



Short communication

Provitamin A carotenoid content of different cultivars of edible pandanus fruit

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Abstract

As part of an overall study to identify vitamin A-rich foods, a study was carried out in the Federated States of Micronesia (FSM) to provide information on production, acquisition, consumption and cultural acceptability of edible pandanus cultivars, *Pandanus tectorius*, and to identify their carotenoid content. Samples of five pandanus cultivars were collected and analyzed for α - and β -carotene by HPLC. The results showed that the two cultivars with yellow fruit coloration contained low levels of carotenoids, while the orange fruits, which were also well liked as a food in the community, contained higher levels at maxima of 190 $\mu\text{g}/100\text{ g}$ and 393 $\mu\text{g}/100\text{ g}$ for α - and β -carotene, respectively. Common patterns of intake when the fruit is available show that pandanus can provide a large proportion of estimated requirements of retinol equivalents. Local people were generally unaware that pandanus had health benefits, although the food was very popular. Nevertheless, key informants report that production had greatly decreased in recent years. To reverse this trend, those acceptable cultivars high in carotenoid content should be promoted both for their general enjoyment and their health benefits.

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1. Introduction

Vitamin A deficiency (VAD) has been identified as a problem of public health significance among preschool children in the four states of the Federated States of Micronesia (FSM) (Fig. 1),

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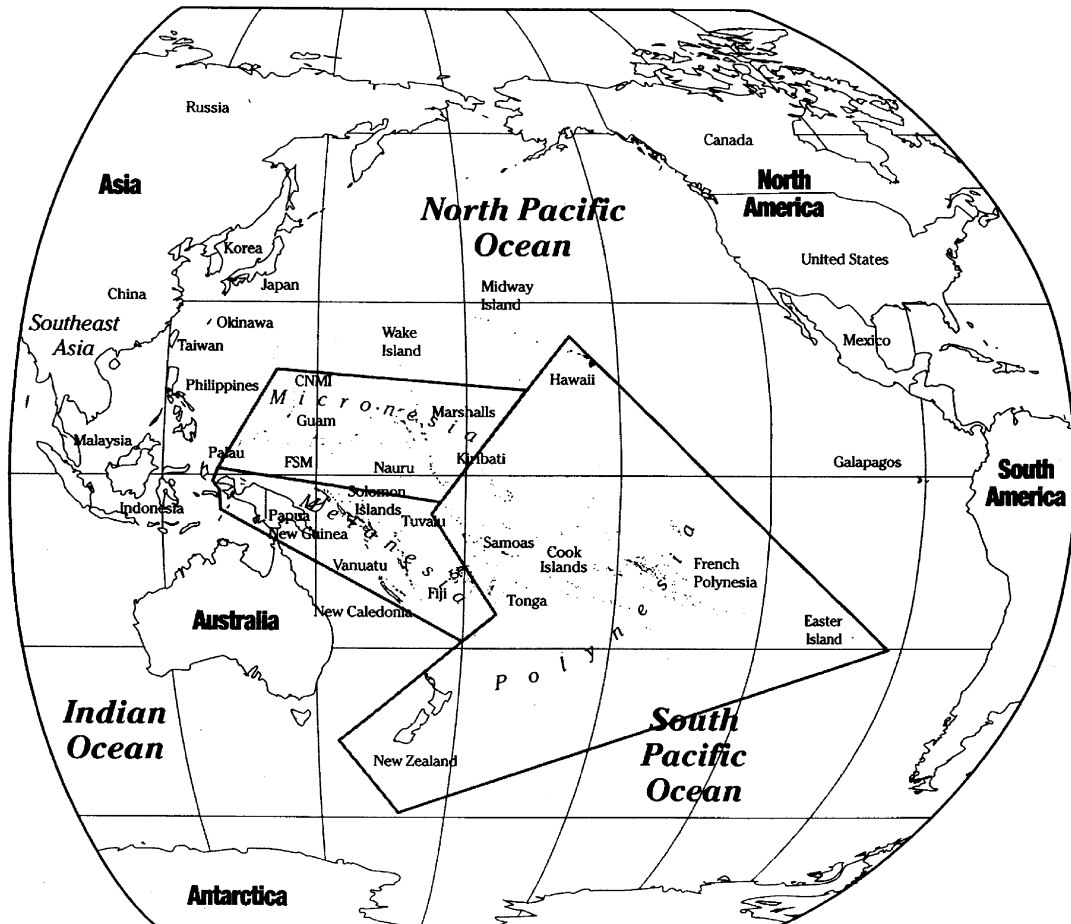


Fig. 1. Map of Micronesia (Close Up Foundation, 2000).

Kosrae, Pohnpei, Chuuk, and Yap (Centers for Disease Control and Prevention, 2001; Lloyd-Puryear et al., 1989, 1991). VAD has also been identified as a public health problem in other Pacific island countries including the Republic of the Marshall Islands (Palafox, 1995), Republic of Kiribati and Solomon Islands (Schaumberg et al., 1995). An understanding of the provitamin A carotenoid content of local foods is essential for planning a food-based approach for eliminating vitamin A deficiency. This includes understanding the acceptability and availability of a vitamin A-rich food and differences between cultivars (Photos 1 and 2).

Edible pandanus, *Pandanus tectorius*, sometimes called “screwpine”, is a fruit unique to certain Pacific islands, particularly atolls, and has been reported as a vitamin A-rich food, based on a few analyses and fruit coloration (Murai, Pen, & Miller, 1958). Yet most cultivars had not previously been analyzed for carotenoid content, and fruits of different cultivars vary greatly in coloration.

Although pandanus is widely distributed in Southeast Asia and the Pacific Islands, there are only a few areas where one finds choice edible pandanus fruit (Miller, 1956). In these areas including the Marshall Islands, Kiribati, and some islands of the FSM, especially Kosrae, and the



Photo 1. Showing color differences of edible slices of *mweng masal srisrik* (orange) and *mweng choipep* (light yellow); edible section of *choipep* key (2nd piece from left), and the inedible outer section of *choipep* key (far left).

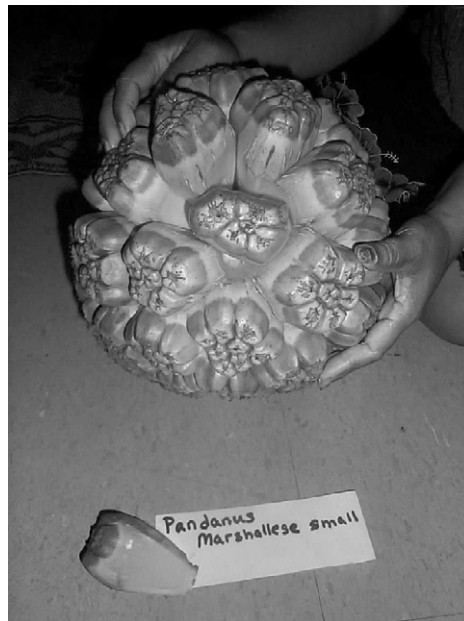


Photo 2. Ripe pandanus *mweng masal srisrik* bunch and key.

outer islands of Pohnpei, pandanus has been a major staple food (Englberger, Marks, & Fitzgerald, 2003b; Hiyane, 1971; Miller, 1956; Miller, 1953; Sarfert, 1919; St. John, 1948; Stone, 1963; Walter & Sam, 1999). Pandanus is also grown and eaten on the islands of Chuuk (Merlin & Juvik, 1996), Yap (Falanruw, 1995; Merlin, Kugfas Keene, & Juvik, 1996), Solomon Islands (Henderson & Hancock, 1988), and Papua New Guinea (French, 1978; Walter & Sam, 1999). Apart from *Pandanus tectorius*, there are other pandanus species, including those in Papua New Guinea which are mainly valued for their edible seeds (French, 1978; Walter & Sam, 1999).

Pandanus is one of the few foods that can be grown on dry, sandy-soiled atoll islands, such as the Marshall Islands, Kiribati, and Pohnpei outer islands (Oliver, 1989; Pollock, 1992; Stone, 1963). Thus, it is particularly important to understand the provitamin A content of the different

cultivars of this species of pandanus and factors affecting its production, in light of the vitamin A deficiency problem in those islands. A carotenoid-rich diet may also contribute to decreased risk of chronic disease (World Cancer Research Fund, 1997), another growing health problem in the Pacific (Coyne, 2000).

Pandanus fruit is a syncarp or multiple fruit, which is sometimes referred to as a bunch, head, or a cone, and is made up of phalanges, also called keys (Hiyane, 1971). The height to which pandanus trees grow depends on the cultivar, some trees growing to 25 feet. The trunk has aerial prop roots, and thus the tree has been called the “walking tree” by some. In addition to the edible fruit of some cultivars, other parts of the pandanus plant are also used. The leaves, which can grow to a length of 3 m and a width of 10 cm, are valued for weaving and roofing material, and the wood is used for building and firewood (Hiyane, 1971).

The keys have an outer hard part, and an inner soft fibrous part which is chewed, sucked, and/or eaten. A few cultivars have a small edible seed in the outer hard part that is eaten. On some islands the fruit is eaten cooked, as well as raw, and a paste and flour are prepared. On the outer island of Pohnpei, Kapingamarangi, in the 1950s, pandanus was preserved by making it into a flour and mixing it later with water as a porridge (Miller, 1953).

There are many cultivars of edible pandanus. The fruits of each are very distinct in appearance and in size, shape and color of the bunch and keys, as well as flavor and water content (Malolo, Matenga-Smith, & Tunidau-Schultz, 2001). In addition to shape, the key has a distinctive appearance by the number of pointed protrusions, groove of the eyes, depth of the visible portion of the key on the bunch, and size of the key in relation to the bunch (Hiyane, 1971). Around 200 pandanus cultivar names have been documented, although some may be synonyms for the same cultivar (Stone, 1963). Not all pandanus fruit are edible. Some have oxalate crystals which produce an irritation to the mouth (Malolo et al., 2001). Edible pandanus must be propagated by cuttings, as any plant grown from the seed reverts to the wild inedible pandanus.

Although Pacific nutritionists have referred to pandanus fruit as a vitamin A-rich food, there appears to be limited information on its nutritional content. We are aware of only five studies. One was a study conducted by a team from the University of Hawaii in the 1950s (Miller, 1956; Murai et al., 1958). That study analyzed carotenoid content for two pandanus cultivars from the Marshall Islands, using a type of column chromatographic method recommended by the Association of Vitamin Chemists in 1951 (Miller, 1956). Both raw and boiled pandanus were analyzed, as well as samples of pandanus paste, flour, and seeds. The two cultivars were presented by their local names *joibeb* and *lojekerer*. There was a great difference in the reported total carotene content of raw samples of the two cultivars, 184 and 1242 $\mu\text{g}/100\text{ g}$, respectively (Miller, 1956; Murai et al., 1958). The second study (Peters, 1958) analyzed one composite of three samples of unspecified pandanus cultivars from Tarawa, Kiribati, described as deep orange in color. That study using the same chromatographic method found 11 μg carotene/100 g for that sample. Peters pointed out the great difference between his findings and that of the Hawaii team and concluded that additional work on pandanus was needed. The Pacific Food Composition Tables present only one entry for pandanus fruit, and gives a provitamin A carotene content of 714 $\mu\text{g}/100\text{ g}$ (Dignan, Burlingame, Arthur, Quigley, & Milligan, 1994), apparently the average of the values of the two pandanus cultivars studied by the Hawaii team. The third study analyzing ripe pandanus fruit was done in 1999 by HPLC analyses at the Covance Laboratories, Madison, Wisconsin. The results indicated a very low content at 20 and 60 $\mu\text{g}/100\text{ g}$ sample of ripe fruit for

α - and β -carotene, respectively (Shovic, 2001; Shovic, A. 1999, pers. comm.). The fourth study of pandanus, which was analyzed at Roche Vitamins Ltd. showed that the sample of ripe pandanus contained 30 and 270 $\mu\text{g}/100$ of α - and β -carotene, respectively (Englberger, Schierle, Marks, & Fitzgerald, 2003c). There were no cultivar names given for either of the last two analyses of pandanus, as the samples were collected on the main island of Pohnpei where pandanus is not a main food and there is no distinction made between cultivar types. All are called by a group name for pandanus, either *deipw* or *kipar* (Raynor, 1991). A fifth study included an analysis of one preserved and one processed pandanus, but no fresh fruit keys (Kumar, Aalbersberg, English, & Ravi, 2001).

In order to provide information for a food-based approach to alleviate the VAD problem in the Federated States of Micronesia, a study was initiated to identify vitamin A-rich foods, and to gain insight on factors affecting the production, acquisition, acceptability and consumption of those foods. A focus was made on the FSM island state of Kosrae. As a part of the overall study, information was collected on different cultivars of edible pandanus, which is a popularly eaten fruit there. Samples were collected and analyzed for carotenoid content by high performance liquid chromatography (HPLC), and information on pandanus grown and eaten throughout FSM was collected. Thus, the purpose of this paper is to present the results of a study on the edible pandanus fruit in the Federated States of Micronesia (FSM), focusing on five cultivars of Kosrae.

2. Materials and methods

Ethnographic methods (Blum, Pelto, Pelto, & Kuhnlein, 1997; Kuhnlein & Pelto, 1997) were used to identify the cultivars of pandanus fruit to be analyzed, and to collect information related to practices and beliefs surrounding the production, acquisition, and consumption of pandanus fruit. Englberger, Fitzgerald, and Marks (2003a) give a description of the ethnographic methods used in the concurrent study, which was part of this study.

2.1. Selection and preparation of samples

All samples were from Kosrae Island and were collected directly from growers. One bunch for each cultivar was collected, and two to four keys per given bunch were collected for the samples and analyzed. The edible part of good quality fully ripe pandanus fruit was cut from the key to make up the samples for analysis. Approximately 10 keys per cultivar were measured to give average sizes. The edible part was weighed to give an average weight per key. The edible portion of the small, medium, and large keys weighed approximately 30, 60, and 75 g, respectively. The keys were 5–10 cm in circumference, respectively, at the larger-size end, and 3–5 cm long, respectively, for the edible portions of the small- and large-sized keys. The cut edible portions were packed in zip-lock plastic bags, and frozen in the freezer of a household refrigerator until transported (continuous cold-chain) to the laboratory.

As pandanus fruit is eaten only in the raw state in Kosrae, only raw samples were analyzed. The samples were prepared and frozen in March 2001. Because no HPLC analytical facilities were available in the country, frozen samples were hand-carried (continuous cold chain) to the

laboratory at the Institute of Applied Sciences, University of the South Pacific, Suva, Fiji. Due to problems in the air services provided between these countries, the samples could only be transported to the laboratory in May 2001. The samples were analyzed in July 2001 for α - and β -carotene. The laboratory setup did not allow for analysis of other carotenoids.

Key informants were asked how many keys they might eat in a day to estimate carotenoid intake in a day from pandanus, and the results of another study that estimated daily consumption of pandanus were reviewed (Miller, 1956, Murai et al., 1958).

2.2. Chemical analysis

Standard carotenoid analysis procedures were followed (AOAC, 1996). Each cultivar sample consisted of a composite of two to four keys. A portion of this composite (5–10 g) was blended for 5 min with 70 cm³ 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 μ m HPLC filter paper.

An appropriate volume of sample (usually 25 μ l) was injected onto a Novapak C18 (3.9 mm internal diameter \times 300 mm length) stainless steel column with C18 guard column. The mobile phase was methanol/tetrahydrofuran (90:10) flowing at 0.5 cm³/min, using a Waters 510 Model Pump. The ultraviolet detector (a Waters 481 Spectrophotometer) was set at 450 nm, with α - and β -carotene eluting at about 30 and 32 min, respectively.

The areas of the 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 samples were run 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 of 80–120%. No corrections based on recoveries were made.

3. Results and discussion

3.1. Carotenoid content and cultivar differences

Table 1 presents the description of the cultivars, cultivar samples, and carotenoid content.

Table 2 presents information on acceptability (taste characteristics), availability, and consumption data for the cultivars.

The results of HPLC analysis showed that there was a great range in carotenoid content between the different cultivars, although all were fully ripe (confirmed by key informants) when collected. The content of β -carotene ranged from 19 μ g/100 g to 393 μ g/100 g in the five cultivar samples. The content of α -carotene ranged from <5 to 190 μ g/100 g in the samples. Carotenoid

Table 1

Carotenoid content of cultivars of ripe raw edible pandanus fruit of Kosrae, Federated States of Micronesia ($\mu\text{g}/100\text{ g}$ edible portion)

Local name	Key size ^a	Color of edible portion	<i>n</i> (keys in sample)	β -carotene ^b	α -carotene
<i>Mweng masal srisrik</i> ^c	Small, narrow	Orange	2	393	157
<i>Mweng masal lulap</i> ^c	Large	Orange	4	334	190
<i>Mweng masal srisrik</i> (new) ^c	Small	Orange	3	211	67
<i>Mweng oa</i>	Small	Yellow	3	87	24
<i>Mweng choipep</i> ^c	Medium	Light yellow	3	19	<5

^a See Table 2 for estimated weights for small, medium, and large keys.

^b Analyses were run in duplicates with the mean reported (results must vary by less than 10%).

^c Cultivars introduced from the Marshall Islands. Names indicate differences in key size and newness to Kosrae.

Notes: HPLC analyses July 2001, Institute of Applied Sciences, University of the South Pacific, Suva, Fiji.

All samples of pandanus fruit were ripe and raw, with the upper part of the pandanus key (that is not chewed) removed.

content was found to be consistently greater in the samples with greater coloration of the edible portions. The fruits with an orange-colored edible portion contained the higher levels, from 211 to 393 $\mu\text{g}/100\text{ g}$ of β -carotene for the ripe sample. Key informants confirmed that the color of the fruits did not seem to vary by location of planting, time of year, or other factor. Additional studies investigating color differences in other pandanus cultivars should be done to confirm this finding. However, it appears that color differences between pandanus fruits are cultivar dependent and can be used to give a rough indication of carotenoid content.

In the earlier study investigating cultivar differences of pandanus, the colors of the edible portion of the two cultivars analyzed were not reported (Miller, 1956; Murai et al., 1958). However, the *joibeb*, which had a very low carotenoid content, appears to be the same cultivar as the Kosrae *choipep* with a different spelling, and which had a light yellow coloration. This gives further confirmation that the yellow-colored pandanus fruit cultivars contain a lower carotenoid content compared to the orange-colored cultivars.

3.2. Quantity eaten per day and impact of pandanus on daily vitamin a requirement

Key informants, selected purposefully for their expert local knowledge of edible pandanus fruit, explained that some people could eat 1–50 keys per day, depending on the amount of pandanus available (there may be 50–100 or more keys on one bunch), and on the characteristics of the keys. If the keys were softer, sweeter, and juicier, more keys could be eaten. In order to further investigate the number of keys that an adult might eat, one female Kosraean adult was asked to count the keys eaten in a day. A *choipep* bunch containing 58 keys was obtained. In one evening, she ate 34 keys, and could have eaten more, but family members consumed the rest. She said that she could eat as many keys from the *masal* cultivars. Other informants said that they could eat all the keys of a bunch in a day, thus showing that consumption of 10–20 keys would not be out of the ordinary.

The edible portion of one key may range from 30 to 100 g, this varying by cultivar and also by the position of the key on the bunch (keys on the very top of the bunch near the stem are smaller and also tougher). If a non-pregnant female adult would consume 20 keys in a day, weighing 65 g/key of the Kosrae *masal lulap* cultivar (see Table 1), she would obtain almost twice her estimated

Table 2

Acceptability (taste characteristics), availability, and consumption data of cultivars of edible pandanus fruit of Kosrae, Federated States of Micronesia

Local name in Kosrae	Acceptability (taste characteristics) ^a	Availability ^b	Bunch size ^c	Key size ^d	Frequency of consumption ^e	Range consumed per day by adult ^f	Range and average consumed per day by child ^g
<i>Mweng masal srisrik</i> ^h	Very sweet, juicy	Common	Large	Small, narrow	Variable	1–50	2–10 (5)
<i>Mweng masal lulap</i> ^h	Sweet, less juicy	Common	Large	Large	Variable	1–50	2–10 (5)
<i>Mweng masal srisrik (new)</i> ^h	Very sweet	Less common	Large	Small	Variable	1–50	2–10 (5)
<i>Mweng oa</i>	Less sweet, fibrous	Rare	Small	Small	Rare	1–25	na
<i>Mweng choipep</i> ^h	Sweet, juicy, crunchy	Common	Medium	Medium	Variable	1–50	2–10 (5)

^a Information obtained from key informants.

^b Little is marketed due to subsistence type of agriculture.

^c Small, medium, and large bunches weighed ~8, 10 and 15 kg; weights taken from bunches weighed at markets and agriculture records.

^d Weight of key with inedible section removed: small, medium, and large keys were ~30, 60, and 100 g. Average weights taken from keys sold at markets and keys obtained from farmers directly. Weight of key also varies greatly within the bunch, smaller at top of bunch and very bottom. Weight of whole key with inedible section: small, medium, and large keys were ~70, 85, and 100 g. Whole key: length 3–5 cm long; 5–10 cm in diameter.

^e Consumption varies according to availability and location on the island. In a 7-day food frequency questionnaire on a randomly selected group of 267 preschool children and 267 caretakers in Kosrae, March 2001, 17 (6%) children and 15 (6%) caretakers consumed pandanus on 3 or more days in 7 days, and 206 (77%) children and 209 (78%) caretakers did not consume any pandanus in 7 days. Cultivars reported included *mweng choipep* and unspecified *mweng masal*.

^f Study in the Marshall Islands over 293 days showed a range of 1–25 pandanus (large keys) eaten per day, with 10 eaten very common (Murai et al., 1958). Key informants in Kosrae said that they could eat 1–50 keys per day and that more keys could be eaten depending on softness, sweetness, and juiciness of the keys.

^g Study in the Marshall Islands over 18 days showed that 9 children, 2–3 years old, ate 2–10 keys per day, averaging 5 keys per day (Murai et al., 1958). Cultivar not specified.

^h Cultivars introduced from the Marshall Islands.

requirement of 500 µg retinol equivalents from pandanus alone, using the conversion factor of 6:1 for β-carotene and 12:1 for α-carotene to retinol equivalents (FAO/WHO, 1988). She would obtain over two-thirds of her total estimated requirement, using the conversion factor of 12:1 for β-carotene and 24:1 for α-carotene to µg retinol activity equivalents (US Institute of Medicine, Food and Nutrition Board, 2001). It is noted that studies have not yet been carried out to provide information on amounts of carotenoid that may be bioavailable from pandanus fruit. Key informants said that an infant of nine months could chew and consume two keys in a day, and that a toddler of around 2 years could chew and consume five.

These estimates of consumption are supported by the observations of Murai et al. (1958) who recorded weekly consumption of pandanus in the Marshall Islands for 324 persons 1 year of age

and older. They found that it was not at all unusual for adults to consume 20 keys in a day; this amount was estimated to cover the entire requirement for vitamin A, niacin, and iron, as well as for half the energy and vitamin C. Murai found that for nine children between 2 and 3 years old studied over 18 days, the average eaten was five keys per day, with the number ranging from two to ten keys per day. Even children 1 year old were found to eat as many as 10 keys per day, when pandanus was available.

Key informants (including local experts from the agriculture department) said that pandanus is available in Kosrae throughout the year.

3.3. Taste and other cultivar-specific differences

Key informants from the community in Kosrae and Pohnpei reported that there was a great difference in the taste of pandanus fruit from cultivar to cultivar, with cultivar-specific differences in sweetness, crunchiness, fibrousness, and juiciness. Informal organoleptic descriptions of the cultivars were collected from local informants, who were not trained with regard to sensory measurements, but who had many years of consuming different cultivars and had expertise in distinguishing between cultivars. The Kosrae cultivar *mweng fienfol* was described as having a very distinctive spicy taste. The Kosrae cultivar *mweng choipep* was described as being crunchier and was very popular as that fruit provided more to eat and had less fibrous strings. It is fortunate that some of the cultivars described as having the best taste are also high in carotenoid content.

3.4. Beliefs and practices

Local people were generally unaware that pandanus had health benefits, although the food was very popular (Englberger et al., 2003a). Nevertheless, key informants report that production had greatly decreased in recent years.

4. Conclusions

This study confirms the logical assumption that pandanus cultivars appear to vary in carotenoid content according to the coloration of the edible portion of the fruit. Certain pandanus fruit cultivars, those with orange-colored edible portions, were shown to contain significant amounts of provitamin A carotenoids and could provide substantial amounts of vitamin A to the diet due to the amount of fruit that may be eaten. Thus, for health benefits, those cultivars with the greater carotenoid content, which also have good taste, should be promoted. The study also provides names of Kosrae cultivars, coloration of edible fruit for each cultivar, and information on acceptability, availability, and consumption. The study suggests that further research of cultivar differences would be important.

This information is particularly important for the Federated States of Micronesia (FSM), as a serious problem of vitamin A deficiency has been identified there. Also, pandanus is one of the few foods that can be grown on atoll islands. Thus, the findings are of particular importance for atoll islands, including those in FSM, and for the Republic of the Marshall Islands, Kiribati, and Solomon Islands, which have many atoll islands and for which vitamin A deficiency has also been identified as a problem of public health significance.

Further studies are needed in three areas: pandanus fruits should be analyzed for other carotenoids, such as β -cryptoxanthin, another provitamin A carotenoid, and for the non-provitamin A carotenoids, lutein and zeaxanthin, in light of the benefits of total carotenoids to chronic disease, which are also of concern to the islands. Cultivars on other island groups should be assessed, further investigating the relationship of coloration of fruit to carotenoid value, and the bioavailability of carotenoids should be investigated to confirm the contribution to VA status.

The study reported here highlights how important it is to include local knowledge, beliefs and practices in studies of this type. This information is important for understanding the cultural and health significance of certain foods and how they can best be promoted in a particular community. Programs to improve vitamin A status are not likely to succeed without the incorporation of such knowledge.

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