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Original Article

# Ascorbic acid and mineral composition of longan (*Dimocarpus longan*), lychee (*Litchi chinensis*) and rambutan (*Nephelium lappaceum*) cultivars grown in Hawaii

Marisa M. Wall\*

US Department of Agriculture, US Pacific Basin Agricultural Research Center, Agricultural Research Service, P.O. Box 4459, Hilo, HI, USA

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#### Abstract

Longan (*Dimocarpus longan*), lychee (*Litchi chinensis*), and rambutan (*Nephelium lappaceum*) cultivars were harvested from different locations in Hawaii and analyzed for vitamin C (ascorbic acid) and mineral content. Longan fruit had the highest vitamin C content (60.1 mg/100 g fresh weight) among the three specialty fruits tested. Average ascorbic acid content was 27.6 mg/100 g for lychees and 36.4 mg/100 g for rambutans. Vitamin C content was 63.3 and 55.3 mg/100 g for the longan cultivars, Biew Kiew and Sri Chompoo, respectively. For rambutans, vitamin C content ranged from 22.047.8 mg/100 g for the six cultivars tested. The early maturing lychee cultivar, Kaimana, had an average ascorbic acid content of 33.2 mg/100 g, and the later maturing Groff and Bosworth-3 cultivars had 21.2 and 22.5 mg/100 g, respectively. No correlation was found between ascorbic acid and total soluble solids (TSS) content. Longans were a good source of K (324.9 mg/100 g) and Cu (0.26 mg/100 g). Consumption of lychee fruit (100 g) would meet 2–4% of the daily recommended intake (DRI) for six minerals (P, K, Mg, Fe, Zn, Mn), and 22% of the DRI for Cu. Rambutan fruit had 20% of the DRI for Cu and 8–10% of the DRI for Mn. In general, fruit mineral content was not associated with soil mineral content.

Keywords: Longan; Lychee; Litchi; Rambutan; Tropical fruit; Minerals; Vitamin C

#### 1. Introduction

Longan (*Dimocarpus longan* Lour.), lychee (*Litchi chinensis* Sonn.), and rambutan (*Nephelium lappaceum* L.) are subtropical and tropical fruit of the *Sapindaceae* family. Longans and lychees are subtropical species originating from South China, whereas rambutan is a tropical species common to Southeast Asia (Nakasone and Paull, 1998; Tongdee, 1997). Important production areas for longan, lychee and rambutans are China, India, Thailand, Taiwan, Malaysia, and Australia (Nakasone and Paull, 1998; Zee et al., 1998).

In Hawaii, production of these specialty fruit has increased rapidly following the decline of the sugarcane plantations. Longan, lychee, and rambutans are grown for local consumption and for export markets. Export

\*Tel.: +18089594343; fax: +18089595470.

E-mail address: mwall@pbarc.ars.usda.gov.

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potential has improved with the development of quarantine treatments for these fruit (Federal Register, 1997, 1998), which are hosts of the Mediterranean fruit fly (*Ceratitis capitata*), the oriental fruit fly (*Bactrocera dorsalis*), the koa seedworm (*Cryptophlebia illepida*), and the lychee fruit moth (*Cryptophlebia ombrodelta*) (Throne et al., 2003).

As production and markets expand, nutritional information is needed for consumers purchasing longans, lychees, and rambutans. Also, reliable fruit composition data is necessary to evaluate diets for nutritional adequacy, and to conduct epidemiological research relating diet to health. Greater consumption of fruits and vegetables is associated with reduced risk of cardiovascular disease (CVD), 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; World Cancer Research Fund—American Institute for Cancer Research (WCRF/AICR), 1997). The 2005 Dietary Guidelines Advisory Committee recommends increasing the dietary intake of vitamins A, C and E, Ca, Mg, K and fiber, which can be met by increasing the consumption of fruits and vegetables to 5–13 servings per day (US Department of Agriculture and US Department of Health and Human Services (USDA/HHS), 2004).

Many tropical fruit appear to be good sources of ascorbic acid (vitamin C), provitamin A, Mg, and K. However, fruit nutritional analyses rarely consider the effects of cultivar or environment on vitamin and mineral content. For longans, lychees, and rambutans, nutritional information is limited and was obtained from a few composite samples (Leong and Shui, 2002; Vinci et al., 1995; Wenkam, 1990; Wills et al., 1986). In most cases, the identity of the cultivar and the location of production were unknown. The nutritional composition of a fruit type at harvest can vary widely depending on cultivar, climate, soil type and fertility (Lee and Kader, 2000; Mozafar, 1994; Shewfelt, 1990). Ascorbic acid levels in fruit are influenced by the availability of light to the crop and to individual fruits. Longer day lengths and higher light intensities can increase the concentrations of ascorbic acid and glucose, the precursor to ascorbic acid, in fruit (Lee and Kader, 2000; Mozafar, 1994; Shewfelt, 1990). Excess soil nitrogen or phosphorous tend to decrease ascorbic acid content of fruit, while excess potassium could increase vitamin C content (Nagy and Wardowski, 1988). Also, the ascorbic acid content of different cultivars may differ by a factor of 2-3 or higher in many fruits (Mozafar, 1994). Mango cultivars varied by 30-fold in vitamin C content (Wenkam, 1990). 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). The composite samples reported in the literature mask this variability. A greater number of samples, from identified cultivars, need to be analyzed from different locations to compile more representative nutritional data.

In addition to supplying vitamin C and provitamin A, fruit 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 (Institute of Medicine (IOM), 2000a, 2001, 2004). However, the mineral values reported in food composition tables often are based on non-representative samples or old methodology. The mineral composition of fruit 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 longans, lychees, and rambutans 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 and mineral content of some longan, lychee, and rambutan cultivars grown in different locations in Hawaii. Two longan, three lychee, and six

rambutan cultivars were analyzed, and samples were collected from orchards on various soil types on two islands. Fruit from 30 longan trees, 36 lychee trees, and 42 rambutan trees were harvested to provide estimates of the variation in vitamin C and mineral content for these fruit. 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 and soil sampling

Longan, lychee, and rambutan fruits were harvested from commercial orchards in the Hawaiian Islands. Longans were obtained from three orchards located at Kurtistown and Puueo on the island of Hawaii, and at Kilauea on the island of Kauai. Longans were harvested in April and June, 2004. Lychees were harvested in late May to early July, 2004 from five orchards at Hakalau, Kurtistown, Puueo, and Waiakea on the island of Hawaii, and at Kilauea on the island of Kauai. Rambutans were harvested from three orchards at Keaau, Kurtistown, and Pepeekeo on the island of Hawaii in December, 2003.

Fruits were harvested from orchards with soils representing three orders (Andisols, Histosols, and Oxisols) in the soil classification system that are common in the agricultural areas of the Hawaiian islands (Uehara and Ikawa, 2000). A composite soil sample was collected from each orchard at the time of fruit sampling. Soil samples were taken using a soil probe to a depth of 20 cm at the drip line of each tree (6) from which fruit were sampled. These soil cores were mixed thoroughly in a bucket to make a composite sample. Orchard elevation was measured using an altimeter and recorded. Elevations ranged from 30 to 200 m.

About 1.5 kg fruit (per tree) were harvested from six randomly selected trees at each orchard. Harvest maturity was based on full-size and peel color (light brown for longans, and bright red for lychees and rambutans) (Paull and Chen, 1987; Zee et al., 1998). Longan cultivars included Biew Kiew and Sri Chompoo. Lychee cultivars were Bosworth-3, Groff, and Kaimana. Rambutan cultivars included Jitlee, R9, R134, R162, Rongrien, and Silengkeng. Eight fruit per tree were combined to create composite samples for extraction and analysis. Individual fruit were peeled and de-seeded, and the edible tissue (aril) was used for analysis. Total soluble solids (TSS) 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

Glacial acetic acid, metaphosphoric acid, and acetonitrile were purchased from Fisher Scientific (Pittsburgh, PA, USA). Ascorbic acid was purchased from Sigma-Aldrich Chemicals Co. (St. Louis, MO, USA).

#### 2.3. Ascorbic acid analysis

Ascorbic acid was extracted (under subdued light) from longans, lychees, and rambutans on the day of harvest by blending 40 g edible aril tissue with 100 mL of cold metaphosphoric-acetic acid (MPA) solution (30 g metaphosphoric acid, 0.5 g EDTA, and 80 mL glacial acetic acid diluted to 1 L with distilled water) in a pre-chilled, stainless steel blender for 3 min. The slurry was centrifuged for 15 min at 10,000 rpm in a cold centrifuge (2–4  $^{\circ}$ C), and the supernatant was collected. Samples (5mL) were passed through C-18 Sep-Paks preconditioned with 2mL acetonitrile followed by 5mL distilled water. Duplicate samples were filtered through 0.22 um 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 µL of sample into an Agilent 1100 series liquid chromatograph (Agilent Technologies, Wilmington, DE, USA), with 0.2 M NaH<sub>2</sub>PO<sub>4</sub>, pH 2.14 as the mobile phase, and a PLRP-S column  $(2.1 \times 250 \text{ mm},$ 5 µm particle size; Polymer Laboratories, Amherst, MA, USA) 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 thermostated 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 was  $92\pm2.8\%$ , and the HPLC minimum detection level was  $0.05 \,\mu\text{g}$ . Vitamin C values were expressed as mg/100 g edible fresh weight.

#### 2.4. Fruit mineral analysis and soil analysis

Fruit samples (20 g edible tissue) 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 and soil samples were sent to the Agricultural Diagnostic Service Center (ADSC) at the University of Hawaii (Honolulu, HI) for complete mineral and soil analyses. Fruit mineral analysis was performed using inductively coupled plasma-atomic emission spectrometry (ICP-AES) according to AOAC official method 985.01 (Association of Official Analytical Chemists (AOAC), 2000). The detection limit was 1 ppb. Prior to ICP-AES analysis, fruit tissue samples were ashed in a muffle furnace at 500 °C and acidextracted (AOAC, 2000; Hue et al., 2000). For soil samples, the modified Truog method was used for extractable phosphorus (P) (Ayres and Hagihara, 1952). Calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were extracted with ammonium acetate and measured by atomic absortion (AA) spectrophotometry (Hue et al., 2000; US Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS), 2004). Micronutrients [iron (Fe), copper (Cu), manganese (Mn), zinc (Zn)] were extracted using the Mehlich No. 3 method and measured with an AA spectrophotometer (Mehlich, 1984; USDA-NRCS, 2004). Boron (B) was hot-water extracted and measured with the azomethine-H colorimetric method (Wolf, 1974).

#### 2.5. 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 tree. Data were subjected to analysis of variance using the general linear models (GLM) procedure of SAS (SAS Institute, 1999). Pearson correlation coefficients were determined using SAS to described the relationship between vitamin C content and soluble solids content.

## 3. Results and discussion

#### 3.1. Ascorbic acid (vitamin C)

Ascorbic acid concentrations were determined for longans, lychees, and rambutans harvested from 30, 36 and 42 trees, respectively, in Hawaii. Dehydroascorbic acid (DHAA) was not detected, even at 214 nm wavelength. The are no reports of DHAA in longan, lychee or rambutans. 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. Tropical fruit 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).

Longan fruit had the highest vitamin C content (60.1 mg/ 100 g) among the three specialty fruit tested (Table 1). Longans compare favorably to fresh papayas (61.8 mg/ 100 g), oranges (53.2 mg/100 g), and strawberries (58.9 mg/ 100 g) for vitamin C content (US Department of Agriculture, Agricultural Research Service (USDA-ARS), 2004). Ascorbic acid content was 63.3 and 55.3 mg/100 g for the longan cultivars, Biew Kiew and Sri Chompoo, respectively. Lychee fruit had a mean ascorbic acid content of 27.6 mg/100 g. The early maturing lychee variety, Kaimana, had an average ascorbic acid content of 33.2 mg/100 g, and

 Table 1

 Ascorbic acid (vitamin C), soluble solids, and moisture content of longan, lychee, and rambutan fruit grown in Hawaii

Crop	Cultivar	Location <sup>a</sup>	Ascorbic acid (mg/100 g)	Soluble solids (°Brix)	Moisture (%)
Longan	Biew Kiew	Kilauea	$44.65 \pm 1.80^{b}$	$18.63 \pm 0.39$	$81.02 \pm 0.37$
-	Biew Kiew	Kurtistown	$79.23 \pm 2.62$	$19.90 \pm 0.43$	$78.98 \pm 0.28$
	Biew Kiew	Puueo	$66.14 \pm 2.78$	$18.88 \pm 0.31$	$80.75 \pm 0.49$
	Sri Chompoo	Kurtistown	$58.98 \pm 2.60$	$20.37 \pm 0.82$	$78.87 \pm 0.90$
	Sri Chompoo	Puueo	$51.55 \pm 1.00$	$21.02 \pm 0.83$	$77.83 \pm 0.32$
Lychee	Bosworth-3	Hakalau	$21.00 \pm 0.60$	$19.93 \pm 0.34$	$79.63 \pm 0.29$
	Bosworth-3	Kurtistown	$24.03 \pm 0.34$	$19.37 \pm 0.27$	$79.05 \pm 0.25$
	Groff	Kilauea	$21.18 \pm 0.77$	$17.47 \pm 0.29$	$81.71 \pm 0.40$
	Kaimana	Hakalau	$32.84 \pm 1.59$	$19.00 \pm 0.27$	$80.08 \pm 0.25$
	Kaimana	Puueo	$36.00 \pm 1.18$	$18.65 \pm 0.41$	$81.89 \pm 0.82$
	Kaimana	Waiakea	$30.66 \pm 1.14$	$18.97 \pm 0.21$	$79.44 \pm 0.15$
Rambutan	R9	Kurtistown	$22.02 \pm 2.66$	_	$80.25 \pm 0.49$
	Jitlee	Keaau	$38.12 \pm 1.31$	$18.18 \pm 0.61$	$81.01 \pm 0.56$
	R162	Keaau	$47.83 \pm 3.28$	$18.07 \pm 0.63$	$81.59 \pm 0.58$
	Rongrien	Keaau	$39.34 \pm 2.14$	$16.73 \pm 1.03$	$81.91 \pm 0.92$
	Rongrien	Pepeekeo	$37.63 \pm 3.85$	$18.03 \pm 0.37$	$79.73 \pm 0.23$
	R134	Pepeekeo	$30.80 \pm 1.64$	$16.73 \pm 0.63$	$81.45 \pm 1.00$
	Silengkeng	Pepeekeo	$39.10 \pm 2.72$	$16.82 \pm 1.08$	$80.70 \pm 0.97$

<sup>a</sup>Hakalau, Keaau, Kurtistown, Pepeekeo, Puueo, and Waiakea are on the island of Hawaii. Kilauea is on the island of Kauai.

 $^{b}Values$  are means (±SE) of six replications per cultivar at each location.

<sup>c</sup>Dietary Reference Intakes (DRI) established by the Food and Nutrition Board of the Institute of Medicine, National Academy of Sciences (2000b). Values given are for adult females and males, ages 19–50 years.

the later maturing, Groff and Bosworth-3, cultivars had 21.2 and 22.5 mg/100 g, respectively. For rambutans, the average vitamin C content was 36.4 mg/100 g and ranged from 22.0 mg/100 g for R9 to 47.8 mg/100 g for R162 (Table 1). The dietary reference intake (DRI) values for vitamin C are 90 mg for adult males and 75 mg for adult females (Institute of Medicine (IOM), 2000b). Therefore, consumption of about 12–14 longan fruit would meet the daily vitamin C requirements for the average adult. About 10–12 rambutan fruit would provide the DRI, as well. Rambutans have a lower concentration of ascorbic acid, but the edible portion weighs twice as much as the longan aril. Depending on cultivar, consumption of 14–17 lychee fruit would meet the average adult DRI for vitamin C.

Mean ascorbic acid content of Hawaii's longan (60.1 mg/ 100 g) was less than that listed by Tongdee (1997) (69.2 mg/ 100 g). The USDA nutrient database (USDA-ARS, 2004) lists longan vitamin C content as 84.0 mg/100 g based on two samples. Rambutans are not listed in the USDA database (USDA-ARS, 2004), but Leong and Shui (2002) measured 50 mg ascorbic acid/100 g for an unidentified cultivar using HPLC analysis. The ascorbic acid content of Hawaii-grown rambutans ranged from 22 to 47 mg/100 g (Table 1), and this agrees with a report by Watson (1984) from Australia. Lychees ranged from 21 to 36 mg/100 g for vitamin C content (Table 1). Vinci et al. (1995) reported lychee vitamin C as 22 mg/100 g using HPLC, but the cultivar was not identified. For Bosworth-3 (a selection from Kwai Mi), the average vitamin C content was 22.5 mg/100 g (Table 1). In comparison, Kwai Mi vitamin C content has been listed as 18.0 mg/100 g (Zee et al., 1998) and 40.2 mg/100 g (Wenkam, 1990) based on old methodology. For the cultivar Kaimana (a selection from Hap ip), vitamin C content (33.2 mg/100 g) was higher than that reported for Hap ip (24.8 mg/100 g) (Zee et al., 1998).

This is the first report for the nutritional content of longans, lychees and rambutans grown at different locations in Hawaii. Average vitamin C content was greater for longans (Biew Kiew and Sri Chompoo) grown at Kurtistown (69.1 mg/100 g) than at Puueo (58.8 mg/100 g). Longans grown at Kurtistown (elevation of 215m) were harvested in April, whereas fruit grown at Puueo (46 m elevation) were harvested in June. The Kurtistown microclimate (warm days and cool nights) may have been more conducive to ascorbic acid accumulation. Although longer daylengths and higher light intensities in summer months can increase the concentrations of glucose (the precursor to ascorbic acid), temperature also influences vitamin C content (Lee and Kader, 2000; Mozafar, 1994; Shewfelt, 1990). Some citrus fruit contained more vitamin C when grown under cool temperatures than hot temperatures (Lee and Kader, 2000; Nagy and Wardowski, 1988).

No correlation was found between ascorbic acid and TSS content for longans, lychees, or rambutans. Although harvest maturity was based on pericarp color, TSS may indicate slight maturity differences that are not easily detected by peel color. However, TSS alone may not be a good maturity index for these crops (Batten, 1989; Kosiyachinda et al., 1987). TSS content is an estimate of fruit sugar content and eating quality. All three species are nonclimacteric, and will not continue to ripen and accumulate sugars after harvest. TSS content increases and acidity decreases as fruit ripen on the tree (Kosiya-chinda et al., 1987; O'Hare, 1997; Paull et al., 1984). Depending on cultivar, TSS content at maturity ranges from 16 to 25 °Brix for longans, 13–20 °Brix for lychees, and 17–21 °Brix for rambutans (Kosiyachinda et al., 1984; Tongdee, 1997; Underhill et al., 1997). Therefore, the Hawaii-grown fruit were within the range of soluble solids reported by others (Table 1).

#### 3.2. Mineral content

Longans are a good source of potassium (K) and copper (Cu). New DRI values have been established for K, and the daily adequate intake for adults is 4700 mg (IOM, 2004). Fresh longans (100 g) can supply 7% of the DRI for K and 29% of the DRI for Cu (Table 2). The cultivar, Sri Chompoo, averaged 334.4 mg K/100 g and Biew Kiew fruit averaged 318.6 mg K/100 g (Table 2). Copper ranged from 0.23 to 0.30 mg/100 g in longan fruit. Longans also may provide 3-5% of the DRI for phosphorus (P), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn). This study is the most complete analysis of longan fruit mineral content, and the values are higher than that listed by USDA (USDA-ARS, 2004). The USDA database (USDA-ARS, 2004) lists 21 mg P, 266 mg K, 1 mg Ca, 10 mg Mg, 0.13 mg Fe, 0.05 mg Mn, 0.05 mg Zn, and 0.17 mg Cu (per 100 g longan fruit), but the data is based on one composite sample.

Consumption of lychee fruit (100 g) would meet 2-4% of the DRI for six minerals (P, K, Mg, Fe, Zn, Mn), and provide 22% of the DRI for Cu (Table 3). The results

generally agree with the USDA database (USDA-ARS, 2004), but are higher for Mg, Na, Fe, Zn and Cu (Table 3). The lychee mineral contents of Bosworth-3, Groff, and Kaimana also fall within the range reported by Wenkam (1990) for cultivars, Brewster and Kwai Mi, grown in Hawaii.

Rambutan fruit (100 g) are a good source of Cu (20% of the DRI) and Mn (8–10% of the DRI). Copper content ranged from 0.16 to 0.20 mg/100 g, and Mn content ranged from 0.07 to 0.38 mg/100 g (Table 4). Rambutan consumption also meets 2–6% of the DRI for five minerals (P, K, Mg, Fe, Zn). This is the most complete report for rambutan fruit mineral composition. Rambutan nutritional composition is not reported in the USDA database (USDA-ARS, 2004) or by Wenkam (1990).

## 3.3. Soil analyses

Fruit were harvested from orchards planted on Andisol and Histosol soils on the island of Hawaii, and from Oxisol soils on the island of Kauai (Uehara and Ikawa, 2000). Hawaii is the youngest island in the state, with active volcanos and recent lava flows. Andisols are found on young, but not recent, land surfaces and have surface deposits of volcanic ash and weakly developed horizons (US Department of Agriculture and Soil Conservation Service (USDA-SCS), 1973). Histosols are organic soils that occur as shallow layers over Aa or pahoehoe lava (USDA-SCS, 1973). Oxisols are strongly weathered soils, acidic and rich in iron and aluminum oxides (US Department of Agriculture, Soil Conservation Service (USDA-SCS), 1972).

The soil analyses are included for informational purposes only (Table 5). No attempt was made to record fertilization practices of the growers, and variability in

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Mineral content of Biew Kiew and Sri Chompoo longan fruit grown in Hawaii

Mineral	$DRI^{a}$	Biew Kiew			Sri Chompoo	
(mg/100 gfw)	(mg/day)	Kilauea <sup>b</sup>	Kurtistown	Puueo	Kurtistown	Puueo
Macro						
Phosphorus	700	$35.7 \pm 1.1^{\circ}$	$31.6 \pm 0.7$	$31.5 \pm 1.3$	$30.1 \pm 1.5$	$31.8 \pm 0.6$
Potassium	4700	$306.9 \pm 6.0$	$338.2 \pm 7.9$	$310.6 \pm 17.7$	$331.6 \pm 14.8$	$337.2 \pm 8.1$
Calcium	1000	$6.9 \pm 0.6$	$6.7 \pm 0.6$	$9.5 \pm 1.1$	$10.7 \pm 1.4$	$8.5 \pm 0.8$
Magnesium	320, 420	$10.4 \pm 0.5$	$13.9 \pm 0.4$	$12.8 \pm 0.8$	$14.3 \pm 0.7$	$14.1 \pm 0.8$
Sodium	1500	$8.5 \pm 1.1$	$12.6 \pm 1.4$	$5.8 \pm 1.4$	$18.7 \pm 1.3$	$9.5 \pm 1.8$
Micro						
Iron	18, 8	$0.67 \pm 0.04$	$0.47 \pm 0.04$	$0.46 \pm 0.05$	$0.46 \pm 0.03$	$0.63 \pm 0.05$
Manganese	1.8, 2.3	$0.08 \pm 0.01$	$0.08 \pm 0.00$	$0.06 \pm 0.00$	$0.10 \pm 0.01$	$0.08\pm0.00$
Zinc	8, 11	$0.23 \pm 0.02$	$0.28 \pm 0.01$	$0.30 \pm 0.04$	$0.27 \pm 0.01$	$0.28 \pm 0.01$
Copper	0.90	$0.32 \pm 0.03$	$0.27 \pm 0.01$	$0.28 \pm 0.02$	$0.23 \pm 0.01$	$0.22 \pm 0.01$
Boron	ND	$0.18 \pm 0.01$	$0.14 \pm 0.01$	$0.19 \pm 0.01$	$0.08 \pm 0.01$	$0.22 \pm 0.03$

<sup>a</sup>Dietary reference intakes (DRI) are the most recent set of dietary recommendations established by the Food and Nutrition Board of the Institute of Medicine (IOM) (2000a, 2001, 2004). Values given are for adult females and males, ages 19–50 years. For boron, ND = not determinable.

<sup>b</sup>Kilauea is on the island of Kauai. Kurtistown and Puueo are on the island of Hawaii.

<sup>c</sup>Values are means ( $\pm$ SE) of six replications per cultivar at each location.

Mineral content	of Bosworth 3, G	roff, and Kaimana l	ychee fruit grown in	Hawaii		
Mineral (mg/100 gfw)	DRI <sup>a</sup> (mg/day)	Bosworth 3		Groff	Kaimana	
(	(ing/day)	Hakalau <sup>b</sup>	Kurtistown	Kilauea	Hakalau	Puueo
Macro						
Phosphorus	700	$25.4 \pm 1.4^{\circ}$	$23.7 \pm 1.6$	$28.2 \pm 0.9$	$26.9 \pm 1.1$	$31.1 \pm 2.0$
Potassium	4700	$172.4 \pm 8.2$	$159.6 \pm 10.7$	$140.2 \pm 3.8$	$153.3 \pm 11.2$	$180.6 \pm 16.8$
Calcium	1000	$4.7 \pm 0.4$	$2.1 \pm 0.1$	$4.9 \pm 0.6$	$3.3 \pm 0.4$	$4.5 \pm 0.4$
Magnesium	320, 420	$11.5 \pm 0.5$	$13.1 \pm 0.8$	$15.5 \pm 0.5$	$13.9 \pm 0.6$	$16.2 \pm 0.6$
Sodium	1500	$6.8 \pm 0.8$	$3.1 \pm 0.4$	$7.9\pm0.8$	$3.7 \pm 0.8$	$4.5\pm0.7$
Micro						
Iron	18, 8	$0.43 \pm 0.05$	$0.36 \pm 0.04$	$0.41 \pm 0.02$	$0.33 \pm 0.05$	$0.38 \pm 0.04$
Manganese	1.8, 2.3	$0.07 \pm 0.01$	$0.05 \pm 0.01$	$0.11 \pm 0.01$	$0.06 \pm 0.01$	$0.10 \pm 0.03$
Zinc	8,11	$0.16 \pm 0.01$	$0.26 \pm 0.02$	$0.28 \pm 0.01$	$0.19 \pm 0.01$	$0.26 \pm 0.01$
Copper	0.90	$0.20 \pm 0.01$	$0.17 \pm 0.02$	$0.23 \pm 0.01$	$0.17 \pm 0.01$	$0.20 \pm 0.02$

 $0.11\pm0.01$ 

Mineral content	of Bosworth 3	Groff and	d Kaimana l	vchee fruit	grown in	Hawaii
winneral content	or bosworth 5.	Oron, and	a ixamnana i	yonce munt	grown m	11a wan

<sup>a</sup>Dietary reference intakes (DRI) are the most recent set of dietary recommendations established by the Food and Nutrition Board of the Institute of Medicine (IOM) (2000a, 2001, 2004). Values given are for adult females and males, ages 19-50 years. For boron, ND = not determinable.

0.12 + 0.01

<sup>b</sup>Hakalau, Kurtistown, Puueo, and Waiakea are on the island of Hawaii. Kilauea is on the island of Kauai.

<sup>c</sup>Values are means ( $\pm$ SE) of six replications per cultivar at each location.

0.09 + 0.01

ND

Table 4

Boron

Mineral content of R9	, Jitlee, R162,	Rongrien, R13	4, and Silengkeng	g rambutan fruit	grown in Hawaii
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Mineral	DRI <sup>a</sup>	R9	Jitlee	R162	Rongrien		R134	Silengkeng
(mg/100 gfw)	(mg/day)	Kurtistown <sup>b</sup>	Keaau	Keaau	Keaau	Pepeekeo	Pepeekeo	Pepeekeo
Macro								
Phosphorus	700	$18.8 \pm 0.8^{\circ}$	$17.6 \pm 0.7$	$16.9 \pm 1.8$	$17.1 \pm 1.6$	$18.4 \pm 1.0$	$17.8 \pm 1.5$	$8.8 \pm 1.6$
Potassium	4700	$174.8 \pm 7.6$	$197.6 \pm 15.7$	$249.4 \pm 26.1$	$229.0 \pm 25.4$	$134.5 \pm 10.6$	$139.2 \pm 14.5$	$133.5 \pm 14.2$
Calcium	1000	$7.6 \pm 0.6$	$6.8 \pm 0.9$	$8.4 \pm 0.7$	$8.7 \pm 0.7$	$7.6 \pm 1.0$	$8.6 \pm 1.1$	$7.7 \pm 0.7$
Magnesium	320, 420	$15.4 \pm 0.5$	$16.6 \pm 0.4$	$17.2 \pm 1.3$	$16.6 \pm 1.9$	$13.3 \pm 0.6$	$16.3 \pm 1.1$	$16.7 \pm 1.6$
Sodium	1500	$6.3 \pm 0.6$	$5.7 \pm 0.8$	$8.2 \pm 1.2$	$6.5 \pm 0.8$	$5.7 \pm 0.6$	$6.2\pm0.8$	$5.5\pm0.5$
Micro								
Iron	18, 8	$0.50 \pm 0.05$	$0.49 \pm 0.10$	$0.44 \pm 0.02$	$0.53 \pm 0.04$	$0.41 \pm 0.04$	$0.42 \pm 0.04$	$0.56 \pm 0.07$
Manganese	1.8, 2.3	$0.11 \pm 0.01$	$0.38 \pm 0.18$	$0.30 \pm 0.07$	$0.19 \pm 0.03$	$0.07 \pm 0.01$	$0.16 \pm 0.02$	$0.12 \pm 0.02$
Zinc	8, 11	$0.26 \pm 0.01$	$0.20 \pm 0.01$	$0.22 \pm 0.02$	$0.21 \pm 0.01$	$0.23 \pm 0.01$	$0.16 \pm 0.01$	$0.18 \pm 0.02$
Copper	0.90	$0.18\pm0.01$	$0.17 \pm 0.01$	$0.17 \pm 0.02$	$0.17 \pm 0.02$	$0.20 \pm 0.01$	$0.18 \pm 0.02$	$0.16 \pm 0.01$
Boron	ND	$0.12 \pm 0.01$	$0.11 \pm 0.01$	$0.16 \pm 0.01$	$0.14 \pm 0.01$	$0.13 \pm 0.01$	$0.13 \pm 0.01$	$0.13 \pm 0.01$

<sup>a</sup>Dietary reference intakes (DRI) are the most recent set of dietary recommendations established by the Food and Nutrition Board of the Institute of Medicine (IOM) (2000a, 2001, 2004). Values given are for adult females and males, ages 19-50 years. For boron, ND = not determinable.

<sup>b</sup>Kurtistown, Keaau and Pepeekeo are on the island of Hawaii.

<sup>c</sup>Values are means  $(\pm SE)$  of six replications per cultivar at each location.

fruit tissue and soil mineral analyses may reflect differences in fertilization patterns rather than inherent soil differences. The results for some nutrients (P, Ca, K, Mg) would be influenced by fertilizer applications more so than others (Fe, Mn, Zn). Older soils on Kauai (Kilauea) had higher Mn levels than the youngest soils on the island of Hawaii. Zn was highest in the Olaa silty clay loam at Kurtistown. Hakalau and Waiakea soils had the highest Fe contents. High rainfall areas (Hilo soil series on Hawaii island) can leach nutrients such as K, Ca, and Mg to low levels, and this is apparent in the soil data. Also, plant nutrient uptake can deplete soil minerals. In general, fruit mineral content was not associated with soil mineral content (Tables 2-5) for the three species.

 $0.13 \pm 0.01$ 

0.16 + 0.01

Waiakea

 $28.8\pm0.8$ 

 $130.7 \pm 8.4$ 3.1 + 0.5

 $13.7 \pm 0.5$ 

 $3.1\pm0.7$ 

 $0.28 \pm 0.03$ 

0.05 + 0.01

 $0.24\pm0.01$ 

 $0.20\pm0.02$ 

 $0.13 \pm 0.01$ 

#### 4. Conclusions

Longan, lychee, and rambutans were harvested from different locations in Hawaii and analyzed for vitamin C and mineral composition. Different cultivars of each fruit type were analyzed, and samples were collected from orchards with various soil types. The data presented are the most complete analyses of vitamin C and mineral compositions for longans, lychees and rambutans.

Table 3

Crop	Cultivar	Location	Soil classification	Hd	Soil analy	sis								
					Ъ	К	Ca	Mg	Na	Mn	Fe	Cu	Zn	
							зн) шdd	s/g)			[	ng/dm <sup>3</sup>		
Longan	Biew Kiew	Kilauea	Lihue silty clay	6.1	80	524	1186	478	68	273	286	6	3	
Longan	Biew Kiew	Kurtistown	Olaa silty clay loam	6.2	225	372	1502	329	37	51	829	6	63	
Longan	Sri Chompoo	Kurtistown	Olaa silty clay loam	5.9	255	286	1348	380	26	65	680	7	68	
Longan	Biew Kiew	Puueo	Hilo silty clay loam	6.0	62	256	345	150	28	38	446	15	2	
Longan	Sri Chompoo	Puueo	Hilo silty clay loam	5.9	40	188	642	200	26	40	913	13	1	
Lychee	Bosworth-3	Hakalau	Hilo silty clay loam	5.7	25	116	146	68	32	14	1853	7	6	
Lychee	Kaimana	Hakalau	Hilo silty clay loam	5.7	52	80	218	76	38	14	2794	9	5	
Lychee	Groff	Kilauea	Lihue silty clay	5.6	37	376	1232	290	44	209	294	12	7	
Lychee	Bosworth 3	Kurtistown	Olaa silty clay loam	6.4	81	206	1324	278	38	49	722	6	37	
Lychee	Kaimana	Puueo	Hilo silty clay loam	5.7	49	58	274	86	26	48	392	14	2	
Lychee	Kaimana	Waiakea	Papai stony muck	5.9	100	38	402	196	24	49	2351	10	7	
Rambutan	Rongrien	Keaau	Olaa silty clay loam	5.6	95	42	636	146	20	43	1058	12	14	
Rambutan	Jitlee	Keaau	Olaa silty clay loam	5.7	76	136	750	194	26	38	852	11	6	
Rambutan	R162	Keaau	Olaa silty clay loam	5.6	116	44	422	130	24	44	829	12	6	
Rambutan	R9	Kurtistown	Olaa silty clay loam	5.9	118	276	1290	489	47	63	897	10	72	
Rambutan	R134	Pepeekeo	Hilo silty clay loam	5.5	26	46	148	94	26	36	1006	6	4	
Rambutan	Silengkeng	Pepeekeo	Hilo silty clay loam	5.5	26	60	150	88	26	41	853	11	9	
Rambutan	Rongrien	Pepeekeo	Hilo silty clay loam	5.6	19	46	82	09	22	22	969	12	4	

Table 5 Soil classification and analysis for tropical fruit orchards in Hawaii

Hakalau, Keaau, Kurtistown, Pepeekeo, Puueo, and Waiakea are on the island of Hawaii. Kilauea is on the island of Kauai.

The daily vitamin C requirement for the average adult (75-90 mg) can be met by consuming about 12–14 longans, 10–12 rambutans, or 14–17 lychees. Among the three Sapindaceae species, longan had the highest vitamin C content (60.1 mg/100 g). Average ascorbic acid content was 27.6 mg/100 g for lychees and 36.4 mg/100 g for rambutans. No correlation was found between ascorbic acid and TSS content for longans, lychees, or rambutans.

Longans are a good source of K (324.9 mg/100 g) and Cu (0.26 mg/100 g), and also may provide 3–5% of the DRI for P, Mg, Fe, Mn, and Zn. Lychee fruit consumption would meet 2–4% of the DRI for six minerals (P, K, Mg, Fe, Zn, Mn), and provide 22% of the DRI for Cu. Rambutan fruit are a good source of Cu and Mn, and also can provide 2–6% of the DRI for five minerals (P, K, Mg, Fe, Zn). Fruit mineral compositions were not related to soil mineral analyses.

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