of carotenoid content of the foods analyzed

From the results of the HPLC analyses for the provitamin A activity of the different foods analyzed, comparisons were made as to the contribution that the different foods and food cultivars might have on meeting the estimated vitamin A requirements (FAO/WHO, 1988). The β-carotene equivalent value was calculated for each cultivar by adding the β-carotene content and half of the α-carotene content. The retinol equivalent (RE) was then calculated as one-sixth of the β-carotene equivalent value, according to the conversion factor 6 μg β-carotene to 1 μg retinol, as advised by the Food and Agriculture Organization/World Health Organization (FAO & WHO, 1988). The potential impact of the local FSM foods was then calculated, using the amounts commonly eaten in daily food patterns and comparing to the estimated vitamin A requirement in RE. The retinol activity equivalent was also calculated for each food, using the newly advised conversion factors 12:1 for β-carotene equivalents (US Institute of Medicine, 2001).

3. Results and discussion

The results of the samples analyzed by Roche Vitamins Ltd., Basel, Switzerland, March 2001, are presented in Englberger et al. (2003c), and can be compared to these results. There was in general an excellent agreement between the two sets of analyses.

3.1. Carotenoid content

Tables 1–4 present the α- and β-carotene content, color of edible portion, if sample was raw or cooked, and other relevant data for the respective food cultivars of banana, giant swamp taro, breadfruit, and other foods.

In most foods, β-carotene levels were higher than α-carotene levels (see also, e.g., Rodriguez-Amaya, 1999). Levels of α-carotene were generally higher in the samples with high β-carotene levels.

3.1.1. Banana

Table 1 presents the carotenoid content and flesh color of the 13 banana cultivars analyzed. Eight were found to have β-carotene levels greater than 525 μg/100 g edible portion, which is 25 times the β-carotene level found in bananas analyzed in the United States (US) and the United Kingdom (UK) (21 μg/100 g) (Holden et al., 1999; Holland et al., 1991). Although those bananas are not documented by cultivar name, they are most likely *cavendish*, the primary banana cultivar marketed globally (International Network for the Improvement of Banana and Plantain, 2001a; Holden et al., 1999; Holland, Welch, Unwin, Buss, Paul, & Southgate, 1991). Reports on bananas elsewhere showed low ranges of carotenoids (West & Poortvliet, 1993). In our study, both laboratories identified the same five banana cultivars with β-carotene levels greater than

Table 1
Carotenoid content of selected cultivars of ripe Micronesian banana (μg/100 g edible portion)

Scientific name[a]	Local name	Source	Color of raw flesh	Raw or cooked[b]	n[c]	β-carotene	α-carotene	β-carotene equivalents	RE[d]	RAE[e]
Mt	*Uht en yap* (2nd analysis)[f]	Pohnpei	Orange	Baked	4	6360	1472	7096	1183	591
Mt	*Uht en yap* (1st analysis)	Pohnpei	Orange	Baked	4	5860	946	6333	1056	528
Ms	*Usr wac*	Kosrae	Orange	Boiled	5	2082	677	2421	404	202
Ms	*Uht ipali*	Pohnpei	Orange	Boiled	2	1181	546	1454	242	121
Mt	*Uht karat*	Pohnpei	Yellow-orange	Steamed	5	918	296	1066	178	89
Mt	*Uht karat*	Pohnpei	Yellow-orange	Raw	5	578	226	691	115	58
Ms	*Usr wac es sie*[g]	Kosrae	Yellow-orange	Steamed	3	686	345	859	143	72
Ms	*Usr wac es sie*[g]	Kosrae	Yellow–orange	Raw	3	309	258	438	73	37
Ms	*Usr taiwang* (wild)	Kosrae	Yellow	Raw	3	662	383	854	142	72
Ms	*Usr taiwang* (common)	Kosrae	Yellow	Raw	3	571	364	753	126	63
Ms	*Usr kuria*[g]	Kosrae	Yellow	Steamed	3	653	478	892	149	74
Ms	*Usr kuria*[g]	Kosrae	Yellow	Raw	3	218	165	301	50	25
Ms	*Usr macao*	Kosrae	Yellow–orange	Boiled	3	589	377	778	130	65
Ms	*Uht akatan*	Pohnpei	Yellow	Steamed	4	515	515	773	129	64
Ms	*Uht akatan*	Pohnpei	Yellow	Raw	3	227	171	313	52	26
Ms	*Usr in yeir*	Kosrae	Yellow	Raw	3	421	214	528	88	44
Ms	*Usr in yeir*	Kosrae	Yellow	Boiled	3	360	198	459	77	38
Ms	*Uht en kerinis*[g]	Pohnpei	Yellow	Raw	3	310	210	415	69	35
Ms	*Marech*[g]	Chuuk	Yellow	Raw	1	189	86	232	39	19
Ms	*Usr fiji/uht en fiji*[h]	Fiji	White	Raw	16	56	42	77	13	6

Note: HPLC analysis in six allotments November 2000–April 2002, Institute of Applied Sciences, University of the South Pacific, Suva, Fiji.

[a] *Mt—Musa troglodytarum*, *Ms—Musa* spp.

[b] Details on the cooking methods are provided in the Methods section.

[c] Number of fruits in one composite sample.

[d] Retinol equivalents (conversion factor 6:1 from β-carotene equivalents to RE).

[e] Retinol activity equivalents (conversion factor 12:1 from β-carotene equivalents to RAE).

[f] The *uht en yap* was analyzed a second time from the same sample for the purpose of verification of high carotenoid content.

[g] Banana cultivars analyzed for the first time in this study, and were not analyzed in the earlier study (Englberger et al., 2003c).

[h] *Usr* fiji and *uht* en fiji are Kosrae and Pohnpei names for the ladyfinger cultivar introduced from Fiji. This sample was collected in Fiji due to difficulties of transporting to the laboratory, and was included in this study for purposes of comparison of carotenoid content with the yellow-fleshed bananas.

525 μg/100 g. Both ranked the top four banana cultivars similarly as to the highest content of β-carotene (Englberger et al., 2003c).

In order to confirm the very high-carotenoid content of the first analysis of the *uht en yap* banana, a second analysis was carried out providing similar results. The mean β-carotene value of the two analyses was over 250 times the β-carotene level of the common banana in the US and UK. The edible flesh of the *uht en yap* had the deepest coloration of all bananas and was orange-colored, similar to a ripe mango. The *uht en yap* and *uht karat* bananas are classified as *Musa troglodytarum* cultivars, also known as Fe'i bananas of the Australimusa division, which are distinctive in that the bunches grow erect (International Network for the Improvement of Banana and Plantain, 2001b). Both banana cultivars have become rare in FSM in recent years and in Kosrae are considered as an endangered species (Josekutty, Kilafwasru, George, & Cornelius, 2002).

Five sets of banana cultivars were analyzed in both raw and cooked forms. The type of cooking was steaming (four sets) and boiling (one set). A higher content of carotenoid was generally found in the cooked samples, which has been found elsewhere (Kumar, Aalbersberg, English, & Ravi, 2001; Renqvist, De Vreeze, & Evenhuis, 1978) and might be explained by the greater ease with which carotenoids are extracted from cooked samples (Rodriguez-Amaya, 1999). However, the water content of the raw and cooked samples was not analyzed and thus exact comparison on a dry-weight basis is not possible. In general, steaming has little effect on moisture content of starchy staples and boiling adds moisture. Therefore, it is likely that the increased carotenoid values were not due to concentration effects due to moisture loss during cooking.

The *usr taiwang* is a common banana in both Pohnpei and Kosrae and grows very easily. Because of its ready availability it has low status and is often fed to the pigs. Some people also reported that they thought they would get worms from eating the ripe raw banana. On the other hand, that cultivar was well-liked for its sweet taste. Key informants stressed their belief that if people's awareness could be raised on the high-carotenoid levels, the status of the *taiwang* banana could be raised and consumption would increase. *Uht akatan* and *usr fiji* cultivars are popular dessert bananas, commonly eaten raw and cooked, and are not rare, although they are not always available at produce markets. All the other banana cultivars are presently rare in FSM, although in the past some were more common, such as the *uht karat* (known as *usr kulasr* in Kosrae), which was said to have been the most common banana in Kosrae in the 1820s (Ritter & Ritter, 1982). Key informants explain that these bananas have become rare due to neglect, greater care needed in comparison to some newly introduced cultivars, and lack of a market demand.

Four yellow-fleshed banana cultivars (*usr wac es sie, usr kuria, uht en kerinis,* and *marech*) were analyzed in addition to those analyzed in the earlier study (Englberger et al., 2003c). The *marech* is among those banana cultivars in Chuuk that are commonly called the medicine bananas, as they are known to have health benefits (Merlin & Juvik, 1996).

3.1.2. Giant swamp taro

Table 2 presents the carotenoid content of the boiled taro and the color of the edible raw corm of the eight giant swamp taro cultivars analyzed. Five of the six yellow-colored cultivars had high-carotenoid levels, two with very high levels. It is likely that there was some carotenoid loss in the cooked *fanal* sample, as the raw sample had a high level (Englberger et al., 2003c). As expected, the two cultivars with off-white-colored corms had low levels of carotenoid. Some farmers explained that the yellow-colored cultivars were highly acceptable in comparison to the

Table 2
Carotenoid content of selected cultivars of Micronesian giant swamp taro (μg/100 g edible portion)

Local and scientific name[a]	Source	Sample details	Color of raw corm	Cooking method[b]	n[c]	β-carotene	α-carotene	β-carotene equivalents	RE[d]	RAE[e]
Pasruk siminton	Kosrae	From two areas Tafunsak, Utwe	Yellow	Boiled	2	1651	484	1893	316	158
Pasruk siminton	Kosrae	From one area Malem	Yellow	Boiled	1	692	266	825	138	69
Pasruk kirngesi	Kosrae	Older corm from one area Utwe	Yellow	Boiled	1	1133	624	1445	241	120
Pasruk kirngesi	Kosrae	Young corms from Malem area	Yellow	Boiled	3	314	271	450	75	38
Pasruk kirngesi	Kosrae	From two areas Lelu, Utwe	Yellow	Boiled	2	296	169	381	64	32
Pasruk wasrwasr	Kosrae	From one area Malem	Yellow	Boiled	2	484	400	684	114	57
Pasruk fukeh	Kosrae	From two areas Tafunsak, Utwe	Yellow	Boiled	3	473	279	613	102	51
Mwang medel	Pohnpei	From one area Utwe	Yellow	Boiled	3	347	269	482	80	40
Pasruk tepat	Kosrae	From one area Utwe	Creamy	Boiled	3	260	80	300	50	25
Pasruk ebon	Kosrae	From one area Malem	Creamy	Boiled	1	85	71	121	20	10
Mwang fanal	Pohnpei	From one area Palikir	Yellow	Boiled	3	73	39	93	16	8

Note: HPLC analysis in three allotments November 2000–July 2001, Institute of Applied Sciences, University of the South Pacific, Suva, Fiji.

[a] The local names in Kosrae are hard taro or *pasruk* and in Pohnpei, giant taro and *mwang*. These all refer to giant swamp taro, scientific name: *Cyrtosperma chamissonis*.

[b] Details on the cooking methods are provided in the Methods section.

[c] Number of corms in composite sample.

[d] Retinol equivalents (conversion factor 6:1 from β-carotene equivalents to RE).

[e] Retinol activity equivalents (conversion factor 12:1 from β-carotene equivalents to RAE).

white-colored, and that they would have planted more of the yellow-colored if they had known that they provided health benefits.

Giant swamp taro, *Cyrtosperma chamissonis*, should be distinguished from common taro, *Colocasia esculenta*, and other types of taro (Englberger et al., 2003c; Secretariat of the Pacific, Malolo, Matenga-Smith, & Hughes, 1999). Giant swamp taro is a special food for atoll islands. It can withstand more saline soils and can be stored in the soil on the plant for over 10 years and remain edible. It is not seasonal and thus provides food security between breadfruit seasons and in times of typhoons and droughts. Although now rice is also commonly eaten, it is sometimes less available due to irregular shipments to the remote islands. As a result, giant swamp taro is still an important survival food on those islands. Giant swamp taro requires more work to grow and prepare (cooking time is 1–3 h) and, according to some key informants, has a less desirable taste in comparison to common taro.

3.1.3. Breadfruit

Table 3 presents carotenoid content and flesh color of the seven cultivars of the breadfruit analyzed. Past Pacific studies had not analyzed ripe breadfruit, but focused on mature breadfruit, as breadfruit is mostly eaten in that state. Mature breadfruit has a creamy colored edible flesh and has low levels of carotenoid (23–40 μg/100 g) (Aalbersberg, Lovelace, Madhoji, & Parkinson, 1988; Dignan, Burlingame, Arthur, Quigley, & Milligan, 1994). In FSM, many people also cook and eat breadfruit at the ripe soft sweet stage, which has a more yellow-colored flesh and a slightly fermented taste desired by many. Despite the yellow color of the ripe breadfruit samples, most were found to have low levels of provitamin A carotenoid.

However, the peeled cooked *mei kole* breadfruit, *Artocarpus mariannensis,* a particularly yellow-colored seeded breadfruit, had high levels of carotenoid content (868 μg/100 g). The same cultivar when raw and unpeeled had medium levels. Although this cultivar is commonly eaten on the atoll islands and is prized as a delicious dish, it was not common on Pohnpei. Key informants in Kosrae reported that it used to be commonly eaten in the past, but is now rare.

3.1.4. Other foods

Table 4 presents carotenoid content and color of edible portion of three other foods: false durian, cassava, and bird's nest fern. False durian, *Pangium edule,* which is a wild food both in Kosrae and Pohnpei, had low levels of carotenoid. The analysis of the two cassava samples showed that the level of carotenoid in the yellow cassava was low, and the level in the white cassava was minimal. The content of α- and β-carotene in the bird's nest fern, which grows commonly throughout FSM and is eaten in Yap as a dark green leafy vegetable, was also minimal.

3.1.5. Quantity eaten per day and impact of high-carotenoid FSM food cultivars on nutrient requirements

The amount of local starch foods (such as banana, taro, or breadfruit) eaten traditionally by a Pacific islander is estimated at around 750–1000 g daily (Malolo et al., 1999). Ripe banana, mature giant swamp taro, and ripe breadfruit are often cooked and eaten as a main part of the meal in FSM. Thus, using these estimations for the amounts that may be commonly consumed, it is possible to look at the potential impact of the local FSM foods on meeting vitamin A requirements.

Table 3
Carotenoid content of selected cultivars of Micronesian breadfruit (μg/100 g edible portion)

Scientific name[a]	Local name	Source	Maturity[b]	Color of raw flesh	Raw or cooked[c]	Rind	n[d]	β-carotene	α-carotene	β-carotene equivalents	RE[e]	RAE[f]
Am	*Mei kole*	Pohnpei	Ripe	Yellow	Boiled	Without	3	868	142	939	157	78
Am	*Mei kole*	Pohnpei	Ripe	Yellow	Boiled	With	2	661	96	709	118	59
Am	*Mei kole*	Pohnpei	Ripe	Yellow	Raw	Without	1	317	75	355	59	30
Am	*Mei kole*	Pohnpei	Ripe	Yellow	Raw	With	1	295	37	314	52	26
Aa	*Mei uhpw*	Pohnpei	Ripe	Creamy	Boiled	Without	1	154	<5	157	26	13
Aa	*Meitoal*	Pohnpei	Ripe	Yellow	Boiled	Without	3	27	6	30	5	3
Aa	*Mos parkas*	Kosrae	Ripe	Yellow	Boiled	Without	3	7	8	11	2	1
Aa	*Meisaip*	Pohnpei	Ripe	Yellow	Boiled	Without	2	<5	<5	<8	1	1
Aa	*Meiniwe*	Pohnpei	Ripe	Creamy	Boiled	Without	3	<5	<5	<8	1	1
Aa	*Mei kalik*	Pohnpei	Ripe	Creamy	Boiled	Without	2	<5	<5	<8	1	1
Aa	*Mar*[g]	Pohnpei	Mature	Creamy	Raw	Without	[g]	<5	<5	<8	1	1

Note: HPLC analysis in four allotments November 2000–July 2001, Institute of Applied Sciences, University of the South Pacific, Suva, Fiji.

[a] *Am—Artocarpus mariannensis* (seeded breadfruit); *Aa—Artocarpus altilis* (unseeded breadfruit).

[b] Ripe refers to the ripest edible soft stage. Mature refers to the edible green hard stage.

[c] Details on the cooking methods are provided in the Methods section.

[d] Number of corms in composite sample.

[e] Retinol equivalents (conversion factor 6:1 from β-carotene equivalents to RE).

[f] Retinol activity equivalents (conversion factor 12:1 from β-carotene equivalents to RAE).

[g] Fermented breadfruit made from raw mature peeled unseeded breadfruit (*mei pedahk* cultivar) and kept in a covered plastic container. The sample was of the uncooked fermented breadfruit material, made from a composite of breadfruit.

Table 4
Carotenoid content of other selected Micronesian foods (μg/100 g edible portion)

Scientific name	English and local name	Source	Plant part	Color of edible portion	Maturity	Raw or cooked[a]	n[b]	β-carotene	α-carotene	β-carotene-equivalents	RE[c]	RAE[d]
Pangium edule	False durian, *duhrien*	Kosrae	Fruit	Yellow	Ripe	Raw	3	189	15	197	33	16
Manihot esculenta	Cassava, *tapioka*	Kosrae	Roots	Yellow	Mature	Boiled	1	104	138	173	29	14
Manihot esculenta	Cassava, *tapioka*	Kosrae	Roots	White	Mature	Boiled	1	<5	<5	<8	1	1
Asplenium nidus	Bird's nest fern, *tehnlik*	Pohnpei	Shoots	Pale green	Young	Boiled	12	<5	<5	<8	1	1

Note: HPLC analysis in two allotments July 2001 and March 2002, Institute of Applied Sciences, University of the South Pacific, Suva, Fiji.
[a] Details on the cooking methods are provided in the Methods section.
[b] Number of fruits, roots, or shoots in one composite sample.
[c] Retinol equivalents (conversion factor 6:1 from β-carotene equivalents to RE).
[d] Retinol activity equivalents (conversion factor 12:1 from β-carotene equivalents to RAE).

If a non-pregnant non-lactating woman ate 500 g in a day (which is approximately two cups and is within the levels of normal eating patterns) of one of the following, she would be able to obtain her total requirement of 500 μg REs: cooked *uht en yap, usr wac, uht ipali, uht karat, usr wac es sie, usr kuria, usr macao, uht akatan,* or raw *taiwang* banana; *siminton, kirngesi, wasrwasr, or fukeh* giant swamp taro; *mei kole* breadfruit. In addition to those cultivars, two other cooked or raw banana cultivars and two other giant swamp taro cultivars would provide half or more of her requirement if she ate the same quantity. A further cultivar of banana would provide over half her requirement if she ate 750 g in a day (still within the levels of normal consumption).

A similar comparison for a 2–5-year-old child shows that the child could obtain the total vitamin A requirement of 400 μg REs (FAO & WHO, 1988), by eating 250 g in a day (a quantity commonly reported for children of those ages) of: cooked *uht en yap, usr wac, uht ipali,* or *uht karat* banana; cooked *siminton* or *kirngesi* giant swamp taro; *mei kole* breadfruit. A further six cultivars of cooked or raw banana cultivars and four cultivars of giant swamp taro would provide half or all the child's requirement if 500 g (also within normal eating patterns) were eaten.

However, studies on bioavailability of these foods have not yet been carried out. Thus, further study is needed to confirm the contribution of these foods to meeting vitamin A requirements.

3.1.6. Relationship of color of banana, taro, and breadfruit edible portion to carotenoid content

In general, the carotenoid levels in banana samples increased with an increasing intensity of banana flesh coloration, from white to yellow to yellow–orange to orange, as determined by visual comparison (Englberger et al., 2003c). Also, carotenoid content of the raw edible taro corm was greater in the taro with yellow-colored corms compared to the creamy-colored corms, although color gradations were not as distinct. The same corm sometimes had streaks of different shades of yellow and coloration (and carotenoid levels). This appeared to vary by area and soil. Once cooked, color differences were less distinguishable. Key informants explained that it is difficult to differentiate between cooked taro cultivars.

Coloration of edible breadfruit flesh was not a consistent indicator of carotenoid content. Some ripe breadfruits were yellow colored but had minimal levels of provitamin A carotenoids.

Table 5
Mineral content of selected cultivars of ripe Micronesian banana and mature giant swamp taro (mg/100 g edible portion)

Food Sample[a]	*N*[b]	Iron	Zinc	Calcium	Magnesium	Phosporus	Manganese	Copper	Sodium	Potassium
Banana, *uht karat*[c]	3	0.2	0.3	68.6	27.1	20.7	0.1	0.3	1.5	253
Banana, *uht taiwang*[d]	4	0.1	0	6.5	27.2	17.7	0.4	0.2	0.8	269
Giant swamp taro, *fanal*[e]	3	0.1	7.0	103.0	24.7	15.5	1.6	0.2	52.8	130
Giant swamp taro, *mwashei*[e]	3	0.2	4.8	137.0	23.7	16.7	2.2	0.4	46.4	141

Note: ICP analysis October 2001, Atlanta Center for Nutrient Analysis, US Food and Drug Administration.

[a] Sample, local and scientific name of cultivar, and sample preparation. Samples were collected in Pohnpei, Federated States of Micronesia. Details on the cooking methods are provided in the Methods section.

[b] Number of banana fruits or taro corms in composite sample.

[c] *Musa troglodytarum*.

[d] *Musa* spp.

[e] *Cyrtosperma chamissonis*.

On the other hand, seeded breadfruit, which is particularly yellow, had a high provitamin A carotenoid content.

3.2. Mineral content

Table 5 presents the mineral content of nine minerals for two cultivars of banana and two of giant swamp taro.

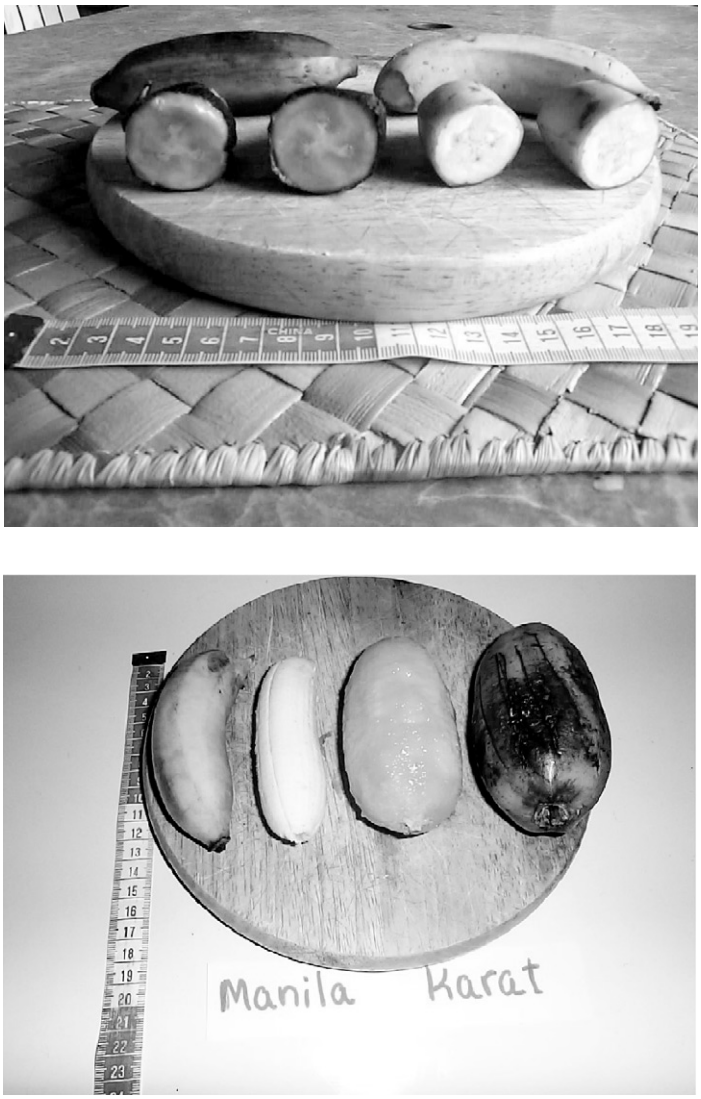

Photo 1. Ripe raw banana, *uht en yap* (top left), *usr kufafa* (top right), *uht manila* (lower left), and *uht Karat* (lower right) showing color differences of the edible flesh and skin. *Usr Kafafa* and *uht manila* are the Kosrae and Pohnpei names for what is considered as the same banana cultivar.

Photo 2. *Mwang medel* giant swamp taro, unpeeled corm (left), raw slice (middle) and cooked slice (right), showing the color changes after cooking.

The *taiwang* banana was selected for mineral analysis as that banana cultivar had a medium content of carotenoid and is commonly available in FSM. The *uht karat* banana was selected due to its high-carotenoid content and high prestige in the community. The two giant swamp taro cultivars *fanal* and *mwashei* were selected as they had been found to contain a high-carotenoid content and as they are highly acceptable cultivars on the atoll islands of Chuuk (Photos 1 and 2).

The results showed that the *uht karat* banana and the two giant swamp taro cultivars had a high calcium content. If a non-pregnant non-lactating woman would eat 500 g of *uht karat* banana, she would obtain almost half her calcium requirement of 800 mg. If she ate the same amount from either of the taro cultivars, she would get over half the requirement (Dignan et al., 1994). If the same woman ate 750 g (also within normal eating patterns) of either of the taro cultivars, she would be able to get her total calcium requirement. A child of 1–3 years would be able to get over a third of the calcium requirement of 700 mg if 250 g of either taro cultivar would be eaten, but would not be able to obtain significant amounts of calcium from the *uht karat* banana.

The cultivars of giant swamp taro contained a very high content of zinc. If a non-pregnant non-lactating woman ate 500 g of *fanal* taro (about two cups) in a day, she would be able to obtain almost three times her daily zinc requirement of 12 mg (Dignan et al., 1994). If she ate the same amount of *mwashei* taro, she would obtain twice her requirement. A child of 1–3 years age would be able to get almost four times the daily zinc requirement of 4.5 mg (Dignan et al., 1994) if 250 g of *fanal* taro would be eaten, and over two and a half times the requirement with the same amount of *mwashei* taro.

The banana and the giant swamp taro cultivars contained high levels of potassium, whereas the iron content was minimal.

4. Conclusions

This paper supports and extends the findings of an earlier set of analyses (Englberger et al., 2003c) that there is a great range in carotenoid content in Micronesian cultivars of banana, giant

swamp taro, and breadfruit. Some contain very high levels of α- and β-carotene. Color is a good indicator of provitamin A carotenoid levels in banana cultivars, but less so in taro and breadfruit. The findings are of particular importance in the Federated States of Micronesia where these foods are easily grown, highly acceptable, and where high-level carotenoid cultivars could contribute meaningfully to alleviating the high prevalence of VAD and add protection against chronic disease.

Yet, there is an urgent need to promote these locally grown staple foods and high-carotenoid cultivars. They are increasingly being replaced by rice and other imported foods of lower nutritional value. Some high-carotenoid cultivars are becoming rare, and as food habits change, knowledge of local food cultivars is decreasing in the younger generations. In particular, banana with its sweet taste and soft texture is well-suited as infant and child food has been cooked and prepared in various recipes for all population groups in the past.

In addition to the findings on carotenoids, high levels of calcium were found in *karat* banana (68.6 mg/100 g) and in two giant swamp taro cultivars (103–137 mg/100 g). High levels of zinc (4.8–7.0 mg/100 g) were found in the two giant swamp taro cultivars. The taro cultivars can meet an adult woman's total daily requirements for calcium and zinc in normal food consumption patterns. This is the first time, as far as the authors are aware, that cultivars of giant swamp taro have been identified as rich sources of zinc.

Further work is needed in several areas. In light of the benefits of total carotenoids to chronic disease, those banana and taro cultivars identified here as carotenoid-rich should be analyzed for a wide range of carotenoids. Other yellow banana and taro cultivars growing in other parts of the Pacific and other parts of the world should be investigated for their carotenoid content, culturally acceptability, and potential for alleviating VAD. A simple color guide to objectively classify color differences in banana cultivars and their estimated levels of carotenoid values might be developed, as this could help individuals in the community to select those carotenoid-rich cultivars having the most health benefits. Such a guide might also provide a useful research tool for selection of banana cultivars in other parts of the world for carotenoid analysis and for estimation of nutrient content of foods in dietary assessment. Bioavailability of the carotenoid-rich banana and taro cultivars should be investigated to confirm the contribution to VA status. Additional cultivars of giant swamp taro should be analyzed for zinc and calcium to further investigate the content of those minerals in taro and the role that taro could play in protecting against micronutrient malnutrition. Finally, an ethnographic approach to identify carotenoid- and nutrient-rich foods and understanding food beliefs and practices is essential in the development of food-based strategies to alleviate vitamin A deficiency, micronutrient malnutrition, and chronic disease.

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