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Original Article

Ascorbic acid, vitamin A, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii

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Abstract

Banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars were harvested from different locations throughout Hawaii and analyzed for vitamin C (ascorbic acid), provitamin A (β-carotene, α-carotene, β-cryptoxanthin), and mineral composition. Dwarf Brazilian ("apple") bananas had almost three times more vitamin C (12.7 mg/100 g fresh weight) than Williams fruit (4.5 mg/100 g). Also, Dwarf Brazilian bananas had 96.9 μg β-carotene and 104.9 μg α-carotene/100 g, whereas Williams fruit averaged 55.7 μg β-carotene and 84.0 μg α-carotene/100 g. Bananas contained higher concentrations of lutein than of the provitamin A pigments, α- and β-carotene. Papaya vitamin C content was 51.2 mg/100 g, with no differences among cultivars. Papaya provitamin A carotenoids averaged 232.3 μg β-carotene and 594.3 μg β-cryptoxanthin/100 g, and vitamin A ranged from 18.7 to 74.0 μg RAE/100 g. Lycopene was not detected in the yellow-fleshed cultivars, Kapoho, Laie Gold, and Rainbow, but the red-fleshed Sunrise and SunUp fruit contained 1350–3674 μg lycopene/100 g. Dwarf Brazilian bananas had higher P, Ca, Mg, Mn, and Zn contents than Williams fruit. The average K content for Hawaii's bananas was 330.6 mg/100 g. Papayas (100 g) contained 9% of the dietary reference intake (DRI) for Cu, 6–8% of the DRI for Mg, but less than 3% of the DRI for other minerals.
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Keywords: Banana; Papaya; Carotenoids; β-Carotene; Minerals; Vitamin A; Vitamin C

1. Introduction

Nutritional information is used increasingly by public agencies and agricultural industries to promote fresh produce. Consumers are looking for variety in their diets, and are aware of the health benefits of fresh fruits and vegetables. Of special interest are food sources rich in antioxidant vitamins (vitamins C, A, and E), calcium (Ca), magnesium (Mg), and potassium (K). The 2005 Dietary Guidelines Advisory Committee recommended increasing the dietary intake of vitamins A, C, and E, Ca, Mg, K, and fiber (USDA/HHS, 2004). Most of these nutrient requirements can be met by increasing the consumption of fruits and vegetables to 5–13 servings/day (USDA/HHS, 2004). In addition to meeting nutrient intake levels, greater consumption of fruits and vegetables is associated with reduced risk of cardiovascular disease, stroke, and cancers of the mouth, pharynx, esophagus, lungs, stomach, and colon (Bazzano et al., 2002; Gillman et al., 1995; Joshipura et al., 2001; Riboli and Norat, 2003; WCRF/AICR, 1997).

Many of Hawaii's tropical fruit appear to be good sources of ascorbic acid (vitamin C), β-carotene (provitamin A), Mg, and K. Bananas (*Musa* sp.) and papayas (*Carica papaya*) are consumed widely throughout Hawaii and the Pacific Basin. Bananas contribute about 2.7% of the total K and fiber consumed by the average adult (USDA/HHS, 2004). Papayas are a good source of vitamin C and A. Papaya ranks first among 13–17 fresh fruits for vitamin C content per 100 g edible tissue (Gebhardt and Thomas, 2002; Vinci et al., 1995). However, fruit nutritional analyses rarely consider the effects of cultivar or environment on vitamin and mineral content. For many tropical fruits, nutritional data were compiled from a few samples purchased randomly from retail outlets (Ben-Amotz and Fishler, 1998; Homnava et al., 1990; Setiawan et al., 2001; Vinci et al., 1995; Wenkam, 1990). In these cases, the identity of the cultivar and the location of

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production were unknown. The nutritional composition of a fruit type at harvest can vary widely depending on cultivar, maturity, climate, soil type, and fertility (Lee and Kader, 2000; Mozafar, 1994; Shewfelt, 1990). For example, the ascorbic acid content of different cultivars may differ by a factor of 2–3 or higher in many fruits and vegetables (Mozafar, 1994). Mango cultivars varied by 30-fold in vitamin C content (Wenkam, 1990). Bananas and papayas increase in carotenoid content with maturation and ripeness, but ascorbic acid content can decrease in bananas and increase in papayas during ripening (Lee and Kader, 2000; Wenkam, 1990). Also, ascorbic acid levels in fruit are influenced by the availability of light to the crop and to individual fruits. Even within a cultivar, there is large plant-to-plant variation and within-plant variation in nutrient composition for fruit harvested from the same field (Shewfelt, 1990). Composite samples often reported in the literature mask this variability. A greater number of samples need to be analyzed from different locations to compile more representative nutritional data. Also, some of the cultivars of tropical fruit grown in Hawaii are unique to the islands and have not been analyzed previously.

The availability of reliable fruit composition data is necessary to evaluate diets for nutritional adequacy and to conduct epidemiological research relating diet to health or disease. However, most vitamin A values reported in food composition tables are overestimated, because they are based on methodology in which β-carotene was not separated from other provitamin A carotenoids with lower activity (Granado et al., 1997; Mangels et al., 1993). Most reported vitamin C values are based on old methodology, such as titration, colorimetric, or fluorometric assays (AOAC, 2000; Bajaj and Kaur, 1981; Deutsch and Weeks, 1965; Wenkam, 1990). These methods have limitations in both specificity and sensitivity (Vinci et al., 1995).

Furthermore, the Food and Nutrition Board of the Institute of Medicine (IOM) recently changed the US dietary reference intakes (DRIs) for most nutrients, and set new units for reporting the DRI values for vitamin A (IOM, 2001; Murphy, 2002). The new DRI values assume a 50% lower conversion of provitamin A carotenoids into active retinol by the body. In the United States of America, vitamin A values now are expressed as retinol activity equivalents (RAE), rather than retinol equivalents (RE). Current US DRI values for vitamin A are 900 and 700 μg RAE for adult males and females, respectively (IOM, 2001). The US DRI values for vitamin C are 90 and 75 mg for adult males and females, respectively (Gebhardt and Thomas, 2002; IOM, 2000a).

The interpretation of previous reports of fruit vitamin A content is complicated by the change in units to RAE, differences in methodology for separating and quantifying carotenoids, and inadequate sample size or description. Reports of papaya and banana vitamin A content often were based on β-carotene content, the most active provitamin A pigment. However, papayas contain high amounts of the less active provitamin A pigment, β-cryptoxanthin (Breithaupt and Bamedi, 2001; Kimura et al., 1991; Philip and Chen, 1988), and bananas contain α-carotene (Heinonen et al., 1989). Therefore, the vitamin A values of papayas and bananas may not be accurate in some studies. In addition to vitamin A activity, carotenoids have antioxidant properties. Lycopene, the major pigment in red-fleshed papaya cultivars (Chandrika et al., 2003; Yamamoto, 1964), has important health implications as a potent antioxidant. Lycopene has the highest free radical scavenging ability among the carotenoids, followed closely by β-cryptoxanthin and β-carotene (Miller et al., 1996).

In addition to supplying vitamin A and vitamin C, fruits contribute significant amounts of minerals to the human diet. Minerals are required for normal cellular function, and are critical for enzyme activation, bone formation, hemoglobin composition, gene expression, and amino acid, lipid and carbohydrate metabolism (IOM, 2000b, 2001, 2004). However, mineral values reported in food composition tables often are based on non-representative samples. The mineral composition of fruits can reflect the trace mineral content of soils in a geographic region (Forster et al., 2002), and varies with climate, maturity, cultivar, and agricultural practices. Limited data exist on the mineral content of tropical fruits in relation to these variables. Additionally, Hawaii's volcanic soils may enhance the K, Mg, Fe, or Mn content of fruit grown in the islands.

The objectives of this project were to determine the variability in vitamin C, vitamin A, and mineral content of banana and papaya cultivars grown in different locations throughout Hawaii. Two banana cultivars and five papaya cultivars were analyzed, and samples were collected from plantations on four islands. Fruit from 66 banana plants and 60 papaya plants were harvested to provide estimates of the variation in vitamin A, vitamin C, and mineral content for these tropical fruits. An overall goal was to provide current nutritional information for tropical fruit growers, for the Hawaii Department of Agriculture, and for the USDA National Nutrient Database.

2. Materials and methods

2.1. Fruit sampling

Banana and papaya fruits were harvested from commercial plantations in the Hawaiian islands during 2003 and 2004. Bananas were obtained from seven different plantations located at Keaau, Paukaa, and Pepeekeo on the island of Hawaii; at Waialua and Waimanalo on the island of Oahu; at Kapaa on the island of Kauai; and at Waikapu on the island of Maui. Papayas were harvested from eight plantations at Kapoho and Keaau on Hawaii; at Laie and Waialua on Oahu; at Moloaa on Kauai; and at Waikapu on Maui. Three of the eight papaya plantations were located in Kapoho, the main papaya production region. Fruits were harvested from plantations with soils representing the four orders (Andisols, Histosols, Mollisols, and Oxisols) in the soil classification system that are common in the agricultural areas of the Hawaiian islands (Uehara and Ikawa, 2000). Plantation elevation was measured using an altimeter and recorded. Elevations ranged from sea level to 230 m, but most plantations were below 60 m.

Hands of mature green, fully developed fruit were harvested from the middle of six randomly selected bunches of bananas at each location. Banana growers use the time interval from bunch emergence (about 15 weeks) and the fullness of the fruit as maturity indicators for harvest. For papayas, 2–3 fruits at color break (surface yellowing at the blossom end) to $\frac{1}{8}$ ripe ($\frac{1}{8}$ surface area yellow) were harvested from six randomly selected trees at each plantation. Papayas are typically harvested at the color break to $\frac{1}{8}$ ripe stages for commercial markets. Bananas cultivars sampled included Williams (Cavendish subgroup, *Musa* sp., AAA) and Dwarf Brazilian (Santa Catarina Prata, *Musa* sp., AAB). Dwarf Brazilian bananas are incorrectly called the "apple" banana in Hawaii. Papaya cultivars were the yellow-fleshed Kapoho, Laie Gold, and Rainbow, and the red-fleshed Sunrise and SunUp. Upon returning to the laboratory, banana and papaya fruits were ripened to full yellow color at 22 °C before analysis. Multiple fruits per plant were combined to create composite samples of edible tissue for extraction and analysis (3 fruit/plant for bananas, 2 fruit/plant for papayas). Total soluble solids were measured using a refractometer. Samples (20 g) were weighed, dried in an oven at 50 °C, and reweighed to calculate percent moisture.

2.2. Chemicals

HPLC-grade acetonitrile (ACN) and methanol (MeOH) were purchased from Fisher Scientific (Pittsburgh, PA). Tetrahydrofuran (THF, analytical-grade and HPLC-grade) was purchased from VWR International Inc. (West Chester, PA). Glacial acetic acid and metaphosphoric acid (MPA) were purchased from Fisher Scientific. Ascorbic acid, β-carotene, α-carotene, lutein, lycopene, magnesium sulfate, and sodium sulfate were purchased from Sigma-Aldrich Chemicals Co. (St. Louis, MO). β-Cryptoxanthin was purchased from Indofine Chemical Co. (Hillsborough, NJ).

2.3. Ascorbic acid analysis

Ascorbic acid was extracted (under subdued light) from bananas and papayas by blending 40 g fruit tissue with 100 mL of cold MPA–acetic acid solution (30 g MPA, 0.5 g EDTA, and 80 mL glacial acetic acid diluted to 1 L with distilled water) in a prechilled, stainless-steel blender for 3 min. The slurry was centrifuged for 15 min at 10 000 rpm in a cold centrifuge (2–4 °C), and the supernatant was collected. Samples (5 mL) were passed through C-18 Sep-Paks preconditioned with 2 mL ACN followed by 5 mL distilled water. Duplicate samples were filtered through 0.22 μm membranes into amber HPLC vials. All samples were kept on ice, and HPLC analysis was performed on the same day as extractions. Ascorbic acid was analyzed by injecting 5–15 μL of sample into an Agilent 1100 series liquid chromatograph (Agilent Technologies, Wilmington, DE), with 0.2 M NaH_2PO_4, pH 2.14 as the mobile phase, and a PLRP-S column (2.1 × 250 mm, 5 μm particle size; Polymer Laboratories, Amherst, MA) as the stationary phase, followed by an Agilent diode array detector set at 254 nm (Lloyd and Warner, 1988; Vanderslice and Higgs, 1990). A flow rate of 0.25 mL/min was used, and the run time was 8 min. The thermostatted autosampler and column compartment were set at 4 °C. Ascorbic acid standards ranging from 25 to 100 μg/mL were used for calibration, and sample peaks were identified according to HPLC retention times and absorbance spectra in comparison with authentic standards. For recovery tests, samples were spiked with standard solutions before extraction. The extraction recovery for ascorbic acid from papaya was 97% ± 11 ($n = 5$), and the HPLC minimum detection level was 0.05 μg. Vitamin C values were expressed as mg/100 g edible fresh weight.

2.4. Vitamin A and carotenoid analysis

HPLC was used to separate and quantify the provitamin A pigments (β-carotene, α-carotene, and β-cryptoxanthin), as well as lycopene and lutein. Although lycopene and lutein do not contribute to vitamin A content, they have high antioxidant activity (Miller et al., 1996) and were included in this study. Banana and papaya carotenoids were extracted under low light and cold temperatures. Extractions and analysis were according to modified methods of Bushway and Wilson (1982) and Bureau and Bushway (1986). Papaya (20 g) or banana (30 g) samples were homogenized with a tissumizer for 3 min with 2 g $MgCO_3$, 40 g anhydrous Na_2SO_4, and 75 mL cold THF (stabilized with 0.01% butylated hydroxytoluene). Extracts were vacuum filtered through Buchner funnels with Whatman #4 paper, and the residue was re-extracted with an additional 100 mL THF to remove all carotenoids. For starchy Dwarf Brazilian bananas, a celite filter aid was included over the Whatman #4 paper. Extracts were taken to volume, and a 10-mL aliquot was concentrated under nitrogen gas and stored at −70 °C until HPLC analysis. Before analysis, samples were resuspended in 0.4 mL stabilized THF (HPLC-grade), vortexed, and brought to a final volume of 4 mL with equal amounts of HPLC-grade ACN and MeOH. Duplicate samples were filtered through 0.22 μm membrane filters into amber HPLC vials for injection.

Carotenoids were analyzed by injecting 20 μL of sample into the HPLC, with ACN (85%):THF (12.5%):H_2O (2.5%) as the mobile phase, and an ODS Hypersil C-18 narrow-bore column (2.1 × 100 mm, 5 μm, Agilent Technologies) as the stationary phase. A diode array detector collected signals in the 380–550 nm range, with maximum detection at 454 nm. A flow rate of 0.3 mL/min was used, and the run time was 25 min with a 5 min post-run. The autosampler temperature was set at 4 °C, and the column temperature was set at 40 °C. Standards of β-carotene, α-carotene, β-cryptoxanthin, lycopene, and lutein ranging from 0.5 to 6.0 μg/mL were used for calibration. Concentrations of standards were determined using spectrophotometry and molar extinction coefficients. The extinction coefficient ($E^{1\%}_{1\text{cm}}$) used for lutein in ethanol was 2550 (445 nm), and for β-carotene, α-carotene, β-cryptoxanthin, and lycopene in hexane were 2592 (453 nm), 2800 (444), 2460 (451 nm), and 3450 (472 nm), respectively, (Bauernfeind, 1981; Hart and Scott, 1995). Sample peaks were identified according to HPLC retention times and absorbance spectra (acquired by the photodiode array detector) in comparison with authentic standards. β-Cryptoxanthin esters were identified as the predominant peaks eluting after 10 min, with absorbance spectra matching that of free β-cryptoxanthin (Cano et al., 1996; Mutsuga et al., 2001). Esterification does not change the shape of a carotenoid's absorbance spectrum (Camara and Moneger, 1978). β-Cryptoxanthin esters were quantified using a β-cryptoxanthin standard. Non-esterified and esterified forms of β-cryptoxanthin have similar bioavailability (Breithaupt et al., 2003) and both forms were included in vitamin A calculations. For recovery tests, samples were spiked with standard solutions of β-carotene before extraction. The extraction recovery was $117\% \pm 5$ ($n = 2$), and the HPLC minimum detection level was 0.005 μg. Vitamin A values for bananas and papayas were expressed as μg β-carotene/12 + μg α-carotene/24 + μg β-crypotoxanthin/24, and expressed as μg RAE/100 g edible fresh weight.

2.5. Fruit mineral analysis

Fruit samples (20 g) were dried in an oven at 50 °C and ground with a mortar and pestle at the USDA-ARS laboratory in Hilo, HI. Dried fruit tissue samples were sent to the Agricultural Diagnostic Service Center at the University of Hawaii (Honolulu, HI,) for complete mineral analyses. Fruit mineral analysis was performed using inductively coupled plasma-atomic emission spectrometry (ICP-AES) according to AOAC (2000) official method 985.01. The detection limit was 1 ppb. Prior to ICP-AES analysis, fruit tissue samples were ashed in a muffle furnace at 500 °C and acid extracted (AOAC, 2000; Hue et al., 2000).

2.6. Statistical analysis

Data were analyzed according to a completely randomized design, with six replications for each cultivar at a particular location. A replication consisted of a composite fruit sample from an individual plant. Data were subjected to analysis of variance using the general linear models procedure of SAS (SAS Institute, 1999). Pearson correlation coefficients were determined using SAS to described the relationship between vitamin content and soluble solids content (SSC).

3. Results and discussion

3.1. Ascorbic acid (vitamin C)

Ascorbic acid concentrations were determined for bananas harvested from 66 plants and for papayas harvested from 60 plants throughout Hawaii. Dehydroascorbic acid (DHAA) was not detected, even at 214 nm wavelength. Wills et al. (1984) did not detect any DHAA in bananas, but Wimalasiri and Wills (1983) detected 1.4 mg DHAA/100 g using UV–Vis at 214 nm. Vanderslice et al. (1990) measured 3.3 mg DHAA/100 g in bananas using fluorometric detection, and Nisperos-Carriedo et al. (1992) reported 2.6 mg DHAA/100 g in papayas using a UV–Vis detector. Sensitivity is a problem in the direct measurement of DHAA by UV–Vis detection systems (Gokmen et al., 2000). DHAA can be determined indirectly by measuring total ascorbic acid content before and after reduction of DHAA to ascorbic acid (Gokmen et al., 2000). However, some DHAA measured in fruit tissues may be an artifact of sample processing. Banana and papaya samples were extracted immediately from ripe fruit using cold MPA to minimize oxidation of ascorbic acid to DHAA. All samples were kept on ice, and the HPLC autosampler and column temperatures were set at 4 °C. HPLC analysis was performed on the same day as extractions. Furthermore, any endogenous DHAA may have very low vitamin C activity (Ogiri et al., 2002).

The average vitamin C content for Dwarf Brazilian bananas was almost three times higher (12.7 mg/100 g) than the vitamin C content of Williams fruit (4.5 mg/100 g) (Table 1). Dwarf Brazilian bananas (100 g) would provide 14–17% of the US DRI for vitamin C for the average adult. These results agree with Wenkam's (1990), who reported vitamin C values of 5.1 mg/100 g for Williams and 14.6 mg/100 g for Dwarf Brazilian bananas. Other reports are for Cavendish bananas, and the vitamin C values based on HPLC ranged from 2.1 to 18.7 mg/100 g (Leong and Shui, 2002; USDA-ARS, 2004; Vanderslice et al., 1990; Wills et al., 1984, 1986; Wimalasiri and Wills, 1983).

Most edible bananas are genetic triploids derived from either *Musa acuminata* (A) or *Musa balbisiana* (B), or a combination of both (Nakasone and Paull, 1998). Dwarf Brazilian bananas (*Musa* sp. AAB) have a different genetic make-up than Cavendish varieties (*Musa* sp. AAA); therefore, fruit composition differs between these banana varieties. Dwarf Brazilian fruit are genetically similar to plantains (*Musa* sp. AAB), and had less pulp moisture and SSCs than Williams fruit (Table 1). Wills et al. (1986) compared the nutritional composition of sugar bananas (*Musa* sp. AAB) to Cavendish fruit. Sugar bananas had higher vitamin C, starch, glucose, fructose, and dietary fiber than Cavendish fruit.

Table 1
Mean vitamin C (ascorbic acid), vitamin A, soluble solids, and moisture content of bananas and papayas cultivars grown in Hawaii

Crop	n[a]	Vitamin C (mg/100 g)	Vitamin A[b] (μg RAE/100 g)	Soluble solids (°Brix)	Moisture (%)
Banana					
Dwf. Braz.[c]	42	12.7±0.7[d]	12.4±1.0[d]	17.9±0.7[d]	68.5±0.6[d]
Williams	24	4.5±0.3	8.2±0.6	20.5±0.4	73.8±0.5
	Mean	9.7±0.7	10.9±0.7	18.8±0.6	70.4±0.5
Papaya					
Kapoho	6	45.4±2.0	29.9±2.4	12.1±0.1	86.0±0.1
Laie Gold	6	51.3±1.5	48.2±3.1	12.5±0.3	85.8±0.6
Rainbow	30	51.8±1.2	50.3±3.0	12.4±0.3	86.1±0.3
Sunrise	12	55.6±2.8	45.6±8.7	12.1±0.4	86.2±0.5
SunUp	6	45.3±1.3	20.4±1.4	10.9±0.3	87.7±0.3
	Mean	51.2±1.0	44.1±2.6	12.2±0.2	86.2±0.2
Dietary reference intake (DRI):[e]					
		75; 90 mg/day	700; 900 μg/day		

[a] n = number of replications. Each replicate was collected from a different plant and consists of a composite sample of 2–3 fruit/plant.
[b] Provitamin A carotenoids include β-carotene, α-carotene, and β-cryptoxanthin. Retinol activity equivalents (RAE): $\frac{\mu g\ \beta\text{-carotene}}{12}+\frac{\mu g\ \alpha\text{-carotene}}{24}+\frac{\mu g\ \beta\text{-cryptoxanthin}}{24}$.
[c] Dwf. Braz. = Dwarf Brazilian.
[d] Values are means ± standard error. Soluble solids were not measured on all bananas.
[e] Dietary reference intakes (DRI) are the most recent set of dietary recommendations established by the US Food and Nutrition Board of the IOM (2000a, 2001). Values given are for adult females and males, ages 19–50 years.

The Cavendish subgroup is the most important banana traded internationally, but in Hawaii, the Dwarf Brazilian banana is grown widely and marketed within the state, with some export to the US mainland. This is the first report comparing the nutritional content of Dwarf Brazilian bananas with fruit of the Williams variety at different locations. At four plantations (Keaau, Pepeekeo, Paukaa, and Kapaa), both Dwarf Brazilian and Williams bananas were harvested. The average vitamin C content for Dwarf Brazilian fruit ranged from 6.3 to 17.5 mg/100 g, whereas the vitamin C content for Williams fruit varied from 2.5 to 6.3 mg/100 g (Table 2).

The average vitamin C content of papayas was 51.2 mg/100 g (Table 1). Papayas compare favorably to fresh oranges (53.2 mg/100 g) and strawberries (58.9 mg/100 g) for vitamin C content (USDA-ARS, 2004). The average adult female could meet the US DRI for vitamin C by consuming about three-quarters (~150 g) of a medium papaya fruit. In previous reports, papaya vitamin C content was higher than in this study, and ranged from 60 to 84 mg/100 g (Franke et al., 2004; Leong and Shui, 2002; Nisperos-Carriedo et al., 1992; USDA-ARS, 2004; Vinci et al., 1995; Wenkam, 1990; Wills et al., 1986). Solo type (Kapoho or Sunrise) papayas obtained from retail markets were analyzed in those studies. This report is the first for vitamin C content of the Laie Gold, Rainbow, and SunUp cultivars grown in Hawaii.

For all papayas harvested from 60 plants throughout the state, the vitamin C content ranged from 36.3 to 67.8 mg/100 g. Average vitamin C content was highest for Sunrise papayas grown at Moloaa, Kauai (64.5 mg/100 g) and Rainbow papayas grown at Waikapu, Maui (60.4 mg/100 g) (Table 2). These fruits were harvested in the summer (June–July), whereas papayas grown at the other locations were harvested in the winter (January–March). Longer day lengths and higher light intensities in summer months can increase the concentrations of ascorbic acid and glucose, the precursor to ascorbic acid, in fruits (Lee and Kader, 2000; Mozafar, 1994; Shewfelt, 1990).

Also, variation in maturity at harvest may have impacted vitamin C content. SSC is an estimate of fruit sugar content and is used as a maturity index. A positive correlation ($r = 0.68$, $P = 0.001$) was found between ascorbic acid and SSC. For papayas, vitamin C content has been shown to increase with maturity and ripening (Wenkam, 1990).

3.2. Vitamin A and carotenoids

In ripe bananas, the major carotenoids were lutein, α-carotene, and β-carotene (Fig. 1a). For yellow-fleshed papayas, β-cryptoxanthin, α-carotene, β-carotene, and β-cryptoxanthin esters were quantified by HPLC (Fig. 1b). Red-fleshed papaya fruit also contained large amounts of lycopene (Fig. 1c).

The average vitamin A content for Dwarf Brazilian bananas was 1.5 times higher than for Williams fruit (Table 1). Dwarf Brazilian bananas had 96.9 μg β-carotene and 104.9 μg α-carotene/100 g, whereas Williams fruit averaged 55.7 μg β-carotene and 84.0 μg α-carotene/100 g. Also, bananas contained higher concentrations of lutein than the provitamin A pigments (Table 3). Average lutein concentrations were 154.9 and 108.3 μg/100 g for Dwarf Brazilian and Williams fruit, respectively. Lutein has antioxidant activity (Miller et al., 1996) and has been associated with a decreased risk of macular degeneration (IOM, 2000a).

Table 2
Ascorbic acid (vitamin C), soluble solids, and moisture content of banana and papaya fruits grown in Hawaii

Crop	Cultivar	Location[a]	Ascorbic acid (mg/100 g)	Soluble solids (°Brix)	Moisture (%)
Banana	Dwf. Braz.[b]	Kapaa	6.3 ± 1.1[c]	22.5 ± 1.0[c]	70.5 ± 0.2[c]
	Dwf. Braz.	Keaau	17.5 ± 0.4	—	68.2 ± 0.2
	Dwf. Braz.	Paukaa	12.5 ± 0.9	20.2 ± 0.5	70.2 ± 0.4
	Dwf. Braz.	Pepeekeo	16.4 ± 0.3	—	67.9 ± 0.3
	Dwf. Braz.	Waialua	9.2 ± 0.8	12.3 ± 0.2	68.9 ± 0.4
	Dwf. Braz.	Waikapu	9.9 ± 0.9	15.4 ± 0.7	69.5 ± 0.7
	Dwf. Braz.	Waimanalo	17.1 ± 1.4	19.1 ± 0.7	64.4 ± 3.9
	Williams	Kapaa	3.6 ± 0.2	21.5 ± 0.4	74.4 ± 0.2
	Williams	Keaau	5.4 ± 0.1	—	74.3 ± 0.4
	Williams	Paukaa	2.5 ± 0.5	19.6 ± 0.4	76.6 ± 0.3
	Williams	Pepeekeo	6.3 ± 0.2	—	70.0 ± 0.7
Papaya	Kapoho	Kapoho (3)	45.4 ± 2.0	12.1 ± 0.1	86.0 ± 0.1
	Laie Gold	Laie	51.3 ± 1.5	12.5 ± 0.3	85.8 ± 0.3
	Rainbow	Kapoho (1)	47.6 ± 1.6	12.9 ± 0.2	86.0 ± 0.3
	Rainbow	Kapoho (2)	46.6 ± 1.8	11.4 ± 0.4	86.8 ± 0.5
	Rainbow	Keaau	55.6 ± 2.0	12.4 ± 0.3	85.8 ± 0.4
	Rainbow	Waialua	49.0 ± 2.0	11.2 ± 0.4	87.5 ± 0.4
	Rainbow	Waikapu	60.4 ± 1.1	14.3 ± 0.3	85.0 ± 0.6
	Sunrise	Kapoho (2)	46.8 ± 1.3	11.2 ± 0.2	87.5 ± 0.2
	Sunrise	Moloaa	64.5 ± 1.0	12.9 ± 0.5	84.9 ± 0.4
	SunUp	Kapoho (2)	45.3 ± 1.3	10.9 ± 0.3	87.7 ± 0.3
Dietary reference intake (DRI) (mg/day):[d]					
			75; 90		

[a]Rainbow papayas were harvested from two different plantations in Kapoho. Solo papaya was harvested from a third plantation in Kapoho. Kapoho, Keaau, Paukaa, and Pepeekeo are on the island of Hawaii. Laie, Waialua, and Waimanalo are on the island of Oahu. Kapaa and Moloaa are on the island of Kauai. Waikapu is on the island of Maui.
[b]Dwf. Braz. = Dwarf Brazilian.
[c]Values are means (±standard error) of six replications per cultivar at each location.
[d]Dietary reference intakes (DRI) established by the US Food and Nutrition Board of the IOM (2000a), National Academy of Sciences. Values given are for adult females and males, ages 19–50 years.

Williams (Cavendish type) bananas harvested from four locations had 8.2 μg RAE/100 g for vitamin A (Table 1), and ranged from 6.1 to 9.3 μg RAE/100 g (Table 3). This is higher than a previous report where Cavendish bananas had 4.5 μg RAE/100 g (Wenkam, 1990). In studies where β-carotene and α-carotene were quantified, Cavendish fruit had 2.6, 5.3, or 8.7 μg RAE/100 g (Hart and Scott, 1995; Muller, 1997; Wills et al., 1986). The USDA National Nutrient Database (USDA-ARS, 2004) lists 3 μg RAE/100 g for Cavendish bananas.

The vitamin A content of Hawaii's Dwarf Brazilian bananas averaged 12.4 μg RAE/100 g (Table 1), but ranged from 7.7 to 17.1 μg RAE/100 g (Table 3). Variability in the maturity of Dwarf Brazilian bananas contributed to the wide range in vitamin A values. However, this variability reflects a range that can be expected in commercially harvested fruit. Wenkam (1990) reported 4.1 μg RAE (49.2 μg β-carotene/100 g) for Dwarf Brazilian bananas, which falls below the range of values in this study. Vitamin A values were higher than those reported by Wenkam (1990), because α-carotene was quantified using HPLC. For most of the Dwarf Brazilian bananas, α-carotene levels were equal to or greater than β-carotene concentrations (Table 3). This illustrates the importance of separating and quantifying all the vitamin A pigments for accurate nutritional information.

Rainbow, Laie Gold, and Sunrise papaya cultivars tended to have higher vitamin A concentrations than the Kapoho or SunUp cultivars (Table 1). However, papaya β-carotene levels ranged from 80.5 to 410.3 μg/100 g (Table 3) for Sunrise fruit, indicating that other factors besides cultivar impacted carotenoids. Most fruit were harvested at the color break to $\frac{1}{8}$ ripe stages of maturity, and ripened at 22 °C before analysis, but slight variability in maturity and ripening (common in commercially marketed fruit) could contribute to a wide range in carotenoid concentrations. A positive correlation ($r = 0.69$, $P = 0.001$) was found between vitamin A concentration and SSC. These results agree with other studies using HPLC, in which papaya β-carotene content ranged from 71 to 380 μg/100 g (Kimura et al., 1991; Muller, 1997; Pepping et al., 1988; Philip and Chen, 1988; Tee and Lim, 1991). In contrast, the most commonly cited β-carotene values for Solo papaya (655.8 μg β-carotene) were determined using older methodology on composite samples (USDA-ARS, 2004; Wenkam, 1990).

Mean vitamin A content for 60 papaya samples was 44.1 μg RAE/100 g, and ranged from 18.7 to

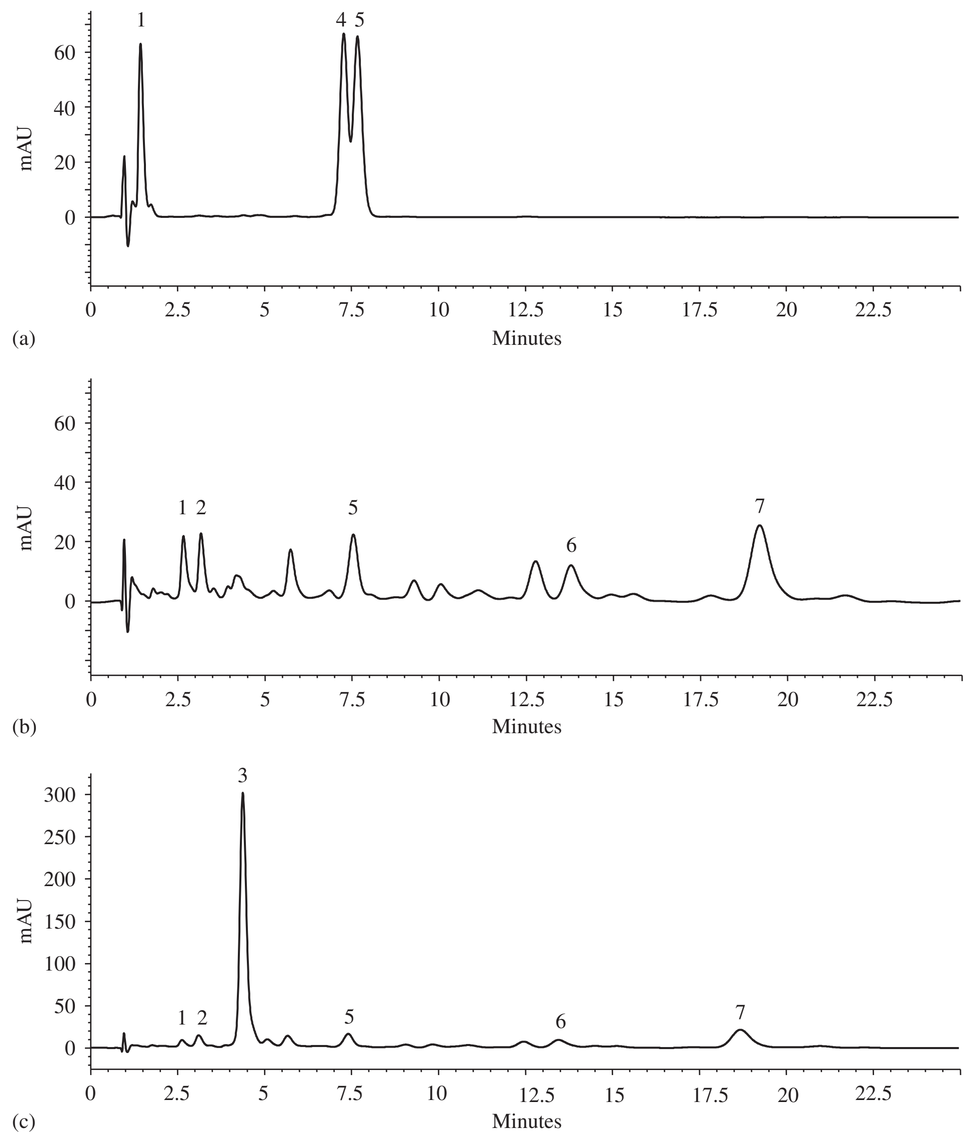

Fig. 1. Typical HPLC chromatograms of the carotenoids of (a) banana, (b) yellow-fleshed papaya, and (c) red-fleshed papaya. Peak identification: (1) lutein, (2) β-cryptoxanthin, (3) lycopene, (4) α-carotene, (5) β-carotene, (6) β-cryptoxanthin ester I, and (7) β-cryptoxanthin ester II.

74.0 μg RAE/100 g (Table 2). Depending on cultivar and ripeness, consuming about one-half of a papaya fruit (~100 g) would provide between 2% and 10% of the US DRI for vitamin A for the average adult. The USDA Nutrient Database (USDA-ARS, 2004) lists 55 μg RAE/100 g for papaya vitamin A content. Vitamin A values (μg RAE/100 g) calculated from previous HPLC analyses for β-carotene, α-carotene, and β-cryptoxanthin concentrations ranged from 26.2 to 44.2 (Ben-Amotz and Fishler, 1998; Holden et al., 1999; Muller, 1997; Setiawan et al., 2001).

The red-fleshed cultivars, Sunrise and SunUp, had high-lycopene concentrations (Table 3). Lycopene was not detected in the yellow-fleshed cultivars, Kapoho, Laie Gold, and Rainbow. The lycopene content for Sunrise fruit sampled from Kauai was 3674.5 μg/100 g, and compares favorably to reports for red, ripe tomatoes (2573 and 3025 μg/100 g), a high-lycopene fruit (Holden et al., 1999; USDA-ARS, 2004).

3.3. Mineral content

Bananas are considered a good source of K and Mg in the diet, and the data support these assertions. Average K content for Hawaii's bananas (Dwarf Brazilian and Williams) was 330.6 mg/100 g fresh weight (Table 4). New DRI values have been published recently for K, and the daily adequate intake for adults is 4700 mg (IOM, 2004). Therefore, 100 g of banana fruit would provide 7% of the K requirement for the average adult. Magnesium content averaged 35.1 mg/100 g (Table 4). The DRI for Mg is 320 mg for female adults and 400–420 mg for male adults. Bananas (100 g) would supply about 9% (males) to 11% (females) of the DRI for Mg. Iron, copper, and manganese are other minerals of nutritional importance in bananas. The DRI for Fe is 18 mg/day (females) and 8 mg/day (males). The Cu DRI is 0.9 mg/day, and the Mn DRI is 1.8–2.3 mg/day (IOM, 2001). Dwarf Brazilian bananas

Table 3
Carotenoid and vitamin A content of banana and papaya fruits grown in Hawaii

Crop	Cultivar	Location[a]	β-Carotene (μg/100 g)	α-Carotene (μg/100 g)	β-Cryptoxanthin (μg/100 g)	Lutein (μg/100 g)	Lycopene (μg/100 g)	Vitamin A[b] (μg RAE/100 g)
Banana	Dwf. Braz.[c]	Kapaa	73.0±19.0[d]	92.6±24.1[d]	ND	144.5±17.1[d]	ND	9.9±2.6[d]
	Dwf. Braz.	Keaau	131.4±20.4	144.5±18.7	ND	169.2±6.8	ND	17.0±2.4
	Dwf. Braz.	Paukaa	127.6±12.7	155.6±14.2	ND	149.7±13.1	ND	17.1±1.6
	Dwf. Braz.	Pepeekeo	57.2±17.6	71.1±26.5	ND	192.2±8.1	ND	7.7±2.6
	Dwf. Braz.	Waialua	77.0±6.0	76.9±5.6	ND	184.6±11.6	ND	9.6±0.7
	Dwf. Braz.	Waikapu	85.5±12.8	67.9±13.1	ND	110.7±10.3	ND	10.0±1.6
	Dwf. Braz.	Waimanalo	126.4±33.9	126.0±31.0	ND	129.3±10.8	ND	15.8±4.1
	Williams	Kapaa	42.8±4.5	60.0±7.7	ND	90.4±5.4	ND	6.1±0.6
	Williams	Keaau	55.2±3.8	107.8±20.7	ND	130.9±5.1	ND	9.1±1.1
	Williams	Paukaa	49.2±12.4	95.9±25.3	ND	86.2±10.4	ND	8.1±2.1
	Williams	Pepeekeo	75.5±6.2	72.3±9.3	ND	125.6±3.3	ND	9.3±0.7
Papaya	Kapoho	Kapoho (3)	145.9±6.0	ND	426.3±53.6	238.2±21.3	ND	29.9±2.4
	Laie Gold	Laie	256.7±27.7	ND	643.8±30.6	146.8±32.8	ND	48.2±3.1
	Rainbow	Kapoho (1)	261.9±13.3	ND	680.6±31.2	241.1±31.2	ND	50.2±2.3
	Rainbow	Kapoho (2)	161.3±11.0	ND	445.5±18.1	186.6±35.3	ND	32.0±1.5
	Rainbow	Keaau	316.4±38.2	ND	662.3±38.7	317.6±9.4	ND	54.0±4.6
	Rainbow	Waialua	222.0±29.0	ND	546.7±36.1	152.5±34.6	ND	41.3±3.8
	Rainbow	Waikapu	370.6±15.6	ND	1034.4±52.4	206.5±14.4	ND	74.0±3.1
	Sunrise	Kapoho (2)	80.5±7.1	ND	288.4±26.6	109.8±26.4	1350.22±251.0	18.7±1.7
	Sunrise	Moloaa	410.3±43.4	ND	920.0±69.9	129.5±16.1	3674.45±367.2	72.5±6.3
	SunUp	Kapoho (2)	97.4±7.1	ND	294.9±21.9	93.3±26.3	1674.40±337.4	20.4±1.4
Dietary reference intake (DRI) (μg/day)[e]:								700; 900

[a]Rainbow papayas were harvested from two different plantations in Kapoho. Solo papaya was harvested from a third Kapoho plantation. Kapoho, Keaau, Paukaa, and Pepeekeo are on the island of Hawaii. Laie, Waialua, and Waimanalo are on the island of Oahu. Kapaa and Moloaa are on the island of Kauai. Waikapu is on the island of Maui.

[b]Provitamin A carotenoids include β-carotene, α-carotene, and β-cryptoxanthin. Retinol activity equivalents (RAE) in μg, calculated as $\frac{\mu g\ \beta\text{-carotene}}{12} + \frac{\mu g\ \alpha\text{-carotene}}{24} + \frac{\mu g\ \beta\text{-cryptoxanthin}}{24}$.

[c]Dwf. Braz. = Dwarf Brazilian.

[d]Values are means (± standard error) of six replications per cultivar at each location. ND, not detected.

[e]Dietary reference intakes (DRI) are established by the US Food and Nutrition Board of the IOM (2001), National Academy of Sciences. Values given are for adult females and males, ages 19–50 years.

Table 4
Mineral content (P, K, Ca, Mg, Na) of banana fruits grown at different locations in Hawaii

Cultivar	Location[a]	P	K	Ca (mg/100 g fresh weight)	Mg	Na
Dwf. Braz.[b]	Kapaa	23.1±1.7[c]	288.5±7.5[c]	5.9±0.1[c]	32.4±1.2[c]	3.4±0.5[c]
Dwf. Braz.	Keaau	25.4±0.7	328.5±7.6	7.4±0.6	35.0±0.2	18.5±2.9
Dwf. Braz.	Paukaa	26.8±1.2	294.8±10.3	7.4±0.6	38.7±0.9	14.4±2.2
Dwf. Braz.	Pepeekeo	26.2±0.6	307.0±8.6	6.4±0.1	41.2±0.5	29.9±1.8
Dwf. Braz.	Waialua	26.9±1.2	361.7±9.9	6.7±0.5	45.1±1.3	17.6±2.4
Dwf. Braz.	Waikapu	29.8±2.6	330.7±16.9	7.1±0.6	37.5±1.7	10.1±1.8
Dwf. Braz.	Waimanalo	25.8±2.5	485.0±37.5	9.7±0.9	45.8±4.3	18.7±2.7
Williams	Kapaa	20.9±1.2	311.4±10.3	5.1±0.0	30.7±1.4	14.1±2.2
Williams	Keaau	19.2±0.7	287.1±12.6	3.8±0.5	26.1±1.1	18.4±3.5
Williams	Paukaa	21.8±1.8	322.1±17.8	6.3±0.8	29.7±0.9	14.8±1.6
Williams	Pepeekeo	25.0±0.7	355.2±11.6	4.5±0.6	36.6±1.5	22.1±5.0
Dietary reference intake (DRI) (mg/day):[d]		700	4700	1000	320; 420	1500

[a]Keaau, Paukaa, and Pepeekeo are on the island of Hawaii; Waialua and Waimanalo are on the island of Oahu. Kapaa is on the island of Kauai. Waikapu is on the island of Maui.

[b]Dwf. Braz. = Dwarf Brazilian.

[c]Values are means (± standard error) of six replications per cultivar at each location.

[d]Dietary reference intakes (DRI) are established by the US Food and Nutrition Board of the IOM (2000b, 2004), National Academy of Sciences. Values given are for adult females and males, ages 19–50 years.

Table 5
Mineral content (Fe, Mn, Zn, Cu, B) of banana fruits grown at different locations in Hawaii

Cultivar	Location[a]	Fe	Mn	Zn (mg/100 g fresh weight)	Cu	B
Dwf. Braz.[b]	Kapaa	0.35±0.04[c]	0.17±0.01[c]	0.19±0.01[c]	0.12±0.01[c]	0.10±0.01[c]
Dwf. Braz.	Keaau	0.72±0.05	0.34±0.04	0.31±0.05	0.22±0.04	0.13±0.01
Dwf. Braz.	Paukaa	0.77±0.06	0.56±0.12	0.27±0.02	0.58±0.02	0.21±0.01
Dwf. Braz.	Pepeekeo	0.98±0.07	1.00±0.11	1.04±0.30	0.31±0.02	0.16±0.01
Dwf. Braz.	Waialua	0.69±0.06	0.69±0.10	0.26±0.02	0.22±0.02	0.26±0.01
Dwf. Braz.	Waikapu	0.75±0.18	1.38±0.41	0.20±0.02	0.20±0.01	0.13±0.01
Dwf. Braz.	Waimanalo	1.04±0.30	0.52±0.19	0.26±0.03	0.20±0.02	0.13±0.01
Williams	Kapaa	1.01±0.05	0.16±0.02	0.17±0.01	0.19±0.01	0.13±0.01
Williams	Keaau	0.62±0.06	0.13±0.02	0.30±0.05	0.20±0.02	0.12±0.01
Williams	Paukaa	0.97±0.12	0.31±0.06	0.24±0.01	0.46±0.01	0.19±0.01
Williams	Pepeekeo	0.70±0.08	0.21±0.03	0.21±0.02	0.17±0.02	0.12±0.01
Dietary reference intake (DRI) (mg/day):[d]						
		18; 8	1.8; 2.3	8; 11	0.90	ND

[a]Keaau, Paukaa, and Pepeekeo are on the island of Hawaii; Waialua and Waimanalo is on the island of Oahu. Kapaa is on the island of Kauai. Waikapu is on the island of Maui.
[b]Dwf. Braz. = Dwarf Brazilian.
[c]Values are means (± standard error) of six replications per cultivar at each location.
[d]Dietary reference intakes (DRI) are established by the US Food and Nutrition Board of the IOM (2001), National Academy of Sciences. Values given are for adult females and males, ages 19–50 years. For boron, ND, not determinable.

Table 6
Mineral content (P, K, Ca, Mg, Na) of papaya fruits grown at different locations in Hawaii

Cultivar	Location[a]	P	K	Ca (mg/100 g fresh weight)	Mg	Na
Kapoho	Kapoho (3)	8.0±0.5[b]	89.7±5.4[b]	9.8±0.7[b]	19.2±1.4[b]	5.6±0.7[b]
Laie Gold	Laie	6.2±0.4	152.9±10.9	20.4±1.1	24.8±1.8	8.9±0.9
Rainbow	Kapoho (1)	6.8±0.2	113.2±11.5	16.0±1.7	24.5±2.9	8.1±0.6
Rainbow	Kapoho (2)	5.0±0.2	146.0±10.5	14.6±1.9	22.5±2.6	5.0±0.4
Rainbow	Keaau	5.2±0.4	120.8±9.9	12.1±1.0	27.4±3.0	7.1±0.7
Rainbow	Waialua	5.8±0.4	148.1±15.3	15.1±1.0	26.4±2.3	24.3±2.4
Rainbow	Waikapu	8.8±1.4	203.7±31.0	32.1±7.9	24.5±2.9	11.5±1.4
Sunrise	Kapoho (2)	5.0±0.1	173.0±8.6	12.4±2.4	24.9±2.2	6.4±0.5
Sunrise	Moloaa	8.0±0.3	221.4±11.3	19.9±3.4	32.7±4.4	14.0±1.5
SunUp	Kapoho (2)	4.9±0.1	170.1±8.8	13.9±1.7	21.1±1.4	6.9±0.8
Dietary reference intake (DRI) (mg/day):[c]						
		700	4700	1000	320; 420	1500

[a]Kapoho and Keaau are on the island of Hawaii; Laie and Waialua are on the island of Oahu. Moloaa is on the island of Kauai. Waikapu is on the island of Maui.
[b]Values are means (± standard error) of six replications per cultivar at each location.
[c]Dietary reference intakes (DRI) are established by the US Food and Nutrition Board of the IOM (2000b, 2004), National Academy of Sciences. Values given are for adult females and males, ages 19–50 years.

(100 g) supply 4–10% of the DRI for Fe, 29% of the DRI for Cu, and 29–37% of the DRI for Mn (Table 5).

A range of mineral concentrations has been reported for bananas (Hardisson et al., 2001; USDA-ARS, 2004; Wenkam, 1990), and the results generally agree with previous reports for P, K, and Ca. However, the average values for Mg, Fe, Mn, Zn, and Cu are higher than those reported by Wenkam (1990) and the USDA Nutrient Database (USDA-ARS, 2004).

Papayas (100 g) can provide 9% of the DRI for Cu and 6–8% of the DRI for Mg (Tables 6 and 7). Papayas contribute less than 3% of the DRI for most of the other minerals. In general, mineral composition was similar for the five cultivars sampled. Papaya fruit harvested from Maui (Waikapu) tended to have high mineral contents for P, K, Ca, Fe, and Cu (Tables 6 and 7). These papaya mineral values are greater than those listed in the USDA Nutrient Database (USDA-ARS, 2004) for six minerals (Mg, Na, Fe, Mn, Zn, Cu), but lower than those listed for K and Ca. Wenkam (1990) reported 12 mg P, 183 mg K, 30 mg Ca, 21 mg Mg, 4 mg Na, and 0.19 mg Fe for Solo (Kapoho) papayas, based on one composite sample.

Table 7
Mineral content (Fe, Mn, Zn, Cu, B) of papaya fruits grown at different locations in Hawaii

Cultivar	Location[a]	Fe	Mn	Zn (mg/100 g fresh weight)	Cu	B
Kapoho	Kapoho (3)	0.29±0.03[b]	0.03±0.00[b]	0.09±0.00[b]	0.11±0.01[b]	0.13±0.01[b]
Laie Gold	Laie	0.44±0.05	0.02±0.00	0.07±0.01	0.06±0.00	0.14±0.01
Rainbow	Kapoho (1)	0.40±0.03	0.02±0.01	0.08±0.01	0.08±0.01	0.13±0.01
Rainbow	Kapoho (2)	0.27±0.02	0.01±0.00	0.06±0.01	0.05±0.00	0.10±0.01
Rainbow	Keaau	0.31±0.03	0.03±0.01	0.08±0.01	0.07±0.01	0.12±0.02
Rainbow	Waialua	0.66±0.08	0.03±0.01	0.08±0.01	0.07±0.01	0.14±0.01
Rainbow	Waikapu	0.65±0.06	0.02±0.01	0.08±0.01	0.14±0.02	0.21±0.03
Sunrise	Kapoho (2)	0.42±0.05	0.03±0.01	0.07±0.01	0.07±0.00	0.14±0.01
Sunrise	Moloaa	0.46±0.03	0.02±0.01	0.09±0.01	0.08±0.01	0.20±0.01
SunUp	Kapoho (2)	0.46±0.08	0.02±0.00	0.07±0.01	0.06±0.00	0.11±0.01
Dietary reference intake (DRI) (mg/day):[c]						
		18; 8	1.8; 2.3	8; 11	0.90	ND

[a]Kapoho and Keaau are on the island of Hawaii; Laie and Waialua are on the island of Oahu. Moloaa is on the island of Kauai. Waikapu is on the island of Maui.
[b]Values are means (± standard error) of six replications per cultivar at each location.
[c]Dietary reference intakes (DRI) are established by the US Food and Nutrition Board of the IOM (2001), National Academy of Sciences. Values given are for adult females and males, ages 19–50 years. For boron, ND, not determinable.

4. Conclusions

Bananas and papayas were harvested from different locations throughout the state of Hawaii and analyzed for vitamin C, vitamin A, and mineral composition. Different cultivars of each fruit type were analyzed, and samples were collected from plantations on four islands.

Dwarf Brazilian bananas are more nutritious than Williams fruit, having higher concentrations of vitamin C, vitamin A, and the minerals P, Ca, Mg, Mn, and Zn. Vitamin C content was almost three times higher in Dwarf Brazilian bananas than in Williams fruit. In general, bananas are a good source of K, Mg, Cu, and Mn in the diet, but do not supply much vitamin C or vitamin A, relative to other fruits. Banana vitamin A content ranged from 6 to 17 μg RAE/100 g. This is less than 2% of the DRI for vitamin A. Bananas contained more of the carotenoid, lutein, than of the provitamin A pigments, β-carotene, and α-carotene.

Papayas can be an important source of vitamin C, vitamin A, and Mg for Pacific island populations. Papayas (one cup; 140 g) contain 8–11% of the DRI for Mg. The average vitamin C content for papaya fruit was 51.2 mg/100 g. Therefore, one cup of papaya cubes (140 g) would provide between 80% and 96% of the DRI for vitamin C for the average adult male and female, respectively. Depending on cultivar, this same amount of papaya would provide between 4% and 9% of the DRI for vitamin A for an adult female, and between 3% and 7% of the DRI for an adult male. However, the red-fleshed cultivars, Sunrise and SunUp, contain high concentrations of lycopene. Therefore, the antioxidant activity of these papayas may have a greater contribution to human health than the vitamin A activity.

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