Journal of Food and Nutrition Research, 2014, Vol. 2, No. 6, 281-287
Available online at http://pubs.sciepub.com/jfnr/2/6/3

DOI:10.12691/jfnr-2-6-3

Chemical Composition, Nutritional Properties and Antioxidant Activity of Monkey Apple (*Anisophyllea laurina R. Br. ex Sabine*)

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Received May 20, 2014; Revised June 03, 2014; Accepted June 09, 2014

Abstract The aim of this study was to determine the chemical composition, nutritional properties and antioxidant activity of Monkey apple methanol extract. Results expressed on dry matter basis revealed the seeds contained the following: 2.74% protein, 15.86% crude fat, 7.67% crude fiber, 468.74kcal, 82.01% moisture content, 5.72% ash, 88.98% carbohydrate. The seeds further contained considerable amounts of minerals and vitamins as follows: 14.14mg/100g for iron, 2.37mg/100g for potassium, 1434.38mg/100g for manganese, 82.71mg/100g for magnesium, 185.49mg/100g for calcium, 28.33mg/kg for ascorbic acid, 13.33mg/kg for thiamine and 55.83mg/kg for pyridoxine. Furthermore, it was found out that both the seeds and pulps were also rich in the following: 297.49-304.94mg QE/100g for total flavonoids, 2086.98-2304.72mgGAE/100g for total phenolics, 1.6-96400mg/kg for citric acid, 5880-9280mg/kg for malic acid, 960-1040mg/kg for tartaric acid, 30.8-38.8mg/kg for fumaric acids, 232-660mg/100g for oxalates, 1186.67-1320mg/100g for phytic acid and 130.23-515.23mg/100g for tannins. The seeds and pulp oils were also found to be rich in unsaturated fatty acids ranging from 46.27-50.21%. Our results therefore demonstrate that Monkey apple could serve as supplementary source of essential nutrient and antioxidant components with health benefits.

Keywords: *Monkey apple (Anisophyllea laurina R.Br. ex Sabine), chemical composition, nutritional properties, antioxidant activity*

Cite This Article: Gbago Onivogui, Huaiyuan Zhang, Erasto Mlyuka, Mohamed Diaby, and Yuanda Song, "Chemical Composition, Nutritional Properties and Antioxidant Activity of Monkey Apple (*Anisophyllea laurina R. Br. ex Sabine*)." *Journal of Food and Nutrition Research*, vol. 2, no. 6 (2014): 281-287. doi: 10.12691/jfnr-2-6-3.

1. Introduction

People in most parts of Africa consume wild and cultivated edible plants to meet their nutritional requirements. Fruits are generally recognized as essential for health optimization, with human health depending to a large extent on factors such as high fruit and vegetable consumption [1,2].

Fruit and vegetables have been recognized as important sources for a wide array of non digestible components and phytochemicals that individually, or in combination, may act synergistically to contribute to the nutritional and health benefits of these food commodities.

Recent research has shown that a wide range of indigenous fruit trees have the potential to provide rural households with a means to meet their nutritional and medicinal needs [2].

In Guinea a biodiversity has a vital role as a source of food and income for rural communities that enormously depend on it for their livelihoods.

Anisophyllea laurina *R. Br. ex Sabine* (family Rhizophoraceae, Guinea) English: Monkey apple, vernacular name: Kantigny (Soussou), kansi (Poular) is the commonest mangrove and consequently accounts for a considerable area, grows in west Africa (in Guinea-Bissau to Sierra Leone, and rarely in Ivory Coast). A shrub or tree 5 to 16 m high, occasionally to 22 m; locally abundant in secondary jungle, particularly upland areas. The timber is light yellow to dark brown, often attractively figured. In the family of Anisophylleaceae comprise 29–34 species in four genera: Anisophyllea with two species in South America, five to nine in mainland Africa, one in Madagascar, and 15–19 in Malesia, Combretocarpus with one species in Sumatra and Borneo, Poga with one species in equatorial Africa, and Polygonanthus with two in the Brazilian Amazon Basin [3]. The bark is rich in tannins, astringents and may eventually form the basis of an industry. A decoction of the leaves is used as a mouth rinse for toothache and the ground leaves are said to have medicinal properties to treat diabetes, emetics, oral treatments, pain-killers and the bark is analgesic [4]. The fruits of monkey apple ripen in April or May, with the size and shape of a pigeon's egg, yellow when maturity, with flavor being something between that of the nectarine and a plum. The fruits have a pleasant taste of sweet cherries and are very common in Guinea. It is consumed in

different ways; the pulp is often eaten fresh or boiled by transforming jam by people of all ages. Monkey apple seeds are also used to treat diseases for women during pregnancy.

Previous studies on Monkey apple have reported the composition of an ethereal extract of the fruit stones [5]. However, detailed analysis of the nutrient content and antioxidant properties of the seeds and pulp has not yet been reported.

Therefore, the main objective of this current study was to determine the chemical composition, nutritional properties and antioxidant activity of both seeds and pulp with regard to their extensive utilization in the food industry.

Monkey apple (*Anisophyllea laurina R.Br. ex Sabine*) fruit

2. Materials and Methods

2.1. Materials

All the analysis for the chemical composition, nutritional properties and antioxidant activity for both the seeds and pulp of Monkey apple fruit were carried out using reagents of analytical grade in the State Key Laboratory of Food Science and Technology, Jiangnan University, Wuxi, Jiangsu province, People's Republic of China.

2.1.1. Sample Collection and Preparation

The samples of Monkey apple fruits were collected in April 2013 from different farm sites at Coyah in Kindia region (Guinea). The fruits were washed with clean water to remove all debris and sand. All fruits were ripe and blemish-free, the seeds were separated from their pulps and then sun-dried for 5 days. The dried samples were ground to fine powder with electric grinder (0.5mm) and stored for further analysis.

2.2. Proximate Analysis of Samples

Moisture, ash, crude fat, crude fiber, and crude protein (microKjeldahl N X 6.25) were determined by following the standard method [6], while Carbohydrate contents were calculated by difference [100-(protein + crude fat + ash + crude fiber)]. The values of analyses were the means of three determinations.

2.3. Mineral Analysis

The minerals (Zn, Fe, Cu, M n, N a, K, Mg, and Ca) were analyzed separately, using the inductively coupled plasma optical emission spectrophotometer, ICP-OES (Perkin Elmer, Model 4300 DV, Norwalk, CT, USA). Phosphorus was analyzed by the phosphovanado molybdate method [6]. The data reported represent the average of three determinations.

2.4. Vitamins Content

Vitamins were analyzed using the HPLC system (Agilent 1100 Technologies, USA) equipped with a UV Vis detector, which was set to 260 nm in absorbance mode method described by [7]. Results were calculated on a dry weight basis.

2.5. Amino Acid Analysis

Reversed phase high performance liquid chromatography (RP-HPLC) analysis was carried out in an Agilent 1100 (Agilent Technologies, Palo Alto, CA, USA) assembly system after precolumn derivatization with o-phthaldialdehyde (OPA) [8]. The amino acid composition was expressed as g of amino acid per 100 g of protein.

2.6. Organic Acids Content

Organic acids (malic, citric, tartaric and fumaric) were determined according to the method described by [9]. The concentrations were expressed as mg per kg dry weight.

2.7. Anti-nutritional Factors

Total oxalate was determined as described by [10]. The oxalate content was then calculated by taking 1 ml of 0.05 mol/L of KMnO4 as equivalent to 2.2 mg oxalate [11].

Phytate was determined using the method of [11]. The following equation gives the percentage of phytic acid:

$$\%Phytic\ acid = \frac{0.66(10-V)}{m} \quad (1)$$

Where, V is the volume of Iron (III) chloride solution in milliliters and m the sample mass in grams.

Tannins level was determined by [12]. The amount of tannins was calculated from the calibration curve of tannic acid standard solutions, and expressed as mg tannic acid /100g of plant material.

2.8. Fatty Acid Analysis

Fatty acid for both seed s and Pulp was determined by Gas chromatography/mass spectra (GC/MS) system according [6].

2.9. Determination of Total Phenolics and Flavonoids

Extracts preparation: 10 grams of each sample was extracted by maceration in 50 mL of methanol for 3 days with frequent agitation at a speed of 280 rpm at 28°C in dark. Between extractions, the samples were centrifuged for 10 min with 2000 rpm. The combined supernatants were collected, filtered through Whatman No. 1 filter paper and evaporated to dryness. The residual crude methanol extract was weighed and stored at 4°C for further use.

Total phenol contents of the extracts were determined by the modified Folin-Ciocalteu method [13]. Gallic acid was used as the standard and a calibration curve in the linear range of 0 - 100 mg/mL. The following formula was used to calculate the final total phenolic acid content:

$$\text{TPC(mg GAE/kg)} = \frac{\text{GAE(mg/L)} \times \left(\begin{matrix} \text{total volume of methanol} \\ \text{extract(mL)} \times 10^{-3}\text{(L/mL)} \end{matrix} \right) \times \text{dilution factor}}{\text{Sample weight(g)} \times 10^{-3}\text{(kg/g)}} \quad (2)$$

The total flavonoids content of honeys was estimated by aluminium chloride ($AlCl_3$) colorimetric method with some minor modification [13]. Quercetin was used as standard for calibration in the linear range 0 – 100 mg/L. Total flavonoid content was calculated as quercetin equivalent (QE)).

$$\text{TFC(mg GAE/kg)} = \frac{\text{QE(mg/L)} \times \left(\begin{matrix} \text{total volume of} \\ \text{methanol extract(mL)} \\ \times 10^{-3}\text{(L/mL)} \end{matrix} \right) \times \text{dilution factor}}{\text{Sample weight(g)} \times 10^{-3}\text{(kg/g)}} \quad (3)$$

2.10. Determination of the Total Monomeric Anthocyanins

The total monomeric anthocyanin content of the plant extracts was determined using the pH-differential method previously described [14]. The absorbance of the extracts was calculated as in Eq 4.

$$A = \left(A\lambda vis - max - A700\right)\ pH\ 1.0 - \left(A\lambda vis - max - A700\right)\ pH\ 4.5. \quad (4)$$

The content of monomeric anthocyanin pigment (MAP) was calculated using Eq 5.

$$MAP\ (mg/L) = \left(A \times MW \times DF \times 1000\right) / \left(\varepsilon \times l\right). \quad (5)$$

Where (ε) is the molar absorptivity (26900), MW is the molecular weight (449.2), and DF is the dilution factor, l is the path length. The result, taken as the monomeric anthocyanin pigment, was expressed as mg of cyanidin-3-O-glucoside/kg

2.11. Determination of the Free Radical Scavenging Activity in the 1,1-diphenyl-2-Picrylhydrazil Radical (DPPH) Assay

The free radical scavenging activity of the plant extracts was analyzed by using 2,2- diphenyl-1-picrylhydrazyl (DPPH) assay [14]. The determinations were performed in triplicate.

Inhibition of DPPH by the extract was calculated from Eq 6.

$$DPPH\ (\%) = \left(1 - A\ sample / A\ blank\right) \times 100. \quad (6)$$

Where A blank is the absorbance of control ($1 \cdot 10^{-4}$ mol/L DPPH methanol solution), and A sample is the absorbance of the test sample.

2.12. Reducing Power Assay

The reducing power was determined according to the procedure of [15]. Deionized water was used as negative control. The assay was done in triplicate.

2.13. Statistical Analysis

Descriptive statistical analyses for calculating the means and the standard deviation of the mean were performed using the Statistical Package for Social Sciences (SPSS) version 19 program. Results were expressed as a mean± standard deviation (SD). A value of $p<0.05$ was used to denote statistical significance

3. Results and Discussion

3.1. Proximate Analysis

Proximate compositions of pulp and seeds of monkey apple expressed on dry matter basis are shown in Table 1. Results showed that monkey apple pulp contained higher amounts of moisture content (82.01%), ash (5.72%), carbohydrate (88.98%) and ash content (5.72% of dry weight) which were higher than the seeds. However, the protein content (2.74%), crude fiber (7.67%), crude fat (15.86%) of the seeds were higher than the pulp.

The crude fat content value in Monkey apple obtained in this study was very close to the value (16%) reported by [5] but higher than crude fat content (9.38% of dry weight) reported for Chrysophyllum africanum (African star apple) by [16].

When comparison was made for moisture and ash contents, it was found out that monkey apple contained higher amounts as compared to values of 50.44-51.91% for moisture and 1.66-1.89g/100g for ash reported in Canarium odontophyllum Miq. (dabai) fruits reported by [17].

The carbohydrate contents of pulp and seeds were found to be 88.98% and 71.11% respectively which was

pretty high. The caloric value of seeds (438.14kcal) was higher than that of the pulp (373.95kcal). The energy value obtained for the monkey apple seeds fruit obtained in this study was found to be higher as compared to the energy value of 420.42kcal reported in African star apple fruit (*Chrysophyllum africanum)* by [16].

Crude fiber content of seeds (7.67%) as shown in Table 1 was higher than the pulp (2.43%). The pH of the monkey apple pulp and seeds were 3.09 and 4.96 respectively and this reveals the acidic nature of the fruit. A pH value range of 2.5 - 5.5 has been reported to prolong the shelf life of fresh fruit and inhibit the multiplication of microorganisms.

Table 1. Proximate composition (%, dry weight) of the monkey apple (*Anisophyllea laurina R.Br. ex Sabine*) fruit pulp and seeds*

Constituent	Pulp	Seeds
Moisture %	82.01±0.04	66.26±0.78
Crude protein N x 6.25%	1.56±0.01	2.74±0.01
Crude Fiber%	2.43±0.01	7.67±0.12
Fats/oil %	1.31±0.11	15.86±0.14
Ash%	5.72±0.17	2.62±0.20
pH	3.09±0.03	4.95±0.06
Carbohydrates%	88.98±0.7	71.11±0.53
Food energy g/calories	373.95±3.82	438.14±3.43

Values are means± standard deviation of three determinations (n=3)..
Energy was calculated by summation of (fat x 9 kcal) + (protein x 4 kcal) + (carbohydrate x 4 kcal).
*Results were expressed as relative percentage of dry weight sample

3.2. Mineral and vitamin contents

Results for the mineral and vitamin contents of the monkey apple are shown in Table 2. The pulp from monkey apple has shown to be a good source of minerals and vitamins as evidenced by the contents as follows: 14.14mg/100g for iron, 1434.38 mg/100g for potassium, 2.37 mg/100g for manganese, 82.71 mg/100g for magnesium and 185.49 mg/100g for calcium.

These mineral contents were found to be higher as compared to the values reported for Monkey jack by [18] who reported the following values for different minerals: 778 µg/100g for iron, 350 mg/100g for potassium, 2025µg/100g for manganese, 23.6 mg/100g for magnesium and 66.6 mg/100g for calcium. The values for sodium content in seed (17.62mg/100g of dry weight) and pulp (17.03mg/100g of dry weight) were almost the same concentration. The calcium content of monkey apple pulp (185.49mg/100g) was higher than seeds (64.33mg/100g). However, the mineral element in monkey apple fruit, such as calcium, sodium, potassium were found to be higher than the values reported in dabai fruits by [17].

Additionally, it was observed that the amounts obtained for copper, iron, potassium, manganese, magnesium and calcium were almost 3-fold greater in the pulp than in the seeds which demonstrate that it if properly utilized, it can adequately meet the nutritional needs of Monkey apple consumers.

The vitamin contents of pulp and seeds are also presented in Table 2. Results showed there were variations in amounts for different vitamins. For both seeds and pulp, it was observed that pyridoxine was the most abundant one followed by ascorbic acid and lastly thiamin.

The vitamin contents were found to be higher in seeds than in the pulp and the values were as follows: 28.33mg/kg for ascorbic acid, 13.33mg/kg for thiamin, 55.83mg/kg for pyridoxine for seeds while the values for the pulp were as follows: 6.83mg/kg for ascorbic acid, (0.02mg/kg for thiamin and 10.03mg/kg for pyridoxine.

The riboflavin content in seeds (0.52mg/kg) was slightly higher than in pulp (0.35mg/kg).The vitamin content ranges for nicotinamide and cyanocobalamin were 0.01 – 0.02 mg/kg and 0.02 - 0.03 mg/kg respectively for seeds and pulp.

It was interesting to note that thiamin; pyridoxine contents of monkey apple seeds were very higher than Recommended Dietary Allowances (RDA) with their values exceeding the RDA of 1.3 mg/ day for adult males and 1.1 mg/ day for women - 1.5 mg/ day pregnant/lactating of thiamin [19]. The values of B1 (thiamin), B2 (riboflavin) B3 (Niacin), B6 (Pyridoxine) obtained in monkey apple fruit were also higher than reported by [20] in banana guava, okra, brinjal and spinach. These vitamins are recommended during pregnancy for lactating women and adolescents during growth and against chronic diseases such as cardiovascular disease, morning sickness, insomnia, anxiety, anti-tuberculosis medication and Post Menstrual Syndrome [21].

Table 2. Mineral compositions and vitamin contents of the monkey apple (*Anisophyllea laurina R.Br. ex Sabine*) fruit pulp and seeds. (mg/100g and mg/kg of dry weight)

Mineral	Pulp	seeds
Zinc (Zn) (mg/100g)	0.88±0.05	1.87±0.05
Iron (Fe) (mg/100g)	14.14±0.01	3.33±0.06
Manganese(Mn) (mg/100g)	2.37±0.01	0.16±0.07
Copper (Cu) (mg/100g)	0.29±0.01	0.48±0.02
Potassium(K) (mg/100g)	1434.38±0.01	411.25±2.05
Sodium(Na) (mg/100g)	17.03±0.01	17.62±0.06
Magnesium(Mg) (mg/100g)	82.71±0.01	45.79±0.02
Calcium(Ca) (mg/100g)	185.49±0.1	64.33±0.23
Phosphorus(P) (mg/100g)	0.70±021	1.56±021
Ascorbic acid (mg/kg)	6.83± 0.03	28.33±0.03
Thiamine (mg/kg)	0.02±0.01	13.33±0.01
Riboflamin (mg/kg)	0.35±0.01	0.52±0.01
Pyridoxine (mg/kg)	10.03±0.15	55.83±0.14
Nicotinamin (mg/kg)	0.01±0.01	0.02±0.01
Cyanocobalamin (mg/kg)	0.02±0.01	0.04±0.01

Values are means± standard deviation of three determinations (n=3).

3.3. Anti-nutrients Factors, Organic Acid Content, Total Phenolic, Total Flavonoids, and Antioxidant Activity

Results for the anti-nutrients contents of monkey apple fruit are presented in Table 3. Results showed the following value ranges for the anti-nutrients:164.66 - 2067.36mg/100g for tannin, 232 - 660mg/100g for oxalates and 1186.67-1320 mg/100g for phytic acid. The phytic acid content of the pulp (1320mg/100g) was higher than in seeds (1186.67mg/100g).

On the other hand, the values of the anti-nutrients contents obtained in this study were found to be higher

than those obtained in some food plant sources such as Alocacia indica Sch. (312.4mg/100g); Asparagusofficinalis DC. (340.8mg/100g) and Portulaca oleracia Linn. (823.6mg/100g) as reported by [22].

Total oxalate content of the seeds and pulp were higher than those values obtained in Gmelina arborea Roxb (50mg/100g), in Oroxylum indicum (L.) Vent (60mg/100g), in Bauhinia recemosa Lam. (20mg/100g), and in Caryotaurens L fruit (10mgmg/100g) as reported by [23].

The tannins content of the seeds and pulp were higher than in C. acreanum, C. Africanum and C .akusae respectively as reported by [24]. In comparison with other fruit species, monkey apple was found to be a good source of anti nutritional factors than in Tamarindus indica pulp and Ziziphus spina christi fruit and seed as reported by [25], and in Grewia tiliifolia, Ficus recemosa, Ziziphus rugosa, Meyna laxiflora as reported by [26].

Organic acids contents of monkey apple are shown in Table 3. The results show that monkey apple fruit pulp and seeds were rich sources of organic acids (Table 3). The following contents were obtained: 9280mg/kg for malic acid, 96400mg/kg for citric acid and 38.8mg/kg for fumaric acid for the pulp while values for the seeds which were lower than in pulp were as follows: 5880mg/kg for malic acid, 1.6mg/kg for citric acid and (30.8mg/kg for fumaric acid. However tartaric acid contents of the pulp (960mg/kg was lower than the seeds (1040mg/kg).

In this study, the values of citric acid content in pulp was higher than in pine apple (2.2 g/kg), in orange(4.5 g/kg), in grape (13.1 g/kg) and in lime (41.2 g/kg) as reported by [27] and in mulberry species (M. laevigataand M. nigra 773–987 mg/100 g) as reported by [28]

Organic acid contents in monkey apple were higher than that of pomegranate (Punica granatum L.) : oxalic acid (0.0313 to 1.0167 g/L), malic acid (0.1175 to 2.2302 g/ L), citric acid (0.6130 to 2.1823 g/ L), fumaric acid (0.0119 to 0.2990 mg/ L) and tartaric acid (0.0330 to 0.1266 g/ L) values as reported by [29].

Results for the total phenolics and total flavonoid of extracts obtained from the pulp and seed samples of using methanol (95%) solvent are shown in Table 3. Results showed that the amounts of phenolic compounds (2304.72 mg GAE/100g of dry weight) and total flavonoids content 2304.72 mg GAE/100g were higher in the pulp than in the seed, with values of (2086.98mgGAE/100g of dry weight) and (297.49 mg QE /100g of dry weight), respectively.

In fact, total polyphenol amount in monkey apple fruit were higher than that of exotic fruit such as Fardh-Tamr (235mgGAE/100g), Khalas-Tamr (231mgGAE/100g), Khasab- Rutab (116mg GAE/100 g) and Khalas-Rutab (81 mg GAE/100g) [30] and pineapple(129mg/100g), mango(546 mg/100 g), guava(39 mg/100 g) as reported by [31], and total flavonoids content in Monkey apple were higher than that in whole fruit such as Fardh-Tamr (34 mg CEQ/100 g) Khasab-Tamr (27mg CEQ/100g) and Khalas-Tamr (25mg CEQ/100g)Fardh-Rutab (66mgCEQ/100g) Khasab-Tamr (46 mg CEQ/100 g)and Khalas-Rutab (19 mg CE/100 g) [29].

The antioxidant properties of monkey apple the fruit were evaluated by DPPH radical scavenging capacity, reducing power (Fe^{3+} into Fe^{2+}) and the total monomeric anthocyanins. The antioxidant activity of the methanol extracts of both seeds and pulp of monkey apple fruit are shown in Table 3. The seeds of monkey apple fruits presented the highest DPPH scavenging activity (72.60% of dry weight) and reducing power (2674.66mg/100g of dry weight) activities, whereas the pulp presented the highest phenolics content and the lowest antioxidant activity for DPPH and reducing power assays.

With respect to total monomeric anthocyanin content, values obtained in this study (Table 3) was lower than those of other fruit, Acerola (Malpighia emarginata DC.) pulp(28.27 mg/kg, cyanidin-3-glucoside), squeezed (52.3 mg/kg, cyanidin-3-glucoside,) and Crushed fruit (49.7 mg/kg cyanidin-3-glucoside).

Table 3. Anti-nutrients factors, Organic acid contents, Antioxidant composition, of the monkey apple (*Anisophyllea laurina R.Br. ex Sabine*) fruit pulp and seeds

Anti nutrients factors	Pulp	Seeds
Yield (w/w %)	48.18±0.05	53.99±0.01
Tannins content mg/100g*	164.66±0.04	2067.36±0.07
Phytic acid (mg/100g)*	1320±0.04	1186.67 ±0.05
Oxalate (mg/100g)*	232±0.01	660±0.15
Malic acid (mg/kg)**	9280±0.20	5880±0.04
Citric acid (mg/kg)**	96400±0.40	1.6±0.06
Tartaric acid (mg/kg) **	960±0.05	1040±0.23
Fumaric acid(mg/kg)**	38.8±0.07	30.8±0.34
Phenolics content GAE mg/100 g [a]	2304.72±0.05	2086.98±0.06
Flavonoids content mg QE/100 g[b]	304.94±0.02	297.49±0.01
Ferric reducing activity mg Fe^{2+}/100g*	2291.80±0.03	2674.66±0.04
DDPH radical-scavenging activity %[c]	64.90±0.06	72.60±0.05
Total monomeric anthocyanin C3GE mg/100 g[d]	4.68±0.06	34.23±0.01

Values are means± standard deviation of three determinations (n=3).
*Results were expressed as mg/100 g of dry weight.
**Results were expressed as mg/100 g of dry weight.
[a] Results were expressed as mg of Gallic acid equivalents (GAE)/100g of extract.
[b] Results were expressed as mg of quercetin equivalents (QE)/100g of extract.
[c] Results were expressed as mg/mL of extract .
[d] Results were expressed as mg of cyanidin-3-glucoside equivalents per 100g of dry weight

3.4. Amino Acid Composition

Results for the amino acid composition of the monkey apple fruit pulp and seeds are presented in Table 4. Seventeen amino acids were identified including seven essential ones (isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine) and ten non-essential (alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, histidine, proline, serine and tyrosine) amino acids. The amounts of amino acids in pulp were higher than in seed except for methionine which was the lowest.

The essential amino acids observed in the both seeds and pulp of monkey apple almost were higher than the suggested pattern of amino acid requirements by [32]. The value ranges of the essential and Non-essential amino acid contents were also higher than that in Canarium odontophyllum Miq. (dabai) fruits as reported by [17]

The values of palmitic acids and palmitoleic acids, oleic acid, linoleic acid was very similar as values palmitic acids (54.4%), palmitoleic acids (26.1%), oleic acid (10.1%), linoleic acid (5.5%) and stearic acid (1.53%) in

seeds of monkey apple as reported by [5]. The most abundant essential and Non-essential amino acid were leucine(51.73-61.20mg/g protein), lysine(42.07-82.13 mg/g protein), threonine (25.09- 43.33 mg/g protein) methionine (9.01-81.48 mg/g protein), valine (33.95-50.99 mg/g protein) and arginine (95.47-162.30 mg/g protein), aspartic acid(84.94-109.32 mg/g protein), glutamic acid(119.19-212.78mg/g protein), glycine (64.98-68.77 mg/g protein) respectively.

Table 4. Amino acid composition of the monkey apple (Anisophyllea laurina R.Br. ex Sabine) fruit pulp and seeds as compared to the FAO/WHO/UNU reference pattern (mg/g protein)*

Amino acid essential	Pulp* mg/g	Seeds* mg/g	FAO/WHO standard (mg/g)**
Leucine	61.20±0.05	51.73±0.05	20
Isoleucine	43.18±0.01	25.80±0.03	25
Lysine	82.13±0.02	42.07±0.01	30
Phenylalanine	47.03±0.01	37.37±0.06	25
Threonine	43.33±0.15	25.09±0.03	15
Methionine	9.01±0.01	81.48±0.01	15
Valine	50.99±0.01	33.95±0.07	26
Amino acid Non-essential			
Arginine	95.47±0.08	162.30±0.12	
Histidine	57.48±0.01	24.39±0.02	
Cysteine	6.01±0.04	11.06±0.05	
Aspartic acid	109.32±0.05	84.94±0.08	
Glutamic acid	119.19±0.03	212.78±0.05	
Serine	51.53±0.05	49.27±0.01	
Glycine	68.77±0.01	64.98±0.01	
Alanine	53.31±0.03	34.72±0.02	
Tyrosine	37.70±0.01	26.10±0.05	39
Proline	64.34±0.03	31.97±0.06	

Values are means± standard deviation of three determinations (n=3).
*Results were expressed as mg/100 g protein of dry weight
**Food and Agricultural Organization/ World Health Organization FAO/WHO/UNU energy and protein requirements (2007).

3.5. Fatty acid content

Results for the fatty acid compositions of the monkey apple are presented in Table 5. The principal fatty acids in the pulp and the seeds were palmitic acid (16:0), oleic acid (18:1), linoleic (18:2), linolenic acid (18:3), behenic acid (22:0). In pulp, the major fatty acids were palmitic acids (16:0) (29.10%) and oleic acid (18:1) (26.88%) followed by linolenic acid (18:3) (15.82%), behenic acid (22:0) (15.18%) stearic acid (18:0) (5.51%), and linoleic acid (18:2) (4.96%). In seeds, palmitic acids (16:0) (52.20%) and palmitoleic acids (16:1) (21.92%) were the most abundant followed by oleic acid (18:1) (12.99%), linoleic acid (18:3) (7.42%).

Both the pulp and seeds also contained higher amounts of oleic acid (26.88%) and (12.98%) respectively with significant nutritional value. The pulp oil also contained higher amounts of linolenic acid (18:3) 15.82%, behenic acid (22:0) 15.18%, stearic acid (18:0) (5.51%).This high content of oleic acid, palmitic acid linolenic acid and behenic acid in pulp may be beneficial to human health.

When comparison was made between the pulp and the seed oil, it was found out that the pulp oil had higher percentage of unsaturated fatty acids (50.21%) than the seeds oil (46.27%). The low total saturated fatty acids (49.79% of dry weight) found in the pulp oil could be an advantage over the seeds oil (53.74% of dry weight) since a diet low in saturated fat can be beneficial to human health.

Table 5. Fatty acid composition of the monkey apple (Anisophyllea laurina R.Br. ex Sabine fruit pulp and seeds (%)*

Name	Fatty acid composition	Pulp	Seeds
C16:0	Palmitic acid	29.1±0.05	52.205±0.2
C16:1	Palmitoleic acid	2.02±0.07	21.92±0.04
C18:0	Stearic acid	5.51±0.30	1.53±0.26
C18:1	Oleic acid	26.88±0.05	12.99±0.08
C18:1	Elaidic acid	0.53±0.06	3.94±0.01
C18:2	Linoleic acid	4.96±0.03	7.42±0.04
C18:3	Linolenic acid	15.82±0.05	nd
C22:0	Behenic acid	15.18±0.06	nd
TSFA (% of total fatty acid)		49.79±0.41	53.74±0.28
TUFA (% of total fatty acid)		50.21±0.26	46.27±0.17

Values are means± standard deviation of three determinations (n=3)
TSFA= Total Saturate Fatty Acid; TUFA = Total Unsaturated Fatty Acid
nd = not detected
*Results were expressed as relative percentage of each fatty acid

4. Conclusions

Results from this study have shown that the chemical composition and antioxidant activity of the pulp and seeds of Monkey apple (*Anisophyllea laurina R.Br. ex Sabine*) fruits differ significantly. The pulp of the monkey apple fruits was found to contain higher amounts for minerals, organic acids, flavonoids and phenolics compared to the amounts contained in the seeds. However, results have also shown that seeds contain higher amounts as compared to the pulp for crude fat, crude fiber, proteins, total energy, vitamins, carbohydrates, ant-nutrient factors and antioxidant activity. Furthermore, the results have shown that both the seeds and pulp contains substantial amounts of fatty acids including others which are unsaturated as well as higher amounts of organic acids. The results of this study have clearly demonstrated that the monkey apple fruit contains substantial amounts of essential nutrients and antioxidants which if well exploited and promoted can address many nutritional related disorders and also be useful in food industry for production of a variety of value added products.

Acknowledgements

The authors gratefully acknowledge the National Natural Science Foundation of China (31271812, 81071685), the National High Technology Research and Development Program of China (863 Program 2012AA022105C for providing financial support for the study and Jeannine Sogony Koivogui from Guinea for facilitating transportation of raw materials to China.

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