Total antioxidant activity, fiber and pectin content of select Florida-grown tropical fruits
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Introduction

Little is known about the nutritional value of tropical fruits, especially the more exotic species. The information available is for various Asian (Chang et al., 1998; Leong et al., 2002) and African (Luximon-Ramma et al., 2003) varieties, which are often different from those grown in Florida, analyzed using different methods, and grown under different conditions. In this study, select tropical fruits from south Florida were analyzed for important nutritional components.

The function of natural antioxidants and dietary fiber in foods and biological systems has received much attention. Fruits and vegetables play a significant role in the human diet providing protection against cellular damage caused by exposure to high levels of free radicals (Ames et al. 1993; Dillard and German 2000; Prior and Cao, 2000), while also aiding digestion (AACC, 2001; Weisburger et al., 1993). This is attributed to the fact that these foods provide an optimal mix of antioxidants such as vitamin C and E, polyphenols, carotenoids (Ness and Powles 1997; Esterbauer et al. 1991; Eastwood, 1999) and complex carbohydrates (AACC, 2001).

Dietary fibers in foods are also beneficial for good health. Physiological impacts of insufficient dietary fiber intake are constipation, increased risk of coronary heart disease, and increased fluctuation of blood glucose and insulin levels (AACC, 2001; Jenkins et al., 1998). With regard to some cancers and coronary heart disease and there is also evidence for beneficial roles of fruits and vegetables in the human diet based on their dietary fiber content (Weisburger et al., 1993; Harris and Ferguson, 1993). The National Research Council (2002) set Dietary Reference Intakes for the first time for dietary fiber determining that "Adequate Intakes" (AI) for dietary fiber be based on 14 grams dietary fiber per 1,000 calories. The FDA (1993) set a Daily Reference Value on food labels for fiber at 25 grams for a 2,000-calorie diet. Five g or more fiber per serving is considered a significant amount. One major component of soluble fibers is pectin, which is largely composed of uronic acid residues such as galacturonic acid. Pectin and other soluble polysaccharides may undergo some metabolism in the small intestine and especially in the large intestine through bacterial enzymes, converting it to products that contribute to maintaining the colonic microflora, which is beneficial to digestion (Weisburger et al., 1993; Cummings et al., 1979; Holloway et al., 1983). One major component of soluble fibers is pectin, which is beneficial to digestion (Weisburger et al., 1993; Cummings et al., 1979; Holloway et al., 1983).

The objective of this study was to obtain nutritional information for Florida-grown tropical fruits (red guava, white guava, carambola, red dragon, white dragon fruit, mamey, sapodilla, lychee, longan, mango and papaya) in terms of antioxidant capacity, total phenolics, total vitamin C (total ascorbic acid, TAA), total dietary fiber (TDF) and pectin. Since different ethnic groups prefer different maturity stages of some fruits, like mango and papaya, both ripe and green stages were assayed.

<u>Materials and Methods</u>

*Fruit***.** Fourteen different tropical fruits from south Florida including red guava (*Psidium guajava* L., cv. Sardina), white guava (*Psidium guajava* L., Thai cultivar), carambola (*Averrhoa carambola* L., cv. Golden Star), red pitaya (red dragon fruit, *Hylocereus sp*, cv. Red Jaina.), white pitaya (white dragon fruit, *Hylocereus sp.*, cv. David Bowie), mamey (*Pouteria sapota,* cv. Pantin*)*, sapodilla (*Achras (manilkara) zapota,* cv. Brown Sugar), lychee (*Litchi chinensis,* cv. Mauritius*)*, longan (*Dimocarpus longana,* cv. Kohala*)*, green and ripe mango (*Mangifera indica* cv. Keitt), green papaya (*Carica Papaya* cv. Exp. 15, a variety that is produced for the green papaya market), and ripe papaya (*Carica Papaya* cv. red lady, a variety that is produced for the ripe papaya market) were obtained from Florida tropical fruit growers. The composite of at least 10 fruit were combined per each of three replicate samples. The edible portion of the fruit was cut and flash frozen in liquid nitrogen and kept at -20 ºC until analysis.

Total antioxidant, phenolics and vitamin C. Two methods were used to evaluate the antioxidant potential of fruit extracts; ORAC (oxygen radical absorbance capacity) (Talcott et al, 2003) and free radical DPPH scavenging activity (Manthey, 2004). DPPH (2,2-diphenyl-2-picrylhydrazyl hydrate) reacts with an antioxidant compound and is reduced, donating a hydrogen, which causes a color change that can be measured using a spectrophotmeter. Total phenolics were analyzed using the Folin-Ciocalteu assay and expressed in gallic acid equivalents. One-way analysis of variance and Duncan Multiple

Range Test (DMRT) as conducted to identify differences among means. Statistical significance was determined at $p < 0.05$.

The total ascorbic acid (TAA) was assayed as previously described with some modification (Nisperos-Cariedo et al., 1992). The total ascorbic acid (TAA) was assayed as previously described with some modification (Nisperos-Cariedo et al., 1992). Detection of the acids was performed at 260 nm (for ascorbic acid) and 295 nm (for dehydroascorbic acid) using a photo diode array detector scanning from 200-500 nm (ThermoFinnigan Spectra System P4000).

Total dietary fiber and pectin. The sample preparation method was according to Theander (1995) with some modification. Briefly, triplicate 500 mg dry fruit puree samples were transferred into 50 mL polypropylene centrifuge tubes (Beckman Instruments, Inc.). Acetate buffer (5 mL) was added at pH 5.0 along with 40 μL α-amylase (heat stable α-amylase from *Bacillus amyloliquefaciens*, Sigma-Aldrich, Inc.). The hydrolyzed solution was then passed through a using a Sep-Pak C-18 (Waters corporation) column and stored at 4°C for galacturonic acid analysis. The determination of galacturonic acid in the hydrolyzed samples was optimized from the original method of Scott (1979) by Luzio (2004) using a microplate reader (Power Wave 340 microplate reader with KC4 version 3.01 software, BioTek Industries). The determination was performed in triplicate for each of the hydrolyzed samples, therefore 9 replicates were obtained per fruit type. The total dietary fiber assay was based on the method published in the 16th Edition of the Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC, 1997) using the total dietary fiber assay kit from Sigma-Aldrich (TDF 100A).

Results

Antioxidants and vitamin C. Carambola and red guava had the highest antioxidant activity of the selected Florida fruit while sapodilla and green papaya (*Carica Papaya* cv. Exp. 15) had the lowest (Table 1). Leong and Shui (2002) reported similar results showing carambola and guava having high antioxidant activity among 27 fruit studied in Singapore markets. Both ripe papaya and mango exhibited higher antioxidant activity and total phenolics compared to their green counterparts, probably due to the increase in carotenoids (give red-orange color to fruits) as the fruits ripened. This pattern was not true for vitamin C measured as total ascorbic acid (TAA), however, with green mango having higher levels of TAA than ripe mango, whereas with papaya the opposite situation was found. This is in agreement with values reported by Salunkhe and Desai (1984) for both fruit at green and ripe stages. The higher antioxidant activity of red compared to white dragon fruit is likely due to the red pigmentation (putatively from anthocyanins), which is in agreement with previous studies (Wang and Lin, 2000; Wang et al, 1997). Both ripe papaya and mango exhibited higher antioxidant activity and total phenolics compared to their green counterparts, probably due to the increase in carotenoids as the fruits ripened. This pattern was not true for TAA, however, with green mango having higher levels of TAA than ripe mango, whereas with papaya the opposite situation was found. This is in agreement with values reported by Salunkhe and Desai (1984) for both fruit at green and ripe stages. Red guava and carambola, which exhibited the highest antioxidant activities, also contained high levels of total phenolics, and while guava was highest also in TAA, carambola was relatively low (Table 1). Some studies have demonstrated a linear correlation between total phenolic and antioxidant activity by ORAC in fruit and vegetables (Cao et al., 1996; Wang et al., 1996; Prior et al, 1998; Wang and Lin 2000, Wu et al. 2004) but total phenolics and antioxidant activity is not correlated across all types of foods (Wu et al. 2004). The higher antioxidant activity of red compared to white dragon fruit is likely due to the red pigmentation (putatively from anthocyanins), which is in agreement with previous studies (Wang and Lin, 2000; Wang et al, 1997). This suggests that the major source of antioxidant capacity of these fruits may be not from vitamin C, but rather from phenolics. For example, carambola has high total phenolic, ORAC and DPPH values, yet relatively low levels of vitamin C (TAA) compared to guava. This would indicate that carambola is more nutritious than would be assumed from vitamin C values alone.

Comparison of the results with literature data for antioxidants. Since ORAC had been extensively used to evaluate antioxidant activity of fruits and vegetables, the data from this study were compared to published ORAC antioxidant values (Table 3). Guava, carambola, red dragon fruit, mamay, lychee and ripe papaya ORAC values were similar to or greater than published ORAC values for other common fruits and vegetables, including cucumber, melon, pear, tomato, carrot, apple, banana, white and red grape, pink grapefruit, kiwi, orange, plum, spinach, strawberry, red raspberry, and blueberries (for which there is quite a range of values reported) (Table 2). The total phenolic (antioxidant compounds) values compared favorably to strawberry, red raspberry, blackberry, black raspberry, and blueberries (for which there also is also a range of values reported).

Total dietary fiber and pectin. The selected Florida tropical fruits had widely different levels of total dietary fiber (TDF) and pectin (component of fiber). The TDF and pectin ranged from 0.88 to 7.25 g/100 g and 0.2 to 1.04 g/100 g for TDF and pectin, respectively (Table 4). Red guava again was highest in TDF and pectin followed by mamey, sapodilla and white quava for TDF, while white guava exhibited the same pectin levels as mamey. Green papaya and green mango had more TDF than their ripe counterparts, although ripe mango had slightly more pectin than green mango. The variety of papaya grown for the green market (Exp. 15) had higher levels of TDF and pectin than the green or ripe stage for the papaya variety produced for the ripe market (Red Lady). Red dragon fruit exhibited higher TDF and pectin than did white dragon fruit.

Comparison of the results with literature data for fiber and pectin.

Tropical TDF and pectin values compared very favorably to those of other common fruits (Table 5). Red guava had TDF values that were higher than all other common fruit literature values except cherries, and mamey TDF was higher than all but cherries and raspberries. Red dragon fruit, white guava and sapodilla all had higher TDF values than most common fruits with the exception of the above and blackberries. Ripe mango, papaya, lychee, guava and mamey all had pectin levels that were comparable to what literature values are available for grape, orange, apple and banana, for which the latter two fruit have a wide range of published values (Table 5).

Conclusion. Overall, the data from this study indicate that consumption of Florida tropical fruit varieties delivers healthful benefits by supplying natural antioxidants that are protective against cellular damage, while improving digestion and maintaining blood sugar levels. Guava is an especially nutritious fruit, with high antioxidant activity, phenolics, vitamin C, TDF and pectin (16.7 μg TE/g, μg GA/g, 131.91 mg/100 g, 7.25 g/100 g and 1.04g/100 g, respectively) compared to other fruits tested as well as those in the literature (Tables 1, 2 ,3 and 4). Carambola is also nutritious, being very high in antioxidants and phenolics (12.94 μg TE/g and 2207.65 μg GA/g, respectively), as well as mamay, being high in TDF and pectin (6.12 and 0.77 g/100 g, respectively) compared to most fruits. Red dragon fruit and sapodilla were likewise elevated in TDF and red dragon fruit was also high in antioxidant activity. Consuming mango and papaya at the ripe stage would be preferable for antioxidant protection, but green mango and papaya offer more fiber, and green mango more vitamin C.

Work is almost complete on volatiles and ongoing for carotenoids to complete the nutrition picture for Florida tropical fruits. We hope to have an updated report in May, 2006.

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Table 1 Moisture (%), total phenolic, total ascorbic acid, antioxidant activity by ORAC and DPPH. Data for total phenolic, ascorbic acid, ORAC and DPPH are ± 95% confidence interval.

Fruit	% Moisture	Total phenolic μg GA/g puree	Total ascorbic acid mg/100 g puree	ORAC μM TE/g puree	DPPH μg GA/g puree
Red guava	85.3	2316.7 ± 167.6	131.9 ± 10.6	16.7 ± 0.6	609.3 ± 31.9
Carambola	91.4	2207.7 ± 156.7	22.7 ± 5.0	12.9 ± 1.0	620.2 ± 40.9
White guava	87.1	1589.3 ± 75.4	159.6 ± 16.1	9.9 ± 0.7	298.6 ± 22.6
Red dragon	83.6	1075.8 ± 71.7	29.2 ± 7.0	7.6 ± 0.1	134.1 ± 30.1
Mamey	64.5	1010.5 ± 40.2	13.6 ± 1.0	6.6 ± 0.3	247.1 ± 18.3
Lychee	85.1	770.1 ± 30.1	35.7 ± 1.5	5.4 ± 0.2	103.8 ± 13.8
White dragon	84.7	523.4 ± 33.6	17.1 ± 2.4	3.0 ± 0.2	34.7 ± 7.3
Ripe mango	82.9	508.9 ± 29.4	21.1 ± 1.5	2.2 ± 0.1	123.7 ± 12.3
Green mango	84.9	505.8 ± 51.8	73.8 ± 1.9	1.5 ± 0.2	167.5 ±13.4
Sapodilla	74.5	501.8 ± 39.3	80.3 ± 4.3	1.4 ± 0.1	2.1 ± 0.2
Longan	82.6	481.9 ± 37.4	106.2 ± 2.4	3.3 ± 0.1	69.6 ± 19.7
Ripe papaya (cv. Red lady)	89.3	442.2 ± 29.7	72.3 ± 3.7	5.3 ± 0.3	65.1 ± 15.8
Green papaya (cv. Red lady)	92.4	311.1 ± 18.9	57.3 ± 1.5	2.6 ± 0.2	29.7 ± 5.4
Green papaya (cv. Exp. 15)	93.9	205.4 ± 35.8	60.2 ± 2.0	0.03 ± 0.01	10.4 ± 1.6

Table 2. Antioxidant activity (ORAC) and total phenolics of other fruits and vegetables compared to the selected tropical fruits from this study (**in bold**). Fruits are ranked from low to high ORAC values

Fruit	ORAC (study and literature)	Total phenolic (study and literature)	Total phenolic (literature only)
	μM TE/g puree	μg GA/g puree	μg GA/g puree
green papaya (exp/115)	**0.01**	**205**	
cucumber[b]	0.50		
melon[a]	0.97		
pear[a]	1.34		
Sapodilla (cv. Brown Sugar)	**1.36**	**502**	
green mango (cv. Keitt)	**1.49**	**506**	
tomato[a]	1.89		
carrot[b]	2.10		
ripe mango (cv. Keitt)	**2.17**	**509**	560
apple[a]	2.18		
banana[a]	2.21		
white dragon (cv. David Bowie)	**2.96**	**523**	
Longan (cv. Kohala)	**3.31**	**482**	
grape, white[a]	4.46		
grapefruit, pink[a]	4.83		
Lychee (cv. Mauritius)	**5.42**	**770**	288
kiwi fruit[a]	6.02		
Mamey (cv. Pantin)	**6.56**	**1010**	
grape,red[a]	7.39		
orange[a]	7.50		
red dragon (cv. Red Jaina)	**7.59**	**1076**	
plum[a]	9.49		
white guava (Thai cultivar)	**9.90**	**1589**	2473
spinach[b]	12.60		
Carambola (cv. Golden Star)	**12.94**	**2208**	2099
strawberry[e]	14.9	1030	
strawberry[a]	15.36		
red guava (cv. Red Lady)	**16.70**	**2317**	1264
red raspberry[e]	18.2	2340	
garlic[b]	19.40		
blackberry[e]	22.4	2260	
black raspberry[e]	28.2	2670	
blueberries[d]	14 - 38	1810 - 4580	

Sources of data on other fruits, and from other reports on tropical fruits:
[a]Wing et al., 1996, [b]Cao et al., 1996, [c]Luximon-Ramma et al., 2003, [d]Priot et al., 1998, [e]Wang and Lin, 2000.

Table 3. Pectin and total dietary fiber (TDF) of Florida tropical fruit

Fruit	% Moisture	TDF g/100 g fruit	pectin g/100 g fruit
Guava (red)	85.33	7.25 ± 0.05	1.04 ± 0.02
Mamey	64.52	6.12 ± 0.06	0.77 ± 0.02
Sapodilla	74.47	4.41 ± 0.09	0.35 ± 0.01
Guava (white)	87.14	4.05 ± 0.07	0.77 ± 0.01
Dragon (red)	83.61	3.20 ± 0.08	0.27 ± 0.01
Papaya (green, cv. Exp.15)	93.85	2.13 ± 0.02	0.60 ± 0.02
Papaya (green, cv. Red Lady)	92.42	1.75 ± 0.00	0.51 ± 0.01
Mango (green)	84.92	1.63 ± 0.02	0.48 ± 0.01
Lychee	85.12	1.59 ± 0.03	0.48 ± 0.01
Papaya (ripe, cv. Red Lady)	89.27	1.48 ± 0.06	0.49 ± 0.01
Mango (ripe)	82.88	1.40 ± 0.03	0.51 ± 0.01
Carambola	91.45	1.28 ± 0.02	0.27 ± 0.01
Dragon (white)	84.7	1.07± 0.03	0.12 ± 0.00
Longan	82.6	0.88 ± 0.01	0.20 ± 0.00

4 Pectin and total dietary fiber (TDF) of other fruit compared to the selected tropical fruits with cultivar names, if known, from this study **(in bold)**[1]

Fruit	TDF g/100 g (study and literature)	Fruit	Pectin g/100 g (study and literature)
Longan[2]	0.19		
Pineapple[4]	0.54		
Mango[2]	0.86		
Cantaloupe[3]	0.88		
Grape[3]	0.88	Grapes[6]	0.70-0.80
Longan (cv. Kohala)	**0.88**		**0.20**
Dragon fruit (white, cv. David Bowie)	**1.07**		**0.12**
Green mango (cv. Kaew)[4]	1.27		
Carambola (cv. Golden Star)	**1.28**		**0.27**
Lychee[5]	1.32		
Mango (ripe, cv. Keitt)	**1.40**		**0.51**
Pineapple[3]	1.42		
Papaya (ripe, cv. Red Lady)	**1.48**		**0.49**
Persimmon[4]	1.48		
Peaches[3]	1.53		
Lychee (cv. Mauritius)	**1.59**		**0.48**
Grapefruit[3]	1.63	Grapefruit (cv. Marsh)[6]	0.65
Mango (green, cv. Keitt)	**1.63**		**0.48**
Rambutan[4]	1.64		
Papaya (green, cv. Red Lady)	**1.75**		**0.51**
Papaya[3]	1.79		
Mango[3]	1.79		
Mango[5]	1.82		
Strawberries[3]	1.99		
Papaya (green, cv. Exp. 15)	**2.13**		**0.60**
Dragon fruit[2]	2.14		
Lychee (cv. Hong Hua)[4]	2.20		
Orange[3]	2.39	Oranges[6]	0.65
Apple[3]	2.39	Apple (cv. Golden Delicious)[6]	0.25-0.63
Blueberries[3]	2.41		
Banana[3]	2.60	Banana (ripening, cv. Williams)[6]	0.25-0.63
Guava[2]	2.70		
Carambola[3]	2.78		
Mamey[5]	3.00		
Pear[3]	3.07		
Ripe mango (cv. Keaw)[4]	3.10		
Dragon fruit (red, cv. Red Jaina))	**3.2**		**0.27**
Guava (white, Thai cultivar))	**4.05**		**0.77**
Sapodilla (cv. Brown Sugar)	**4.41**		**0.35**
Blackberries[3]	5.28		

Sapodilla[5]	5.31		
Guava[5]	5.39		
Guava (cv. Klom Sali)[4]	5.60		
Mamey	**6.12**		**0.77**
Raspberries[3]	6.50		
Guava (red)	**7.25**		**1.04**
Cherries (cv. Lambert and cv. Bing)[6]			0.44-1.02

[2]Nitithan et al 2004

[3]USDA National Nutrient database (www.nal.usda.gov)

[4]Gorinstein et al. 1999

[5]www.nutritiondata.com

[6] published values for pectin contents of fruits expressed as anhydrogalacturonic acid, cited in Baker, 1997