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Original article

Comparative characterisation of durian, mango and avocado

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Summary The aim of this investigation was to determine the nutritional and bioactive properties of relatively less investigated exotic fruit durian (*Durio zibethinus Murr*.) and to compare these indices with widely used mango (*Mangifera indica* L.) and avocado (*Persea americana*). For this purpose HPLC, three-dimensional fluorescence (3D-FL), several radical scavenging assays and multivariate factor analysis were used. It was found a similarity in acetone extracts between durian and mango in the contents of polyphenols (1.66 ± 0.08, 1.48 ± 0.05, mg GAE g^{-1} DW, respectively), and in some antioxidant assays such as ABTS (11.98 ± 0.5, 12.24 ± 0.5, μM TE g^{-1}DW, respectively) and DPPH (5.61 ± 0.3, 5.22 ± 0.2, μM TE g^{-1} DW, respectively). Durian and avocado were similar in the contents of polyphenols, and ABTS and DPPH values in water and in methanol extracts, respectively. Based on the obtained results the nutritional and bioactive properties of durian are comparable with those indices in mango and avocado. In conclusion, durian can be recommended as a part of disease prevented diets.

Keywords Avocado, durian, mango, nutritional and bioactive properties.

Introduction

The consumption of new exotic fruits has significantly increased (Luximon-Ramma *et al*., 2003; Haruenkit *et al*., 2007, 2010; Corral-Aguayo *et al*., 2008). Among these fruits durian (*Durio zibethinus Murr*.) is less known than mango (*Mangifera indica* L.) (Dutta *et al*., 2008; Melo *et al*., 2008; Wu & Ke, 2008; Robles-Sanchez *et al*., 2009) and avocado (*Persea americana*) (Elez-Martinez *et al*., 2005). It was shown that durian (Haruenkit *et*. *al*., 2010), mango (Masibo & He, 2008; Robles-Sanchez *et al*., 2009) and avocado (Elez-Martinez *et al*., 2005) possesses high nutritional and bioactive properties. The above-mentioned data were received using different methods and therefore could not be reliable for comparing nutritional and bioactive properties of these three fruits.

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Therefore, in this investigation samples of durian, mango and avocado were purchased at the same stage of ripeness and unified methods were used for determination of nutritional and bioactive properties with application of different radical scavenging assays (Apak *et al*., 2004; Ozyurek *et al*., 2007; Pellegrini *et al*., 2007). The content of ascorbic acid in the studied samples and its contribution to the total antioxidant activity were determined as well (Wang *et al*., 1996; Gardner *et al*., 2000). We did not find published articles which compare the nutritional and bioactive properties of durian, mango and avocado.

Materials and methods

The used chemicals were listed previously (Haruenkit *et al*., 2007, 2010).

Durian (*Durio zibethinus Murr*. cv. Mon Thong), mango (*Mangifera indica* L. cv. Nam Dok Mai No. 4) and avocado (*P*. *americana* cv. Ettinger) were at the

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same stage of ripeness. The fruits were collected at the optimal harvest time, and the ripening was monitored by analysing fruit firmness, shape, hardness flesh colour, total acidity and sugar/acid ratio. In addition to all these indices skilled workers participated in determination of the ripeness of durian. The samples were picked up from the orchard (Muang district, Chantaburi province, Thailand) at the same climatic conditions during the last three years (2007–2009) and prepared as previously described (Haruenkit *et al.*, 2007, 2010).

Fluorescence spectra for all fruit extracts in methanol at a concentration of 0.01 mg mL^{-1}, acetone (0.02 mg mL^{-1}) and hexane (0.001 mg mL^{-1}) were recorded on a model Jasco FP-6500 spectrofluorometer, serial N261332 (Jasco Corp., Tokyo, Japan). The three dimensional spectra were collected with subsequent scanning emission spectra from 250 to 750 nm at 1.0-nm increments by varying the excitation wavelength from 250 to 500 nm at 10-nm increments (Wang *et al.*, 2009).

Lyophilised fruit samples were extracted from a 50-mg aliquot with 5 mL of solvent. The following polyphenol extracts were also obtained with 100% methanol at room temperature (DurMe, ManMe and AvoMe), water ((DurW, ManW and AvoW), acetone (DurAc, ManAc and AvoAc) and hexane (DurHe, ManHe and AvoHe).

The contents of minerals, trace elements, total polyphenols, flavonoids, flavanols, tannins, anthocyanins, ascorbic acid, total carotenoids and β-carotene were determined as previously described (Gouado *et al.*, 2007; Haruenkit *et al.*, 2007, 2010; Khoo *et al.*, 2008).

In order to receive reliable data, it was decided to use durian, mango and avocado of the same ripeness and to determine their antioxidant potentials by four complementary assays: (i) ferric reducing antioxidant power (FRAP); (ii) 2,2-Azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid) diamonium salt ($ABTS^{\cdot+}$); (iii) 1-Diphenyl-2-picrylhydrazyl method (DPPH); (iv) Cupric reducing antioxidant capacity (CUPRAC). The antioxidant activity in methanol and water extracts of fruits was evaluated by β-carotene bleaching assay. For comparison BHT was used as a standard.

Extraction and determination of phenolic acids and HPLC polyphenols profile

Free, methanol soluble ester-bound (released after alkaline hydrolysis) and methanol soluble glycoside-bound (released after acid hydrolysis) phenolic acids were obtained from a methanolic extract of tissue ground in liquid nitrogen (Cvikrová *et al.*, 1991).

Flavonoid compounds were extracted with 80% methanol accordingly to the method of glycoside-bound phenolic acids extraction (released after acid hydrolysis). Compounds were eluted using gradient of acetonitrile (ACN) with phosphoric acid by modified method of Peifeng (Xue *et al.*, 2007).

Statistical analysis

Multivariate factor analysis was performed by means of Unistat® v. 5.6 (Unistat, 4 Shirland Mews, London, UK) statistical software.

The results of this investigation are means ± SD of five measurements. Differences between groups were tested by two-way ANOVA. In the assessment of the antioxidant potential, Spearman correlation coefficient (R) was used. Linear regressions were also calculated. The P-values of <0.05 were considered significant.

Results

The soil, where the investigated fruits grown, was a sandy loam with the following data: pH 5.4, EC 296 μS cm^{-1}, organic matter 3.7%, available P (Bray II) 1400 mg kg^{-1}, exchangeable (NH_4OAc) K, Ca and Mg 105, 1773 and 75.2 mg kg^{-1}, respectively; extractable (DTPA) Fe, Mn, Cu and Zn 104, 14.9, 15.8 and 7.2 mg kg^{-1}, respectively.

From multidimensional pattern recognition techniques, the factor analysis (FA) was involved in the mineral composition of fruits. The results of factor analysis (FA) of durian, avocado and mango fruits based on the content of macro- and micro-elements P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B are depicted on a score plot of factors (Fig. 1). Figure 1a shows that avocado and mango are more similar on the element profile than durian when compared with avocado or mango. From the plot of factor score of elemental transposition data matrix (Fig. 1b) we can see that the K and P play significant role for fruit differentiation, whereas the concentrations of the other elements were not so dispersed and important. The contents of K and Na were comparable in all three studied fruits ($P > 0.05$), and the amounts of Ca and B were significantly higher in avocado and mango, respectively ($P < 0.05$). Other minerals differed from one fruit to another: so, the contents of Fe and Zn were significantly higher in mango and avocado, Mg – in durian and avocado, Mn, Cu – in durian and mango ($P < 0.05$).

Fluorimetric measurements

Three-dimensional fluorescence spectra (Figs S1 and S2) illustrated the elliptical shape of contours. The x axis represents the emission spectra from 250 to 750 nm, while the y axis is the excitation spectra from 250 to 500 nm: of mango (a), avocado (b) and durian (c) in methanol extract (Fig. S1). Hexane extracts of

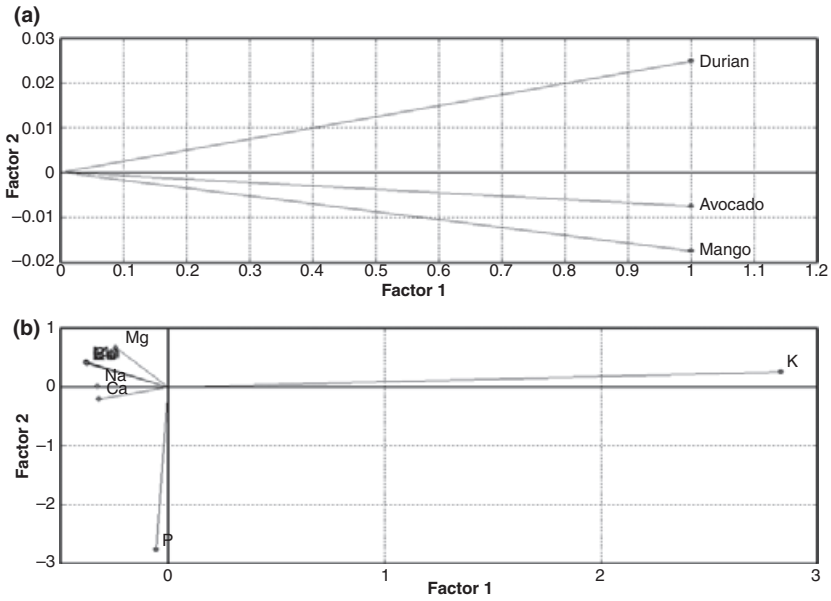

Figure 1 Comparison of durian, avocado and mango by the factor analysis of their nutritional mineral profiles (Score plot of factors with quartimax rotation) (a) elements: P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B); (b) elements: P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B.

mango (a), avocado (b) and durian (c) and acetone extracts of mango (d), avocado (e) and durian (f), respectively, are shown in Fig. S2. In three-dimensional fluorescence spectra the excitation and the emission wavelengths and the fluorescence intensity were used as the axes in order to investigate the information of the extracted bioactive compounds in the samples, and the contour spectra provided more information. The contour map (Figs S1 and S2, Aa, Ba, Ca, Da, Ea and Fa) displayed a view of the fluorescence spectra. The contour maps of methanol extracts (Fig. S1) showed exactly the same profile of one main peak for mango (Aa) and durian (Ca) at location of ex/em 275/300 and 275/550 nm and for avocado (Ba) with a shift in comparison with the first two of 275/310, 275/370 and 275/550 nm. Hexane extracts of mango (Aa), avocado (Ba) and durian (Ca) differed in their configuration, oppositely acetone extracts showed similar configuration between mango (Da) and durian (Fa). A summarised comparison and difference in contour maps between methanol and acetone extracts of the three fruits investigated is shown in Fig 2. 3D fluorescence can be an additional tool for the comparison of different fruits.

Bioactive compounds and antioxidant potentials

The total polyphenols (mg GAE g^{-1} DW) ranged from 3.65 to 5.04 (Table 1, DurMe, ManMe, AvoMe); flavonoids (mg CE g^{-1} DW) from 0.41 to 7.09; flavanols (μg CE g^{-1} DW) from 2.03 to 100.41; tannins (mg CE g^{-1}) from 0.87 to 4.97. In water extracts (Table 1, DurW, ManW, AvoW) the total polyphenols (mg GAE g^{-1} DW) ranged from 2.61 to 3.38; flavonoids (mg CE g^{-1} DW) from 0.012 to 1.45; flavanols (μg CE g^{-1} DW) from 31.02 to 67.05; tannins (mg CE g^{-1} DW) from 0.36 to 0.72.

The antioxidant potentials (μM TE g^{-1} DW, Table 2, DurMe, ManMe, AvoMe) determined by CUPRAC, ABTS, DPPH and FRAP assays in the methanol extracts of the three studied fruits were in the range from 20.06 to 30.00; from 10.72 to 27.31; from 6.12 to 10.00; from 7.45 to 14.89, respectively. For water extracts (Table 2, DurW, ManW, AvoW) the antioxidant activities (μM TE g^{-1} DW) showed the following results for CUPRAC, ABTS, DPPH and FRAP: from 8.01 to 20.40; from 15.74 to 39.41; from 6.19 to 27.31; from 6.51 to 18.33, respectively. The antioxidant activity (%) in methanol and water extracts was also determined by β-carotene linoleic acid. For samples of DurMe, ManMe and AvoMe at concentration of 12.5 mg mL^{-1} the antioxidant activity (%) showed the following meanings: 25.33, 76.72 and 41.06. Samples of DurW, ManW and AvoW at the same concentration showed higher antioxidant activities (%) than in methanol extracts: 48.85, 88.79 and 81.42. The 0.5 mM BHT showed the highest antioxidant activity of 92.9%. The lipophilic bioactive compounds in acetone extracts were the following: [polyphenols (mg GAE g^{-1} DW) for DurAc, ManAc, AvoAc, Table 1, from 1.48 to 3.35]. Flavonoids (mg CE g^{-1}) and flavanols (μg CE g^{-1}) were the highest for AvoAc and ranged from 0.87 to 12.71 and from 17.22 to 37.18. For acetone extracts (Table 2, samples DurAc, ManAc, AvoAc) the antioxidant activities (μM TE g^{-1} DW) showed the following results for CUPRAC, ABTS, DPPH and FRAP: from 6.23 to

Table 1 Bioactive compounds of durian, mango and avocado in methanol (Me), water (W), acetone (Ac) and hexane (He) extracts[1,2,3]

	POL mg GAE g^{-1}	FLAVON mg CE g^{-1}	FLAV μg CE g^{-1}	TAN mg CE g^{-1}
DurMe	3.65 ± 0.2^{e}	2.571 ± 0.1^{d}	100.41 ± 5.8^{g}	0.87 ± 0.04^{c}
ManMe	3.79 ± 0.2^{e}	0.412 ± 0.02^{b}	2.03 ± 0.1^{a}	1.86 ± 0.09^{c}
AvoMe	5.04 ± 0.3^{f}	7.090 ± 0.3^{f}	10.21 ± 0.5^{c}	4.97 ± 0.25^{d}
DurW	2.61 ± 0.1^{d}	1.451 ± 0.07^{d}	67.05 ± 3.4^{f}	0.36 ± 0.02^{a}
ManW	3.38 ± 0.2^{e}	0.012 ± 0.001^{a}	31.02 ± 1.6^{d}	0.68 ± 0.03^{c}
AvoW	2.86 ± 0.1^{d}	0.191 ± 0.01^{b}	34.11 ± 1.7^{e}	0.72 ± 0.03^{c}
DurAc	1.66 ± 0.08^{c}	3.510 ± 0.2^{e}	20.05 ± 1.1^{d}	0.36 ± 0.02^{b}
ManAc	1.48 ± 0.05^{c}	0.872 ± 0.04^{c}	17.22 ± 0.9^{d}	0.12 ± 0.01^{a}
AvoAc	3.35 ± 0.2^{e}	12.711 ± 0.6^{d}	37.18 ± 1.9^{e}	8.32 ± 0.41^{e}
DurHe	0.47 ± 0.02^{b}	0.730 ± 0.03^{c}	4.68 ± 0.25^{b}	3.44 ± 0.17^{d}
ManHe	0.16 ± 0.008^{a}	0.031 ± 0.002^{a}	18.19 ± 1.0^{c}	2.05 ± 0.11^{c}
AvoHe	0.61 ± 0.03^{b}	0.168 ± 0.01^{b}	8.57 ± 0.41^{c}	6.25 ± 0.31^{e}

[1]Values are means ± SD of five measurements.
[2]Values in columns with different superscript letters are significantly different ($P < 0.05$). [3]per g dry weight.
POL, polyphenols; FLAVON, flavonoids; FLAV, flavanols; TAN, tannins; CE, catechin equivalent; GAE, gallic acid equivalent.
DurMe, ManMe and AvoMe, durian, mango and avocado extracted with 100% methanol; DurW, ManW and AvoW, durian, mango and avocado extracted with water. DurAc, ManAc and AvoAc, durian, mango and avocado extracted with acetone; DurHe, ManHe and AvoHe, durian, mango and avocado extracted with hexane.

Table 2 The antioxidant activity (μM TE g^{-1} DW) of durian, mango and avocado in methanol (Me), water (W), acetone (Ac) and hexane (He) extracts[1,2,3]

	ABTS	CUPRAC	FRAP	DPPH
DurMe	10.72 ± 0.5^{c}	21.98 ± 1.1^{e}	14.89 ± 0.8^{d}	6.39 ± 0.3^{b}
ManMe	27.31 ± 1.3^{d}	20.06 ± 1.1^{e}	7.45 ± 0.4^{c}	10.00 ± 0.5^{c}
AvoMe	13.83 ± 0.7 ^{c}	30.00 ± 1.5^{f}	8.32 ± 0.4^{c}	6.12 ± 0.3^{b}
DurW	39.41 ± 2.1^{e}	20.40 ± 1.1^{e}	18.33 ± 0.9^{e}	10.72 ± 0.5^{c}
ManW	25.54 ± 1.3^{d}	19.34 ± 0.9^{e}	11.85 ± 0.5^{c}	27.31 ± 1.3^{d}
AvoW	15.74 ± 0.6^{c}	8.01 ± 0.4^{c}	6.51 ± 0.3^{c}	6.19 ± 0.3^{b}
DurAc	11.98 ± 0.5 ^{c}	6.23 ± 0.3^{c}	2.15 ± 0.1^{b}	5.61 ± 0.2^{b}
ManAc	12.24 ± 0.5^{c}	16.26 ± 0.8^{d}	2.81 ± 0.1^{b}	5.22 ± 0.2^{b}
AvoAc	11.31 ± 0.5 ^{c}	20.10 ± 1.1^{e}	3.05 ± 0.1^{b}	2.50 ± 0.1^{a}
DurHe	1.14 ± 0.05^{a}	1.70 ± 0.09^{b}	0.82 ± 0.04^{a}	2.01 ± 0.1^{a}
ManHe	5.28 ± 0.3 ^{b}	0.18 ± 0.009^{a}	0.86 ± 0.04^{a}	2.01 ± 0.1^{a}
AvoHe	0.86 ± 0.04^{a}	1.20 ± 0.06^{b}	0.87 ± 0.04^{a}	3.09 ± 0.2^{a}

[1]Values are means ± SD of five measurements.
[2]Values in columns with different superscript letters are significantly different ($P < 0.05$). [3]per g dry weight.
CUPRAC, ABTS, DPPH, FRAP, Cupric reducing antioxidant capacity; 2,2-Azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid) diamonium salt; 1-Diphenyl-2-picrylhydrazyl method; Ferric-reducing/antioxidant power, respectively; TE, Trolox equivalent.
DurMe, ManMe and AvoMe, durian, mango and avocado extracted with 100% methanol; DurW, ManW and AvoW, durian, mango and avocado extracted with water. DurAc, ManAc and AvoAc, durian, mango and avocado extracted with acetone; DurHe, ManHe and AvoHe, durian, mango and avocado extracted with hexane.

20.10; from 11.31 to 12.24; from 2.50 to 5.61; from 2.15 to 3.05, respectively. All indices in hexane fraction were lower than in acetone and showed the following data: polyphenols (mg GAE g^{-1} DW, Table 1) for DurHe, ManHe and AvoHe from 0.16 to 0.61; CUPRAC (μM TE g^{-1} DW, Table 2, for DurHe, ManHe and AvoHe from 0.18 to 1.70; ABTS from 1.14 to 5.28; DPPH from 2.01 to 3.09). Six different extracts were compared by their polyphenols and CUPRAC, ABTS, DPPH and FRAP values. As can be seen, the studied indices were higher in some extracts of mango that in avocado and durian. However, the differences were significant only in the studied indices of ABTS and DPPH methanol and DPPH water extracts values in mango were higher that in avocado and durian ($P < 0.05$).

Methanol soluble individual phenolics acids and flavonoids

p-Hydroxybenzoic, vanillic, caffeic and ferulic acids were detected in all fruit samples; and the most abundant was ferulic acid. Protocatechuic, caffeic and anisic acids were not abundant. Gallic acid was found only in mango and *m*-hydroxybenzoic acid – only in avocado and *p*-coumaric only in durian (Fig. 3).

Flavonoids were determined and quantified by monitoring of their first absorption maxima at 260 nm (quercetin 255.9 nm; apigenin 267.6 nm). Quercetin and apigenin were detected in all three fruits: quercetin was equal in avocado and durian and about five times higher in mango. Apigenin was detected only in traces in durian and the highest was found in mango (Figure S3 and Table 3). The contents of *p*-hydroxybenzoic and vanillic acids, and quercetin were significantly higher ($P < 0.05$) in mango. The contents of ascorbic acid, carotenoids and anthocyanins present in Fig. 4. Ascorbic acid (mg g^{-1} DW) for durian, avocado and mango was in the range between 2.52 and 5.65. The amount of total carotenoids (mg 100 g^{-1}) in the investigated three fruits was from 2.49 to 13.84 and β-carotene from 1.24 to 9.87 mg 100 g^{-1}. The anthocyanins (mg CGE g^{-1}) were from 1.7 to 4.3 (Fig. 4).

Discussion

The aim of our investigation was to determine the nutritional and bioactive properties of relatively less investigated exotic fruit durian (*Durio zibethinus Murr.*) and to compare these indices with widely used mango (*M. indica* L.) and avocado (*P. americana*).

We found that only contents of K and Na were comparable in all three studied fruits ($P > 0.05$) and of Ca and B were significantly higher in avocado and mango, respectively ($P < 0.05$). The contents of other minerals were different. So, the contents of Fe and Zn were significantly higher in mango and avocado, Mg – in durian and avocado, Mn, Cu – in durian and

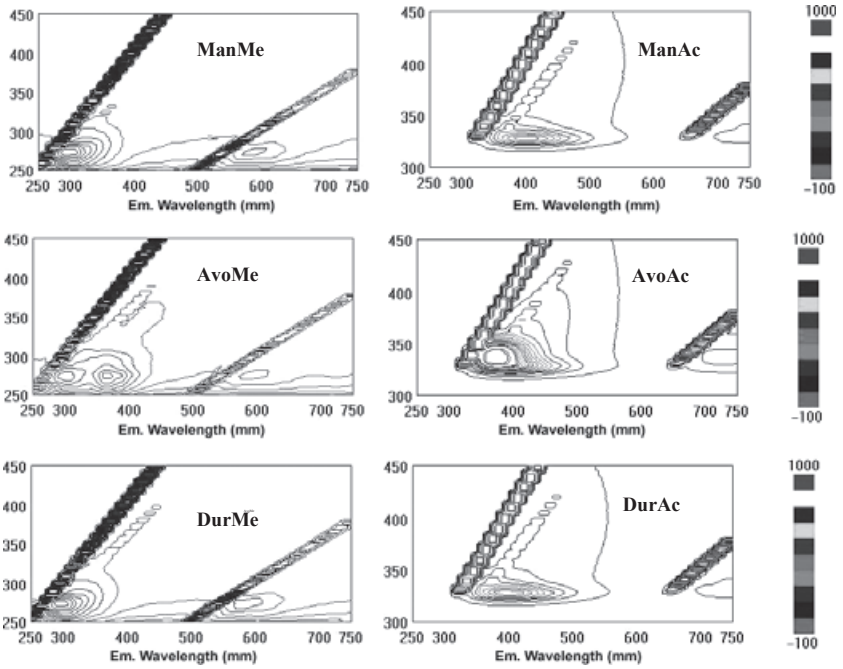

Figure 2 The contour map of methanol (Met) and acetone (Ac) extracts of mango (Man), avocado (Avo), durian (Dur), respectively, displayed a view of the corresponding three-dimensional fluorescence spectra (3-D FL). Fluorescence intensity values from < 100 to 1000 are presented. Details of the experiment are presented in Materials and Methods and in Supporting Information.

mango ($P < 0.05$). It was found (Leterme *et al*., 2006) that tropical fruits were generally high in K (36–1.782 mg K 100 g^{-1} edible portion) and low in sodium (< 45 mg Na 100 g^{-1} edible portion). The results of this investigation were in accordance with the reported in the present study. It was shown in other reports (Hirasawa *et al*., 2008; Lee *et al*., 2008) that avocado was low in sodium.

The results (Fig. 1) show that even between three fruits avocado is with relatively low sodium content in comparison with mango.

It was found that the content of total phenols was high in all three studied fruits and comparable ($P > 0.05$). On the contrary, tannin was significantly higher (Table 1) in avocado in all extracts ($P < 0.05$).

The obtained results of polyphenols were reported (Luximon-Ramma *et al*., 2003; Haruenkit *et al*., 2007; Corral-Aguayo *et al*., 2008) in avocado 3.44 and in mango 2.78 mg GAE g^{-1} DW in comparison with the hydrophilic extracts of 2.86 and 3.38 mg GAE g^{-1} DW (Table 1, AvoW and ManW). The lipophilic extracts (Corral-Aguayo *et al*., 2008) showed lower level of polyphenols as for avocado 0.70 and for mango – 2.30 in comparison with 0.61 and 1.48 mg GAE g^{-1} DW for AvoHe and ManAc, respectively (Table 1). Methanol extract of mango contained total phenolics of 2.30 mg GAE g^{-1} DW (Corral-Aguayo *et al*., 2008) in comparison with our results of 3.79 mg GAE g^{-1} DW for ManMe. Our results are in accordance with others (Ribeiro *et al*., 2008) that the antioxidant level depends on the geographical growth. Mango (cv. 'Irwin') showed 37.9% by DPPH and 4.30 μM TE g^{-1} by ABTS radical scavenging abilities; and phenolics (mg GAE 100 g^{-1}) of 37.14 (Wu & Ke, 2008). The relationship between the antioxidant components and the antioxidant activity corresponded with our data. It was shown in recent publication (Wolfe *et al*., 2008) that the polyphenols in mango and avocado recalculated on dry weight were 2.57 and 0.70 mg GAE g^{-1} DW. These data correspond with our results (Table 1) for mango (ManW) and for avocado (AvoHe).

The reported data (Lee *et al*., 2008) of total polyphenols in avocado methanol extract (13.89 μg mg^{-1}) were higher than ours (Table 1, AvoMe). The radical-scavenging activities of the methanol extracts by DPPH radicals and ABTS assay differed as well in our determination (Lee *et al*., 2008).

The experimental results of hydrophilic fractions isolated with different proportions of methanol with and without hydrolysis and with water and lipophilic isolated with acetone and hexane compare favourably with literature value (Vinokur & Rodov, 2006) in the total polyphenols and their antioxidant activities.

Mango contained high amounts of gallic, *p*- and *m*-hydroxybenzoic and vanillic acids, and apigenin, which corresponds with Masibo & He (2008), showing that the major polyphenols in terms of antioxidative capacity and quantity were mangiferin, catechins, quercetin, gallic and ellagic acids, benzoic acid, and protocatechuic acid.

The methanol extract of all fruits using different assays was significantly higher than the others ($P < 0.05$). In

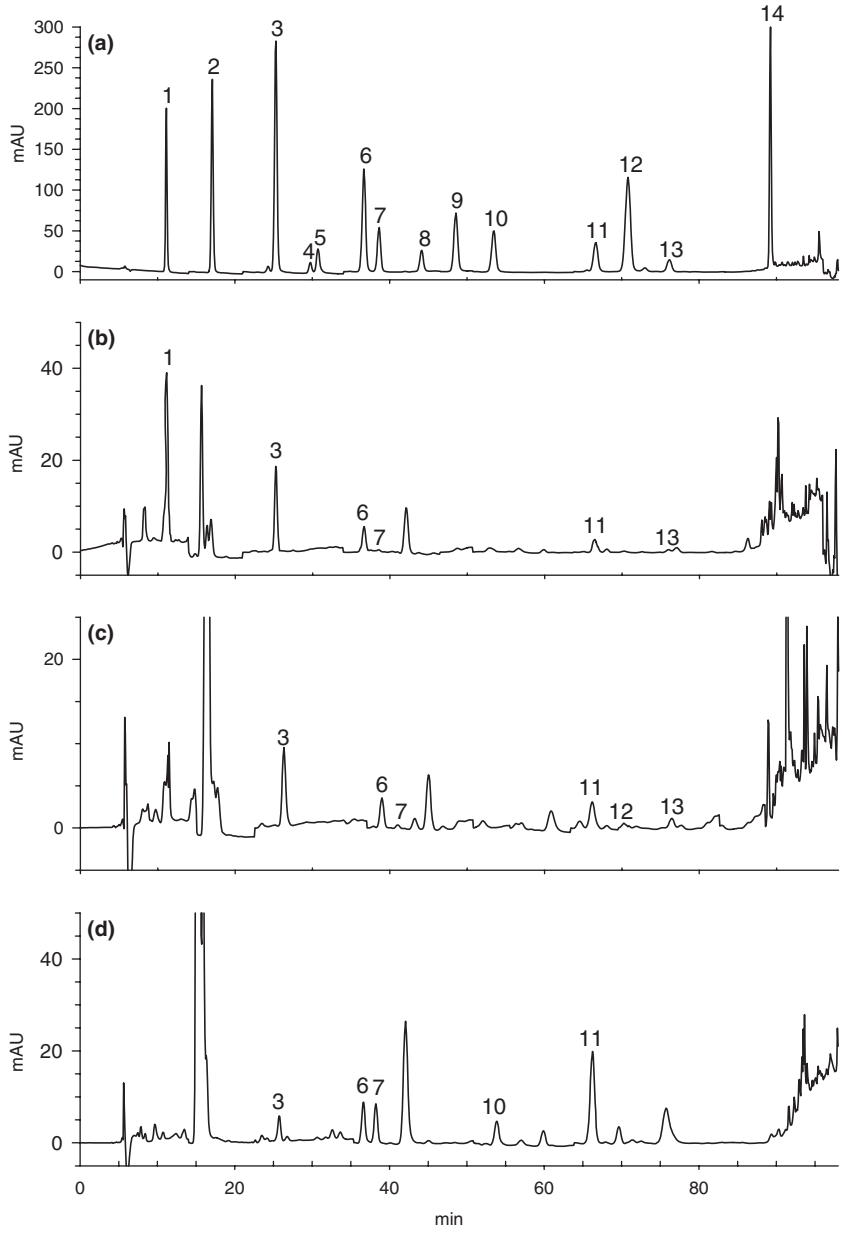

Figure 3 HPLC analysis of methanol soluble ester-bound phenolic acids extracted from fruits. Each profile represents an equivalent amount of extract, normalised on a volume of extract per 5 mg of tissue basis. Chromatograms are showing the separation: a, standard mixture; b, Mango; c, Avocado; d, Durian. 1, gallic acid; 2, protocatechuic acid; 3, *p*-hydroxybenzoic acid; 4, *m*-hydroxybenzoic acid; 5, 2,3 dihydroxybenzoic acid; 6, vanillic acid; 7, caffeic acid; 8, chlorogenic acid; 9, syringic acid; 10, *p*-coumaric acid; 11, ferulic acid; 12, anisic acid; 13, sinapic acid; 14, cinnamic acid.

addition, other investigators show that the antioxidant potential of tropical fruits was high (Haruenkit *et. al.*, 2007; Corral-Aguayo *et. al.*, 2008). So, these authors reported that the antioxidant potential according to ORAC and DPPH ranged from < 0.1 to 16.7 μM TE g^{-1} puree, and 2.1 to 620.2 μg GAE g^{-1} puree, respectively. Others showed the antioxidant activity determined by ORAC for avocado as 39.08 μM TE g^{-1} DW and for mango –46.56 μM TE g^{-1} DW (Wolfe *et al.*, 2008). Our results by CUPRAC for avocado (AvoMe) and by ABTS for mango (ManMe) were slightly lower than the cited ones (Wolfe *et al.*, 2008). The presented results were in correspondence with the data cited of total phenols, flavonoids, β-carotene, ascorbic acid and antioxidant activity estimated by TEAC, and DPPH assays (Robles-Sanchez *et al.*, 2009).

The obtained antioxidant activities by FRAP (Table 2) in hydrophilic extracts corresponded with 7.48–217.75 μM TE g^{-1} DW, including a big range of other fruits (Luximon-Ramma *et al.*, 2003; Corral-Aguayo *et al.*, 2008). Avocado (Table 2, AvoMe) showed exactly the same number as was reported of 7.57 μM TE g^{-1} DW. The lipophilic fractions of DPPH values (Table 2, ManAc) were in comparison with the

Table 3 Contents of phenolic acids in fruits (μg g^{-1} DW)

Compounds	Mango	Avocado	Durian
Gallic acid	53.41 ± 2.7	–	–
Protocatechuic acid	0.39 ± 0.02[a]	0.37 ± 0.02[a]	–
p-Hydroxybenzoic ac.	21.32 ± 1.1[a]	5.38 ± 0.3[b]	2.12 ± 0.1[c]
m-Hydroxybenzoic acid	–	8.63 ± 0.4	–
Vanillic acid	16.74 ± 0.8[a]	5.61 ± 0.3[b]	2.54 ± 0.1[c]
Caffeic acid	0.96 ± 0.05[c]	2.46 ± 0.1[b]	5.49 ± 0.2[a]
Ferulic acid	14.87 ± 0.7[b]	9.38 ± 0.5[c]	18.29 ± 0.9[a]
p-Coumaric acid	–	–	2.88 ± 0.1
Sinapic acid	7.55 ± 0.3[a]	1.93 ± 0.05[b]	–
Anisic acid	–	0.26 ± 0.01[a]	0.035 ± 0.002[b]
Quercetin	1.76 ± 0.05[a]	0.40 ± 0.02[b]	0.34 ± 0.02[b]
Apigenin	57.55 ± 2.8[a]	15.59 ± 0.7[b]	trs

Methanol soluble individual phenolic acids (represented by the sum of free, ester – and glycoside – bound forms) were extracted from the fruits. Values are means of two independent experiments with two replicates; deviations did not exceed 10% of the mean in one experiment. Values in rows with different superscript letters differ significantly ($P < 0.05$).
ac, acid; trs, traces.

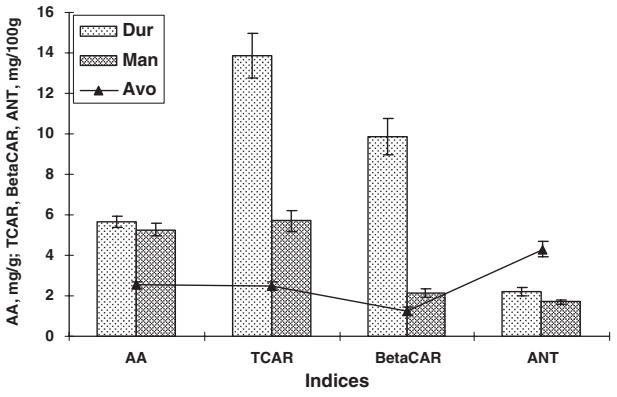

Figure 4 Bioactive compounds in Durian (Dur), mango (Man) and Avocado (Avo). AA, ascorbic acid (mg g^{-1}); TCAR, total carotenoids (mg 100 g^{-1}); BetaCAR, β-carotene (mg 100 g^{-1}); ANT, anthocyanins, mgCGE 100 g^{-1}, cyanidin-3-glucoside equivalent.

value of 6.15 μM TE g^{-1} DW (Corral-Aguayo *et al.*, 2008). ABTS data for hydrophilic avocado fraction (Table 2, AvoW, 74 μM TE g^{-1} DW) were in comparison with 16.00 (Corral-Aguayo *et al.*, 2008). Mango (Table 2, ManHe-ManAc) was 5.28–11.21 μM TE g^{-1} DW and in the cited literature was 1.23 μM TE g^{-1} DW. The hydrophilic fraction of mango by ABTS showed 28.7 μM TE g^{-1} DW in comparison with our data of 27.31 μM TE g^{-1} DW for ManMe (Table 2).

In avocado the ratio between the lipophilic and hydrophilic antioxidants varied from 1.5:1 to 1.2:1 (AvoMe:AvoAc, Table 2) with CUPRAC and ABTS in comparison with cited results where the ratio between lipophilic and hydrophilic antioxidants varied from 1:1 to 1:3 with ABTS (Vinokur & Rodov, 2006). In case of mango the results were similar, where the same above-mentioned samples showed the ratio between lipophilic and hydrophilic antioxidants from 1:2 to 1:5 (Vinokur & Rodov, 2006).

Comparison of only water extracts of different fruit pulps showed that mango was in the same list as guava and grapes with a strong scavenging capacity toward DPPH radicals (> 70%). These results were comparable with our data (Melo *et al.*, 2008).

The extractive power of various solvents based on the yield of mangiferin showed the following relative order of the studied solvents as methanol > water > chloroform > *n*-butanol. In our case only methanol and water were used and the order was the same, depending on the temperature percentage of methanol and the time of the extraction. Our results were in correspondence with Pellegrini *et al.* (2007), showing that the obtained antioxidant activity depends on the solvents used such as water and acetone. In our case methanol and water were the main contributors of antioxidant activity.

The role of ascorbic acid in the total antioxidant activity of fruits is controversial. Some authors claim that the antioxidant activity of fruits might be attributed mainly to the content of phenols (Wang *et al.*, 1996; Gardner *et al.*, 2000), and the contribution of ascorbic acid is < 15%. (Gardner *et al.*, 2000). On the contrary, there are investigators who claim that ascorbic acid plays a major role in the total antioxidant activity. Low correlations with levels of ascorbic acid 0.35 and 0.23 for ORAC and DPPH data, respectively, were reported. The results of our investigation show relatively high contents of ascorbic acid in all three studied fruits and moderate correlation with the used antioxidant assays. The cited data of ascorbic acid (mg g^{-1} DW), where avocado showed 1.12–3.03 and mango 1.58–4.26 (Luximon-Ramma *et. al.*, 2003; Corral-Aguayo *et. al.*, 2008; Wu & Ke, 2008), corresponded with our results (Fig. 4).

The results for carotenoids (Fig. 4) differ from the cited ones, where two cultivars of mango and durian from different locations were in the range of 2.6–15.0 mg 100 g^{-1} (Poerwanto *et al.*, 2008; Gouado *et al.*, 2007; Khoo *et al.*, 2008) and other reports (Dutta *et al.*, 2008) of β-carotene of 6976 μg 100 g^{-1} mango pulp.

The order of the obtained data differed between mango and durian because in the cited report (Khoo *et al.*, 2008) Nyekak and Daun durians and Bacang and Kuini mangoes were investigated, which differ completely from the cultivars used in the present research, but these underutilised fruits have an acceptable amount of carotenoids that are potential antioxidant fruits. For the future studies it is important to mention that all exotic fruits during the harvest season are available in abundance, but fruits are scarce during the off-season (Poerwanto *et al.*, 2008), therefore may

be also dry fruits can be used as a supplement in off-season.

Conclusions

Nutritional and bioactive values of durian are comparable with these indices in mango and avocado. These fruits contain high comparable quantities of basic nutritional and antioxidant compounds, and exercise high level of antioxidant activity. All fruits show high level of correlation between the contents of phenolic compounds and the antioxidant potential. The contribution of ascorbic acid to the total antioxidant potential is moderate.

Mon Thong durian can be recommended as a valuable nutritional supplement to normal diet in amount between 5% and 7%, based on our previous results of nutritional, antioxidant and anti-proliferative properties, and *in vivo* experiments on rats and on the comparative studies with avocado and mango.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Three-dimensional fluorescence map of 0.01 mg mL^{-1} of methanol extracts of mango (a), avocado (b), durian (c), respectively. The contour map (Aa, Ba, Ca) displayed a view of the corresponding fluorescence spectra. The three dimensional spectra were with emission from 250 to 500 nm and the excitation wavelengths from 250 to 750 nm, scanning speed was 1000 nm min^{-1}, emission mode and fluorescence intensity till 500. Abbreviations: A-C on axis Z: Int, fluorescence intensity; X: Em. Wavelength, emission wavelength; Y: Ex. Wavelen, excitation wavelength; Aa, Ba, Ca on axis X: Em Wavelength, emission wavelength; Y, excitation wavelength; all the fluorescence intensity values from –50 to 550 are presented.

Figure S2. Three dimensional fluorescence map of hexane (0.001 mg mL^{-1}) of mango (a), avocado (b), durian (c); and acetone extracts (0.02 mg mL^{-1}) of mango (d), avocado (e), durian (f), respectively. The contour map (Aa, Ba, Ca, Da, Ea, Fa) displayed a view of the corresponding fluorescence spectra. The three dimensional spectra were with emission from 250 to 750 nm and the excitation wavelengths from 250 to 500 nm, scanning speed was 1000 nm min^{-1}, emission mode and fluorescence intensity till 500. Abbreviations: A-F on axis Z: Int, fluorescence intensity; X: Em. Wavelength, emission wavelength; Y: Ex. Wavelen, excitation wavelength; Aa, Ba, Ca, Da, Ea, Fa on axis X: Em Wavelength, emission wavelength; Y, excitation wavelength; all the fluorescence intensity values from –50 to 550 are presented.

Figure S3. HPLC analysis of flavonoids extracted from fruits. Each profile represents an equivalent amount of extract, normalised on a volume of extract per 10 mg of tissue basis. Chromatograms are showing the separation: a, standard mixture; b, mango; c, avocado; d, durian. 1, epicatechin; 2, esculetin; 3, quercetin; 4, kaempferol; 5, apigenin.

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