Kor. J. Hort. Sci. Technol. 30(4):363-370, 2012 DOI http://dx.doi.org/10.7235/hort.2012.11094

Physicochemical Characteristics and Fatty Acid Composition of Four Papaya Cultivars Grown under Plastic Greenhouse Conditions

Ebru Kafkas[1], Esma Gunes[2], and Hamide Gubbuk[2*]

[1]*Department of Horticulture, Faculty of Agriculture, University of Cukurova & Biotechnology Research and Experimental Center, 01330, Balcali, Adana, Turkey*

[2]*Department of Horticulture, Faculty of Agriculture, University of Akdeniz, 07059, Antalya, Turkey*

Abstract. Some physicochemical characteristics like nutritional values, sugar content, and fatty acid composition (FAs) in fruits of four papaya (*Carica papaya* L.) cultivars ('Red Lady', 'Sunrise Solo', 'Tainung', and 'BH-65') grown under plastic greenhouse conditions in the Mediterranean region of Turkey were evaluated. The chemical characteristics, except acidity in the fruits, significantly varied among the cultivars. Nitrogen (N) was the most abundant mineral in all papaya cultivars and ranged from 0.80 $g \cdot 100\ g^{-1}$ in 'Red Lady' to 1.28 $g \cdot 100\ g^{-1}$ in 'BH-65' in fresh weight. Potassium (K) and calcium (Ca) were found the highest amount in dry weight. Glucose and fructose were identified as the main sugars in all cultivars. Sucrose was in trace amounts in the three cultivars, but not detectable in cultivar 'Red Lady'. Twenty-five FAs were detected in the papaya fruits. Polyunsaturated fatty acids (PUFAs) were found to be in a highest amounts compared to the saturated fatty acid (SFAs) and monounsaturated fatty acids (MUFAs). Palmitic (C16:0), oleic (C18:1), and linoleic (C18:2n6) acids were the major fatty acids detected in all cultivars. The results of this study implied that dietary intake of papayas may supply substantial nutrient components necessary for human health.

***Additional key words*:** GC, HPLC, mineral elements, protected cultivation, sugar

Introduction

Tropical fruits are grown under subtropical conditions in Turkey. Due to the low temperature limitation in winter time, more recently the protected cultivation of tropical fruits is becoming increasingly popular in the subtropical areas. Because of better plant health, increased productivity, superior fruit quality, and substantially high income per unit land area protected cultivation has been seen as the best alternative.

Papaya is a tropical fruit which needs warm temperatures all year around to produce good quality fruits (Galan Sauco and Rodriguez Pastor, 2007). Therefore, the protected cultivation of papaya may provide an optimal environment for its growth and yield especially under subtropical condition. Furthermore, it will prevent the transmission of papaya ringspot virus (a major threat to field plantations), by its vectors (Galan Sauco and Rodriguez Pastor, 2007).

Papaya is known to be the most important species within the family *Caricaceae*, and is widely cultivated for consumption as a fresh, dried, or processed fruit in beverages, jams, candies, and crystallized items (Villegas, 1997). The green fruits, leaves, and flowers can be consumed as a cooked vegetable. In addition, the seeds and leaves of papaya are used in pharmaceutical products (Watson, 1997). Papaya leaves and unripe fruits contain the enzyme *papain* that is used as a meat tenderizer (FDA, 2008). Papain breaks down proteins into amino acids. The papaya fruit has neither cholesterol nor saturated fats (Anonymous, 2012).

Papaya has a higher content of vitamins (A, B_1, B_2, and C), dietary fiber, and minerals and provides good flavor, aroma, and texture (Oliveira and Vitoria, 2011; Othman, 2009). Nutritionally, papaya is also a good source of calcium (Nakasone and Paull, 1998; Oliveira and Vitoria, 2011) and

***Corresponding author:** gubbuk@akdeniz.edu.tr

※ Received 31 August 2011; Revised 12 May 2012; Accepted 22 May 2012. This study was supported by the Scientific Research Projects Coordination Unit of Akdeniz University. The authors thanks to Dr. Uri Lavi, Volcani Center (Israel), Dr. Barbara M. Reed, Agricultural Research Service, United States Department of Agriculture (USDA-ARS, Oregon/U.S.A), Dr. Tomas Ayala Silva, Agricultural Research Service, United States Department of Agriculture (USDA-ARS, Miami, FL/U.S.A) and Prof. Dr. Peter D S Caligari, c/o Facultad de Ciencias Agrarias Universidad de Talca, Talca/Chile for their critical review of this manuscript.

other minerals and nutrients such as magnesium, phosphorus, potassium, lipids, and amino acids (OECD, 2010). Therefore, papaya is important for the human diet (Anonymous, 2012). Papaya has a high primary antioxidant potential (Thanaraj and Terry, 2011). Özkan et al. (2011) evaluated the total phenolic and antioxidant potential of 'Sunrise Solo', 'Red Lady', and 'Tainung' cultivars. The highest total phenolic and antioxidant were found in the cultivar 'Sunrise Solo' followed by, 'Red Lady' and 'Tainung'.

Fruit quality features can vary depending on the cultivars developmental stage, ecological condition, and cultural practices. Zaman et al. (2006) compared the physicochemical composition of four papaya varieties grown at Rajshahi, Bangladesh and reported the highest fruit weight in 'Bombai' and the lowest in 'Shahi' (red). Amongst the four varieties studied, recovery of pulp, total soluble solids (TSS), and total sugar content differed between 80.46-87.41, 9.0-13.0, and 6.96-10.50% respectively. The physical and chemical composition of early, middle, and late season papaya (*Carica papaya* L.) fruits was evaluated by Othman (2009). Moisture content, reducing sugar, total sugars, TSS, titratable acidity, ascorbic acid (vitamin C), and polyphenol oxidase activity varied according to season and ripening period. Schweiggert et al. (2012) evaluated the chemical and morphological features in different papaya hybrids and lines grown in Costa Rica. Depending on the cultivar, TSS content ranged from 8.8 to 13.5 °Brix, and ascorbic acid content was 24.9-72.9 $mg \cdot 100\ g^{-1}$. L-ascorbic acid (vitamin C) levels ranged from 54 to 118 $mg \cdot 100\ g^{-1}$ depending on cultivars and ripening conditions (Islam et al., 1993; Vinci et al., 1995). Principal sugars in the fruit are glucose, fructose, and sucrose (Schweiggert et al., 2012). The sugar content of papaya can vary with the ripening stage and also seasonal variation (Othman, 2009). The reducing sugar and total sugar content of the papaya fruit increased during the ripening process and the highest content of total sugar were found in early season papaya fruits while the lowest were in late season fruit (Othman, 2009).

Linolenic acid is an essential fatty acid (FA) that cannot be synthesized by humans and must be obtained through daily diet. Studies indicated that reducing the dietary ratio of n-6 to n-3 FAs might play a role in decreasing the risk of heart diseases and cancer (Iso et al., 2002). Several studies have reported that various fruits play a role in the prevention of diseases and that anti-oxidative constituents in these fruits can scavenge free radicals and protect the body cells against oxidative damage to cellular macromolecular proteins, nucleic acids, and lipids (Hayatsu et al., 1999). Othman (2009) reported low levels (0.10 $g \cdot 100\ g^{-1}$) of crude fat in papaya fruit. OECD (2010) indicated that FA levels are low in papaya and palmitic acid and linolenic acid are the two major FAs in papaya. Chan and Taniguchi (1985) reported that FA composition changes in papaya pulp during fruit ripening stage, however, no significant difference was found in lipid composition with maturity of papaya fruits.

To our knowledge, there is no detailed previous publication describing fat and FA compositions of papaya and very little information exists on physical and biochemical features of papaya fruit grown under plastic greenhouse conditions. The purpose of this study was to determine the food quality parameters, nutritional value, and sugar, fat and FA composition of different papaya cultivars grown under plastic greenhouse condition in subtropical conditions.

Materials and Methods

Plant Materials

The study was conducted in the experimental field of the Seed Research and Development Center of Akdeniz University (altitude 38 m, latitude 36° 028' N, 030° 38-810' E). The average minimum and maximum temperatures in the experimental site were 15/28℃, and the relative humidity average over 60%. Three commercial papaya cultivars 'Red Lady', 'Sunrise Solo', and 'Tainung' and one South African selection 'BH-65' (Institute Tropical and Subtropical Crops (ARC) in South Africa) were propagated from seeds. The plastic greenhouse structure used in this study was made of metal. The top height and the height below the gutter was 6 m and 5 m, respectively, covered with low density polyethylene (LDPE) plastic (UV+IR, 150 micron thick). The plastic greenhouse was ventilated from the sides and the top. The greenhouse was not heated during the two growing seasons. The soil pH (between 0-60 cm) was 7.0, organic matter content was 4%, and the texture was clay-loam. Plants (40 cm height) were planted at 3.0 × 1.8 m (1.850 ha) spacing and a line drip irrigation system was installed on both sides (about 30-40 cm from the plants). The following nutrients were applied at the prescribed rates: Nitrogen (NH_4SO_4) 350 g, phosphorous (MAP) 225 g, potassium (KNO_3) 550 g, magnesium ($MgSO_4$) 25 g, and calcium ($CaNO_3$) 5 g per plant a year.

The fruits were harvested at a commercially ripening stage (about a fourth of the peel color approached yellow). All analyses were carried out on fruits at the full ripening stage (May harvest).

Fruit Quality Measurements

The juice extract from the homogenized fresh flesh of the fruits of each cultivar was used for determining the total soluble solids (TSS) using a hand-held refractometer (ATAGO N1, Tokyo, Japan). The titratable acidity measurements were made using 0.1 N NaOH solutions. Vitamin C was measured by the 2, 6-dichlorophenolindophenol titrimetric method (Cemeroğlu, 1992). The reaction mixture contained 0.5 mL fruit juice combined with 4.5 mL of 6% metaphosphoric acid followed by titration with 2:6-dichlorophenolindophenol until a solution pink color was obtained.

Mineral Elements Analysis

Mineral elements in the fruit were analyzed using ICP (Perkin Elmer 2100, Norwalk, CT, USA) on a dry weight basis (except for N) (USDA, 2004). Measurements were carried out at wavelengths specific for each element (P: 214,914 nm; K: 766,940 nm; Ca: 315,887 nm; Mg: 279,077 nm; Cu: 324,752 nm; Fe: 259,939 nm; Zn: 213,857 nm; Mn: 257,610 nm).

Sugars Determination

Approximately 100 g of each frozen sample was used and each replicate was analyzed separately using the procedure of Miron and Schaffer (1991). One gram of the sample weighed from the 100 g mixture and powdered in liquid nitrogen in a mortar and pestle and 20 mL of aqueous ethanol (80%, v/v) were added. The reaction mixture was placed in a Falcon tube with a screw cap, sonicated for 15 min at 80℃ in an ultrasonic bath, and filtered. The extraction procedure was repeated 3 times. All filtered extracts were combined and evaporated to dryness in a boiling water bath. The residue was dissolved in 2 mL of distilled water and filtered before HPLC analysis (Miron and Schaffer, 1991). The liquid chromatography apparatus (Hewlett Packard Agilent 1100 Series, Germany) consisted of an in-line degasser, pump and controller coupled to a refractive index detector (Hewlett Packard Agilent 1100 Series, Germany) equipped with an automatic injector (20 mL/injection) interfaced to a PC running Class VP chromatography manager software (Shimadzu, Japan). The separations were performed on a 150 mm × 4.6 mm *i.d.*, 5 μm reverse phase Nucleosil, NH_2 analytical column (Shimadzu, Japan) operating at room temperature with a flow rate of 1 $mL \cdot min^{-1}$. Elution was effected using an isocratic elution of the solvent, 75% aqueous acetonitrile. Components were identified by comparison of their retention times with those of authentic standards under analysis conditions. A 10 minute equilibrium time was allowed between injections.

FAs Determination

FAs extraction was carried out according to the protocol by Bligh and Dyer (Bligh and Dyer, 1959). Five g of frozen fruit among the 100 g homogenate included 5 fruits was weighed and 40 mL hexane was added for each sample. The samples were extracted using automatic extractor namely ASE (Accelerated Solvent Extraction, 350). Hexane was removed under nitrogen and then methyl esterification was done using Boron trifluoride/methanol mixture (AOAC, 1990). FAs composition was analyzed by GC Clarus 500 with auto sampler (Perkin Elmer, USA) equipped with a flame ionization detector and a fused silica capillary SGE column (30 m × 0.32 mm, ID × 0.25 μm, BP20 0.25 UM, USA). The oven temperature was 140℃, held 5 min, raised to 200℃ at a rate of 4℃ min^{-1} and then to 220℃ at a rate of 1℃ min^{-1}, while the injector and the detector temperature were set at 220℃ and 280℃, respectively. The sample size was 10 μL and the carrier gas was controlled at 16 spin a 1:100 dilution. FAs were identified by comparing the retention times of fatty acid methyl ester (FAME) with a standard 37 component FAME.

Statistics

The experiment was laid out with three replications and five fruits (fruits were randomly taken from 12 plants) in each replicate in a completely randomized design. The results were analyzed, using analysis of variance (ANOVA). Means were separated by LSD multiple range test at 0.05 levels.

Results and Discussion

TSS, Titratable Acidity, and Ascorbic Acid Content

TSS content in papaya fruits ranged from 10% to 12%. The highest TSS was found in 'Sunrise Solo' and the lowest in 'BH-65' (Table 1). Tsai and Ke (2004) reported higher TSS for 'Sunrise' (13.4 °Brix), 'Tainung No.2' (11.9 °Brix), and 'SR-mu' (12.0 °Brix) as in our study. Zaman et al. (2006) found that TSS content varied from 9-13% in the papaya cultivars. Unnithan (2008) reported the highest TSS (to be 15 °Brix) in 'Sunrise Solo' as compared to the cultivars ('Co-5', 'Coorg Honey Dew', '9-1D', 'Thailand', 'Tainung', 'Pusa Dwarf', 'Pusa Nanha', and 'Washington'). Depending on the papaya hybrids and lines, TSS content ranged between 8.8-13.5 °Brix (Schweiggert et al. 2012). There were no significant differences amongst cultivars in the titratable acidity ranging between 0.16 and 0.19%. The amount of ascorbic acid ranged from 111.67 $mg \cdot 100\ g^{-1}$ in 'Sunrise Solo' to 77.00 $mg \cdot 100\ g^{-1}$ of fresh weight of fruit in 'BH-65' (Table 1). Tsai and Ke (2004) reported a lower value for this vitamin in 'Sunrise' (74.5 $mg \cdot 100\ g^{-1}$) and other cultivars including 'SR-mu' (74.5 $mg \cdot 100\ g^{-1}$) and 'Tainung No.2' (62.5 $mg \cdot 100\ g^{-1}$). Babu and Sharma (2002) compared 12 papaya cultivars and found the highest ascorbic acid content (71.86 $mg \cdot 100\ g^{-1}$) in 'Co-5'. Zaman et al. (2006) found higher ascorbic acid content in the variety, 'Bombai' (42.20 $mg \cdot 100\ g^{-1}$ pulp) followed by 'Shahi' (42 $mg \cdot 100\ g^{-1}$ pulp). Similarly, Unnithan (2008) in Kerala/

Table 1. TSS, titratable acidity, and ascorbic acid content based on fresh weight in 'Red Lady', 'Sunrise Solo', 'Tainung', and 'BH-65' cultivars at the full ripening stage.

Cultivar	TSS (%)	Titratable acidity (%)	Vitamin C ($mg \cdot 100\ g^{-1}$)
Red Lady	10.47 c[z]	0.18	85.67 b
Sunrise Solo	12.13 a	0.19	111.67 a
Tainung	11.67 b	0.16	80.67 c
BH-65	10.00 d	0.17	77.00 d
$LSD_{0.05}$	0.426	N.S.[y]	0.999

[z]Means followed by the same letter are not significantly different according to LSD, P < 0.05.
[y]N.S.: Non significant.

Table 2. Macro element concentration based on dry weight in 'Red Lady', 'Sunrise Solo', 'Tainung', and 'BH-65' cultivars at the full ripening stage.

Cultivar	N[z] ($g \cdot 100\ g^{-1}$)	P ($g \cdot 100\ g^{-1}$)	K ($g \cdot 100\ g^{-1}$)	Ca ($g \cdot 100\ g^{-1}$)	Mg ($g \cdot 100\ g^{-1}$)
Red Lady	0.80 c[y]	0.12 c	0.21 b	0.52 a	0.14 b
Sunrise Solo	1.10 b	0.16 b	0.23 a	0.50 a	0.19 a
Tainung	1.01 b	0.17 a	0.19 b	0.27 b	0.15 b
BH-65	1.28 a	0.15 b	0.24 a	0.13 c	0.11 c
$LSD_{0.05}$	0.1403	0.0133	0.0173	0.0605	0.0172

[z]Nitrogen value based on fresh weight in fruit.
[y]Means followed by the same letter are not significantly different according to LSD, P < 0.05.

Table 3. Micro element concentration based on dry weight in 'Red Lady', 'Sunrise Solo', 'Tainung', and 'BH-65' cultivars at the full ripening stage.

Cultivar	Cu ($mg \cdot 100\ g^{-1}$)	Fe ($mg \cdot 100\ g^{-1}$)	Mn ($mg \cdot 100\ g^{-1}$)	Zn ($mg \cdot 100\ g^{-1}$)
Red Lady	0.34 a[z]	2.87 b	0.45 b	1.16
Sunrise Solo	0.42 a	2.65 b	0.54 b	1.07
Tainung	0.29 a	4.08 a	0.65 a	1.32
BH-65	0.14 b	2.17 b	0.27 c	0.87
$LSD_{0.05}$	0.1368	0.7181	0.1097	N.S.[y]

[z]Means followed by the same letter are not significantly different according to LSD, P < 0.05.
[y]N.S.: Non significant.

India found wide variation in the ascorbic acid content of 12 papaya cultivars, with 'CO-3' recording the highest (131.26 $mg \cdot 100\ g^{-1}$) and '9-1-D' (66.18 $mg \cdot 100\ g^{-1}$) the lowest amounts. Schweiggert et al. (2012) reported that the ascorbic acid content varied depending on hybrids and lines and ranged 24.9-72.9 $mg \cdot 100\ g^{-1}$. Various genetic and environmental variables and their interaction with metabolic processes may affect the levels of the ascorbic acid in papaya cultivars.

Mineral Elements Composition

The cultivars differed in their composition of macro (N, P, K, Ca, and Mg) and micro (Cu, Fe, Mn, and Zn) elements (Tables 2 and 3). Nitrogen was the most abundant element (based on fresh weight) in all papaya cultivars and ranged from 0.80 $g \cdot 100\ g^{-1}$ in 'Red Lady' to 1.28 $g \cdot 100\ g^{-1}$ in 'BH-65'. However, K and Ca were the most abundant elements in dry weight and their quantity varied between 0.19-0.24 $g \cdot 100\ g^{-1}$ and 0.13-0.52 $g \cdot 100\ g^{-1}$ respectively. As in our study, Wall (2006) reported K as the most abundant element (89.7-221.4 $mg \cdot 100\ g^{-1}$) in dry weight. Phosphorus and magnesium levels varied according to cultivar and ranged between 0.12-0.17 $g \cdot 100\ g^{-1}$ and 0.11-0.19 $g \cdot 100\ g^{-1}$ in dry weight respectively. Hardisson et al. (2001) found the contents of macro elements (N, K, Ca, Mg, and P) in the cultivar 'Sunrise' to be somewhat similar based on dry weight. Othman (2009) reported values of 420.7 $mg \cdot 100\ g^{-1}$ for K, 21.44 $mg \cdot 100\ g^{-1}$ for Ca and 38.48 $mg \cdot 100\ g^{-1}$ for Mg in papaya fruit. Other macro elements such as Mg, Ca, Na, and P have been reported by Wall (2006) in fruits and ranged 19.2-32.7 mg·100 g^{-1}, 9.8-32.1 mg·100 g^{-1}, 5-24.3 mg·100 g^{-1} and 4.9-8.8 mg·100 g^{-1} respectively. Ercisli et al. (2010) reported genotype dependent mineral contents in mulberries too. Among the microelements included in this study (Table 3), Fe had the highest concentrations in the fruit, ranging from 2.17 mg·100 g^{-1} in 'BH-65' to 4.08 mg·100 g^{-1} in 'Tainung', followed by Zn (0.87-1.32 mg·100 g^{-1}), Mn (0.27-0.65 mg·100 g^{-1}) and Cu (0.14 to 0.42 mg·100 g^{-1}). Among the microelements, Hardisson et al. (2001) found the concentrations of boron (B) to be the highest followed by Fe, Zn, Cu, and Mn. They found the contents of microelements (Fe, Cu, Zn, Mn, and B) in the cultivar 'Sunrise' to be similar to our findings. Othman (2009) reported the microelements Fe, Mn, Zn, and Na to be at the levels: 0.21 mg·100 g^{-1}, 0.13 mg·100 g^{-1}, 0.12 mg·100 g^{-1}, and 3.26 mg·100 g^{-1} respectively. Wall (2006) reported Fe, Mn, Zn, Cu, and B in papaya fruit to range from 0.27-0.66 mg·100 g^{-1}, 0.01-0.03 mg·100 g^{-1}, 0.06-0.09 mg·100 g^{-1}, 0.05-0.14 mg·100 g^{-1} and 0.11-0.21 mg·100 g^{-1} respectively. The data demonstrates the differential ability of papaya cultivars in withdrawing various mineral elements from the soil and incorporating them into the fruit which may have an impact on nutritional programs. On the other hand, the nutritional composition of the fruit at harvest can vary widely depending on cultivar, maturity stage, climate, soil type, and fertility (Lee and Kader, 2000).

Sugars

Table 4 shows the content of glucose, fructose, sucrose, and total sugar content of papaya fruits. Glucose (2.83% to 3.39%) and fructose (2.80% to 3.52%) were the principal sugars while sucrose (0.03% to 0.09%) was present in minor quantities and was not detected at all in 'Red Lady'. Similar results were also obtained by Schweiggert et al. (2012). Both glucose and fructose were reported as the major sugars by the same authors and ranged 2.6-3.8 g·100 g^{-1} and 1.9-3.5 g·100 g^{-1} respectively. Similarly to our results, sucrose was lower than glucose and fructose and ranged from 0.5 to 1.8 g·100 g^{-1} (Schweiggert et al., 2012). The cultivars 'Red Lady' and 'Tainung' had lower levels of fructose as compared to 'BH-65' and 'Sunrise Solo'. All the cultivars did not differ significantly with regard to the quantities of glucose and total sugars in their fruits. On the other hand, 'Sunrise Solo' the sweetest fruit of the four cultivars, showed the highest levels of fructose (3.52%) and glucose (3.39%). 'Sunrise Solo' had the highest total sugar (6.99%), followed by 'BH-65' (6.09%), 'Tainung' (6.06%), and 'Red Lady' (5.90%). The total sugar levels of 'Sunrise Solo' in this study are higher than the 95.4 g·kg^{-1} (9.54%) reported by Guillermo and Lajolo (2004). However, they measured neutral sugar levels as glucose in water soluble polysaccharides during the whole ripening process. In addition to the stage at which the fruit sample is taken for assessment of sugars, the differences in total sugar value may also be due to the variation in management techniques and the protected cultivation system applied in this study. In our study, we used the samples at the full ripening stages of fruits whereas Guillermo and Lajolo (2004) analyzed the fruits throughout the ripening process. Zaman et al. (2006) reported that total sugar content were between 6.96% and 10.50% in papaya cultivars. Othman (2009) also reported that reducing and total sugar content could fluctuate according to the season and ripening stage.

FAs

The highest lipid content (percent of FAs) was detected in 'Red Lady' (0.54%) and the lowest in 'BH 65' (0.27%) (Table 5). The total FAs contents in all the cultivars ranged from 83.87% to 93.36% (Table 5). The highest total FAs was found in 'Tainung' and the lowest in 'Red Lady'.

Saturated FAs (SFAs) were detected in all the papaya cultivars. Palmitic acid methyl ester (C16:0), myristic acid methyl ester (C14:0), and stearic acid methyl ester (C18:0)

Table 4. Sugar contents values based on fresh weight in 'Red Lady', 'Sunrise Solo', 'Tainung', and 'BH-65' cultivars at the full ripening stage.

Cultivar	Glucose (%)	Fructose (%)	Sucrose (%)	Total Sugar (%)
Red Lady	3.10	2.80 c[z]	N.D.[y]	5.90
Sunrise Solo	3.39	3.52 a	0.07 a	6.99
Tainung	3.14	2.82 bc	0.09 a	6.06
BH-65	2.83	3.24 ab	0.03 b	6.09
$LSD_{0.05}$	N.S.[x]	0.4239	0.0453	N.S.

[z]Means followed by the same letter are not significantly different according to LSD, $P < 0.05$.
[y]N.D.: Not detected.
[x]N.S.: Non significant.

Table 5. FAs composition and percentages in 'Red Lady', 'Sunrise Solo', 'Tainung', and 'BH-65' cultivars (%) at the full ripening stage.

FAs	Red Lady	Sunrise Solo	Tainung	BH-65
Total (%)	0.54 ± 0.11	0.31 ± 0.03	0.31 ± 0.01	0.27 ± 0.01
C8:0	0.21 ± 0.03	0.21 ± 0.04	0.55 ± 0.07	0.34 ± 0.01
C10:0	N.D.[z]	0.13 ± 0.01	3.73 ± 0.23	2.26 ± 0.32
C12:0	0.48 ± 0.06	0.72 ± 0.06	0.53 ± 0.10	0.70 ± 0.08
C14:0	2.02 ± 0.01	2.85 ± 0.02	2.09 ± 0.11	2.88 ± 0.43
C15:0	0.27 ± 0.01	0.17 ± 0.01	0.20 ± 0.05	0.15 ± 0.01
C16:0	20.35 ± 0.64	17.26 ± 6.29	17.60 ± 0.79	21.54 ± 0.63
C17:0	N.D.	N.D.	0.05 ± 0.00	N.D.
C18:0	1.47 ± 0.02	1.19 ± 0.08	1.22 ± 0.16	1.01 ± 0.08
C20:0	N.D.	0.08 ± 0.04	0.03 ± 0.00	0.06 ± 0.08
C24:0	0.27 ± 0.06	N.D.	N.D.	N.D.
Σ SFAs	25.07	22.61	36.00	29.94
C14:1	N.D.	0.14 ± 0.02	0.12 ± 0.04	0.13 ± 0.03
C16:1	4.14 ± 0.07	8.37 ± 0.08	6.29 ± 0.26	10.14 ± 0.67
C17:1	0.33 ± 0.01	0.11 ± 0.05	0.20 ± 0.05	0.11 ± 0.06
C18:1	14.70 ± 0.42	16.14 ± 0.75	13.46 ± 0.57	15.51 ± 0.85
C20:1	0.11 ± 0.04	N.D.	0.28 ± 0.04	N.D.
C22:1 n9	0.44 ± 0.04	0.19 ± 0.07	0.42 ± 0.30	0.28 ± 0.12
C24:1	0.74 ± 0.16	N.D.	0.49 ± 0.21	N.D.
Σ MUFAs	20.46	24.95	21.26	26.07
C18:2 n6	31.96 ± 1.17	19.56 ± 0.61	16.42 ± 1.24	11.55 ± 1.73
C18:3 n3	10.66 ± 0.33	18.37 ± 0.98	18.68 ± 3.92	19.96 ± 0.71
C20:2 cis	0.07 ± 0.03	0.20 ± 0.06	0.12 ± 0.01	N.D.
C20:3 n3	0.50 ± 0.21	0.04 ± 0.02	0.47 ± 0.05	0.16 ± 0.08
C20:3 n6	0.59 ± 0.19	N.D.	N.D.	0.42 ± 0.02
C20:4 n6	0.25 ± 0.08	N.D.	N.D.	N.D.
C22:2 cis	0.16 ± 0.01	0.17 ± 0.08	0.17 ± 0.02	0.05 ± 0.02
C22:6 n3	0.30 ± 0.19	N.D.	0.24 ± 0.08	N.D.
Σ PUFAs	44.49	38.34	36.10	32.14
Σ	83.87	85.90	93.36	88.15

[z]N.D.: Not detected.

were the main SFAs. Total SFAs content ranged from 22.6% in 'Sunrise Solo' to 36.0% in 'Tainung'. OECD (2010) reported the SFAs content between 38.4% and 38.9%. Palmitic acid was the highest followed by myristic acid as in our study. We detected much more SFAs such as C8:0, C10:0, C15:0, C17:0, C20:0, and C24:0 compared to previous study. The composition of the monounsaturated FAs (MUFAs) also differed among cultivars. Total MUFAs was between 20.46% and 26.07% according to cultivar. However, total MUFAs ranged between 33.6 and 33.9% by OECD (2010). Oleic acid (C18:1) was the most prevalent MUFAs in all the four cultivars accounting for 13.46-16.14% of total MUFAs. The second important MUFAs was palmitoleic acid (C16:1) ranging from 4.14% in 'Red Lady' to 10.14% in 'BH-65'. Our results were similar to OECD (2010) results in terms of MUFAs. Because, oleic and palmitoleic acid were the major MUFAs in our study too. The most prevalent polyunsaturated FAs (PUFAs) was linoleic acid (C18:2n6) followed by linolenic acid (C18:3n3). The highest linoleic acid was found in 'Red Lady' (31.96%) and the lowest in 'BH-65' (11.55%). However, the highest linolenic acid was determined in 'BH-65' (19.96%) and the lowest in 'Red Lady' (10.66%). Both linoleic and linolenic acid were also found as major PUFAs and ranged from 27.4% and 27.7%, respectively (OECD, 2010). PUFAs are important nutrients to human health (Moreira et al., 2001). Alpha-linoleic acid is an essential fatty acid that cannot be synthesized in the human body and must be obtained through the diet (HEA, 1996). According to our results, linoleic acid was the most prevalent PUFAs in all the tested papaya cultivars. It is shown that papaya is very important in terms of diet.

In conclusion, the fruit quality features and mineral composition of the fruit, except acidity, varied significantly between the cultivars grown under plastic greenhouse conditions. TSS content of papaya fruits ranged from 10% in ‘BH-65’ to 12% in ‘Sunrise Solo’. Ascorbic acid ranged from 112 mg·100 g^{-1} in ‘Sunrise Solo’ to 77 mg·100 g^{-1} of fresh weight of fruit in ‘BH-65’. Among the detected macro elements (in all cultivars), N was the most abundant element (based on fresh weight) followed by K and Ca (based on dry weight). Iron was the most abundant micro element in all the four cultivars. ‘Sunrise Solo’ was the sweetest of the four cultivars with the highest levels of glucose, fructose and total sugars. Twenty-five fatty acids were detected in the fruits of the four papaya cultivars. PUFAs were found in higher amounts compared with SFAs and MUFAs.

Literature Cited

Anonymous. 2012. Papaya fruit nutrition facts. http://fruitbenefits.wordpress.com/2012/03/01/papaya-fruit-nutrition-facts/.

Association of Official Analytical Chemists (AOAC). 1990. Official method of analysis. 15th ed. AOAC, Washington, DC.

Babu, N. and A. Sharma. 2002. Performance of papaya (*Carica papaya* L.) cultivars under Nagaland foot hill conditions. J. Appl. Hort. 4:35-36.

Bligh, E.C. and W.J. Dyer. 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 37:913-917.

Chan, H.T. Jr. and M.H. Taniguchi. 1985. Changes in fatty acid composition of papaya lipids (*Carica papaya*) during ripening. J. Food Sci. 50:1092-1094.

Cemeroğlu, B. 1992. Principal analytical methods in fruit and vegetable processing industry. Biltav publishing, Ankara, Turkey. (in Turkish)

Ercisli, S., M. Tosun, B. Duralija, S. Voca, M. Sengul, and M. Turan. 2010. Phytochemical content of some black (*Morus nigra* L.) and purple (*Morus rubra* L.) mulberry genotypes. Food Technol. Biotech. 48:102-106.

Galan Sauco, V. and M.C. Rodriguez Pastor. 2007. Greenhouse cultivation of papaya. Acta Hort. 740:191-195.

Guillermo, D.M. and F.M. Lajolo. 2004. Cell-wall polysaccharide modifications during postharvest ripening of papaya fruit (*Carica papaya* L.). Postharvest Biol. Tec. 33:11-26.

Hardisson, A., C. Rubio, A. Baez, M.M. Martin, and R. Alvarez. 2001. Mineral composition of the papaya (*Carica papaya* variety ‘Sunrise’) from Tenerife Island. Eur. Food Res. Technol. 212:175-181.

Hayatsu, H., C. Sugiyama, S. Arimoto-Kobayashi, and T. Negishi. 1999. Porphyries as possible preventers of heterocyclic amine carcinogenesis. Cancer Lett. 143:185-187.

Health Education Authority (HEA). 1996. Nutritional aspects of cardiovascular disease: Nutrition briefing paper. HEA, London.

Islam, M.N., T. Colon, and T. Vargas. 1993. Effect of prolonged solar exposure on the vitamin C contents of tropical fruits. Food Chem. 48:75-78.

Iso, H., S. Sato, U. Umemura, M. Kudo, K. Koike, A. Kitamura, H. Imano, T. Okamura, Y. Naito, and T. Shimamoto. 2002. Linoleic acid, other fatty acids, and the risk of stroke. Stroke 33:2086-2093.

Lee, S.K. and A.A. Kader. 2000. Pre-harvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol. Tec. 20:207-220.

Miron, D. and A.A. Schaffer. 1991. Sucrose phosphate synthase, sucrose synthase and acid invertase in developing fruit of *Lycopersicon esculentum* Mill. and the sucrose accumulating *Lycopersicon hirsutum* Himb. and Bonpl. Plant Physiol. 95:623-627.

Moreira, A.B., J.V. Visentainer, N.E. de Souza, and M. Matsushita. 2001. Fatty acids profile and cholesterol contents of three Brazilian Brycon Freshwater fishes. J. Food Compos. Anal. 14:565-574.

Nakasone, H.Y. and R.E. Paull. 1998. Tropical fruits. CAB International, Oxon, UK p. 443.

Oliveira, J.G. and A.P. Vitoria, 2011. Papaya: Nutritional and pharmacological characterization, and quality loss due to physiological disorders, an overview. Food Res. Int. 44:1306-1313.

Organization for the Economic Cooperation and Development (OECD). 2010. Consensus document on compositional considerations for new varieties of papaya (*Carica papaya* L.): Key food and feed nutrients, anti nutrients, toxicants and allergens. Series on the safety of novel Foods and feeds No. 21. OECD Environment Directorate, Paris, p. 40.

Othman, O.C. 2009. Physical and chemical composition of storage-ripened papaya (*Carica Papaya* L.) fruits of eastern Tanzania. Tanz. J. Sci. 35:47-55.

Özkan, A., H. Gübbük, E. Güneş and A. Erdoğan. 2011. Antioxidant capacity of juice from different papaya (*Carica papaya* L.) cultivars grown under greenhouse conditions in Turkey. Turk. J. Biol. 35:619-625.

Schweiggert, R.M., C.B. Steingass, P. Esquivel, and R. Carle. 2012. Chemical and morphological characterization of Costa Rican papaya (*Carica papaya* L.) hybrids and lines with particular focus on their genuine carotenoid profiles. J. Agric. Food Chem. 60:2577-2585. DOI: 10.1021/jf2045069.

Thanaraj, T. and L.A. Terry. 2011. Tropical fruit (banana, pineapple, papaya and mango), p. 352-370. In: L.A. Terry (ed.). Health-promoting properties of fruit and vegetables. CABI, Oxfordshire, UK.

Tsai, Y.H. and L.S. Ke. 2004. Studies on the physico-chemical changes of papaya (*Carica papaya* L.) fruits during growth and development. J. Chinese Soc. Hort. Sci. 50:63-78.

United States Department of Agriculture (USDA). 2004. Soil survey laboratory methods manual: Soil survey investigations, Rept. No. 42, Version 4.0. USDA-NRCS, Lincoln, NE.

Unnithan, L. 2008. Studies on physico chemical composition of fruits of twelve varieties of papaya (*Carica papaya* L). Mysore J. Agric. Sci. 42:121-125.

U.S. Food and Drug Administration (FDA). 2008. Topical drug products containing papain; Enforcement action dates.

Docket No. FDA-2008-N-0481. Department of Health and Human Services (HHS), FAO, Silver Spring, MD.
Villegas, V.N. 1997. *Carica papaya* L., p. 108-111. In: E.W.M. Verheij and R.E. Coronel (eds.). Edible fruits and nuts. Vol. 2. . Wageningen University, The Netherlands.
Vinci, G., F. Botre, G. Mele, and G. Ruggieri. 1995. Ascorbic acid in exotic fruits: A liquid chromatographic investigation. Food Chem. 53:211-214.
Wall, M.M. 2006. Ascorbic acid, vitamin A, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii. J. Food Compos. Anal. 19:434-445.
Watson, B. 1997. Agronomy/agroclimatology notes for the production of papaya. Soil and Crop Evaluation Project, Maffra, Australia p. 15.
Zaman, W., S.K. Biswas, M.O.H., Helali, M. İbrahim, and P. Hassan, 2006. Physicochemical composition of four papaya varieties grown at Rajshahi. J. Bio-Sci. 14:83-86.