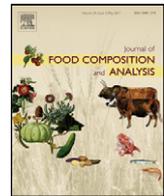




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### Original Research Article

# Carotenoid content and traditional knowledge of breadfruit cultivars of the Republic of the Marshall Islands

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#### ABSTRACT

Vitamin A deficiency (VAD) and non-communicable diseases including cancer, heart disease and diabetes, are serious health problems in the Republic of the Marshall Islands (RMI), a small island nation of the Pacific. These health problems are related to the trend towards over-consumption of unhealthy imported processed foods and neglect of traditional foods. Breadfruit (*Artocarpus altilis* and *Artocarpus mariannensis*) is the most widely available traditional starch food for Marshall Islands people. The ripe fruit flesh is yellow or sometimes orange, as with the *Mejwaan* cultivar, indicative of carotenoid content. Carotenoid-rich foods can protect against VAD and non-communicable diseases. Yet little information on carotenoid content of Marshallese breadfruit cultivars is available. This study documents traditional knowledge of breadfruit cultivars using ethnography, and analyzed 6 breadfruit cultivars of 2 species, *A. altilis* and *A. mariannensis*, for provitamin A ( $\beta$ - and  $\alpha$ -carotene) and total carotenoid content, of using high performance liquid chromatography (HPLC). The ripe seeded breadfruit *Mejwaan* contained strikingly rich concentrations of  $\beta$ -carotene (3540  $\mu\text{g}/100\text{ g}$  fresh weight). Samples of other ripe and mature cultivars, characterized by lighter-colored flesh, contained-medium to low-carotenoid content (<5–102  $\mu\text{g}/100\text{ g}$  fresh weight). As samples were harvested from field-grown plants, it should be noted that the quantity of carotenoids may vary when the same cultivars are planted in different sites. Local experts reported that *Mejwaan* was once common but is now becoming rare, and that people are now consuming its ripe flesh much less frequently; the discovery of *Mejwaan*'s rich carotenoid content should be used to promote this cultivar for its important health benefits.

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## 1. Introduction

The Republic of the Marshall Islands (RMI), a Pacific Island atoll<sup>2</sup> nation where food production is limited, has a serious vitamin A deficiency (VAD) problem (WHO, 2009; Gamble et al., 2001). In a random survey of 919 children from 10 of the 29 RMI atolls, 59.5% of the children showed VAD (Palafox et al., 2003).

VAD disorders involve vulnerability to infection, increased morbidity and mortality, and higher risk of blindness, night blindness, and anemia (McLaren and Frigg, 2001). Where VAD problems exist, it is critical to identify locally grown foods that can minimize them (Kuhnlein and Pelto, 1997). Parasitic infection (in particular helminthiasis), anemia, stunting and underweight have also been shown to be problems among Marshallese children (Hughes et al., 2004).

There have been significant lifestyle changes in the RMI, including urbanization, increasing reliance on imported foods and neglect of traditional foods, and decrease in exclusive and continued breastfeeding, similar to the rest of the Pacific Islands (Alfred, 2003; Coyne, 2000; Hughes and Marks, 2009). This has led to an epidemic of non-communicable diseases (e.g. diabetes, cancer and heart disease) (Government of the Republic of the

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<sup>1</sup> Lois Englberger passed away while editing this paper in 2011; we publish it in memoriam to her.

<sup>2</sup> An atoll is a ring-shaped low-lying coral island or group of islands, often consisting of only a narrow strip of land with seawater on both sides, circling a lagoon. Agriculture is limited due to low rainfall and poor soils.

Marshall Islands and UNICEF, 2003). The dietary shift from locally grown and caught foods to imported processed foods high in fat, sugar and salt is considered to be largely responsible for the deterioration of the nation's health (Government of the Republic of the Marshall Islands and UNICEF, 2003). A study of Ministry of Health records showed that diabetes and diabetes-related illnesses were the number one cause of death from 1996 to 2001 (Government of the Republic of the Marshall Islands and UNICEF, 2003).

Radiation-exposed communities in the RMI have had problems with cancers for many years (Johnston and Barker, 2001). However, a government document states that risk factors for cancer like use of refined and fatty food, tobacco and alcohol, lack of exercise, and increased overweight and obesity have increased cancer rates (WCRF/AICR, 2007; Government of the Republic of the Marshall Islands and UNICEF, 2003).

Foods rich in provitamin A carotenoids, including  $\beta$ -carotene (the carotenoid with the most vitamin A activity) and  $\alpha$ -carotene protect against VAD (McLaren and Frigg, 2001). In addition to provitamin A carotenoids, there are many other carotenoids. Carotenoid-rich foods protect against non-communicable diseases, including certain cancers (WCRF/AICR, 2007), heart disease (Kritchevsky, 1999) and diabetes (Coyne et al., 2005, Ford et al., 1999). An indicator of carotenoid content in foods is yellow or orange coloration of ripe flesh (Rodríguez-Amaya, 1997; Englberger et al., 2003a).

Breadfruit (*Artocarpus altilis* and *Artocarpus mariannensis*) is among the four most important RMI food crops, along with coconut, pandanus and taro (Merlin et al., 1994), and breadfruit is considered the most important locally grown starch food (Reti, 2008). When Marshallese people were asked in a study to name their island foods, breadfruit was the leading food listed (Cortes et al., 2001). Breadfruit is generally consumed in the mature state, before it is ripe and soft. At this stage of maturity, carotenoid content is low because carotenoids develop with ripeness (Rodríguez-Amaya, 1997).

However, in the RMI, breadfruit is also frequently consumed in the ripe stage, and its flesh is yellow, which indicates that it could be a source of carotenoids. In particular, the ripe seeded breadfruit cultivar *Mejwaan* (*A. mariannensis*) has a deep yellow (and sometimes orange) flesh color. In the past it has often been consumed both raw and cooked (Tibon, personal communication, 2011). A study on the nutrient content of Marshallese breadfruit cultivars was carried out in the 1950s, but it did not analyze for carotenoids (Murai et al., 1958). Other studies included the carotenoid content of breadfruit, although only a few assessed ripe breadfruit flesh (Jones et al., 2011; Huang et al., 2000; Englberger et al., 2003a,b; Ragone and Cavaletto, 2006).

A study in Pohnpei, Federated States of Micronesia, situated around 1000 km west of Majuro, showed that a ripe seeded breadfruit cultivar, *Meikole* (*A. mariannensis*), similar to *Mejwaan* with a deep yellow colored edible flesh, contained up to 868  $\mu\text{g}$   $\beta$ -carotene/100 g in fresh breadfruit (Englberger et al., 2003a) and also showed high lutein and total carotenoid concentrations, 750 and 1260  $\mu\text{g}/100$  g, respectively (Englberger et al., 2003b).

Seventeen to 20 cultivars have been documented for the RMI (Ragone, 1988; Merlin et al., 1994) and the Marshallese dictionary lists 8 breadfruit cultivars (Abo et al., 1976). Murai et al. (1958) selected 3 Marshallese breadfruit cultivars (*Petaaktak*, *Bukdoj* and *Mejwaan*) for nutrient analysis; and Ragone (1988) selected the same 3 cultivars for botanical characterization. However, little information has been available on the other Marshallese breadfruit cultivars.

Breadfruit flesh is a good source of vitamin C, with up to 34 mg/100 g in raw *Mejwaan* (Murai et al., 1958). It is also rich in other vitamins, minerals, energy and dietary fiber; and the seed (which is

eaten cooked) is rich in protein (Dignan et al., 2004; SPC, 2006). The cooked dried breadfruit flesh *ma jaankun* (Alfred, 2003) has been shown to be rich in provitamin A carotenoids (Englberger et al., 2007).

Thus, the purposes of this study were to (1) document traditional knowledge relating to production, consumption, and acceptability of breadfruit, and (2) identify carotenoid-rich Marshallese breadfruit cultivars by analysis for  $\beta$ -carotene and  $\alpha$ -carotene, total carotenoids, and water content. An overall aim was to identify cultivars that could be promoted for their health benefits and to collect information that could be used in a breadfruit promotion campaign.

## 2. Methods

Ethnographic methods (Blum et al., 1997; Kuhnlein and Pelto, 1997), similar to those used in other recent studies in the Pacific (Englberger et al., 2009), were used to identify cultivars for analysis and collect information on production and consumption factors and on characteristics of Marshallese breadfruit cultivars. These methods included key informant interviews, informal focus group discussions in a breadfruit workshop setting, observations, photography, literature review and structured collection of breadfruit samples. Ethnographic data on Marshallese breadfruit were collected in two time periods, 2003 and 2010 (Englberger and Jekkein, 2003; Englberger, 2010). Communication with an informal RMI network assisted in data collection and confirmation of data collected.

A sample data collection kit included: a formatted documentation list and interview guide; measuring tape, labeling tape, sample labels, black labeling marker; DSM (formerly Roche Vitamins) Yolk Color Fan; digital camera; vacuum-pack sealing machine (Sunbeam FoodSaver Vac 420/Ultra); and a styrofoam coolbox, gel-ice and newspaper for wrapping and insulating samples to keep them frozen during the long transit to the laboratory.

### 2.1. Material

Due to limited resources, sample collection focused on Majuro Atoll. Prior to sample collection, agriculture officers conducted a pre-survey of breadfruit cultivars in order to identify those farmers who were growing different cultivars of breadfruit. Sample collection was carried out in Laura, the rural area of Majuro Island, where most breadfruit on the island grows, although one rare cultivar Nonnon was obtained from a more urban area, Long Island.

### 2.2. Selection, documentation and preparation of samples

Samples were collected and prepared from July 14–16, 2010, during the height of the breadfruit season. RMI government staff and Laura community members assisted in sample collection; 5–10 individuals were involved in each sample collection, confirming cultivar identification. The collection aimed for 3 good quality fruits per cultivar in order to construct representative composite samples, taking equal portions (about 1/2 cup,  $\approx 100$ –120 g) from each fruit. Abnormally small, large or damaged fruits were excluded. The length and girth were measured on fruits. Fruits were then peeled and cored and only edible flesh was taken for samples, except for *Mejwaan* fruit where the edible peel was included in the sample as this cultivar is sometimes consumed with the skin.

One aim was to collect ripe breadfruit. However, as breadfruits generally fall from the tree when ripe and become damaged, most sample breadfruits had to be harvested at the mature stage and a few did not ripen during the time allotted for the sampling. They

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