



Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Antioxidant properties and bioactive constituents of some rare exotic Thai fruits and comparison with conventional fruits *In vitro* and *in vivo* studies

Shela Gorinstein^{a,*}, Sumitra Poovarodom^b, Hanna Leontowicz^c, Maria Leontowicz^c, Jacek Namiesnik^d, Suchada Veerasilp^e, Ratiporn Haruenkit^f, Pramroj Ruamsuke^g, Elena Katrich^a, Zev Tashma^a

^a The Institute of Drug Research, School of Pharmacy, The Hebrew University, Hadassah Medical School, Jerusalem 91120, Israel

^b Department of Soil Science, King Mongkut's Institute of Technology, Ladkrabang, Bangkok, Thailand

^c Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences (SGGW), Warsaw, Poland

^d Department of Analytical Chemistry, Chemical Faculty, Gdańsk University of Technology, 80 952 Gdańsk, Poland

^e Department of Plant Science and Natural Resources, Faculty of Agriculture/Postharvest Technology Research Institute/Postharvest, Technology Innovation Center, Chiang Mai University, Chiang Mai 50200, Thailand

^f Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

^g Faculty of Agricultural Technology, Rambhai Barni Rajabhat University, Chanthaburi 22000, Thailand

ARTICLE INFO

Article history:

Received 8 September 2010

Accepted 6 October 2010

Keywords:

Exotic and conventional fruits
Bioactive compounds
Antioxidant potentials
Rats
Plasma lipids
Antioxidant activity

ABSTRACT

The aim of this research was to investigate the bioactivity of durian, snake fruit and mangosteen, rare exotic Thai fruits. These fruits were compared among them and with conventional fruits: durian with mango and avocado, and snake fruit with mangosteen and kiwifruit in order to find the preferable diet for human consumption. The contents of polyphenols, flavonoids, flavanols, tannins, anthocyanins, ascorbic acid and carotenoids, and the level of antioxidant potential by ABTS, DPPH, FRAP and CUPRAC in different extracts (methanol, water, acetone, and hexane) were determined. The presence of polyphenols (flavonoids and phenolic acids) in the investigated samples was characterized by Fourier transform infrared (FT-IR) spectroscopy and three-dimensional fluorimetry (3D-FL).

The *in vivo* studies were carried out on 25 male Wistar rats, divided into 5 diet groups, each of 5. During 30 days of the experiment the rats of all 5 groups were fed basal diet (BD), which included wheat starch, casein, soybean oil, vitamin and mineral mixtures. The rats of the Control group were fed only the BD. The BD of the other 4 groups was supplemented with 1% of nonoxidized cholesterol (NOC) (Chol group), 1% of NOC in each group and 5% of lyophilized fruits: durian (Chol/Durian), snake fruit (Chol/Snake), mangosteen (Chol/Mangosteen). After the experiment diets supplemented with exotic fruits significantly hindered the rise in plasma lipids and hindered the decrease in the plasma antioxidant activity. In conclusion, the contents of bioactive compounds and the antioxidant potential are relatively high in the studied fruits and varied among them depending on the extraction procedure. FT-IR and 3D-FL can be used as additional tools for identification and comparison of bioactive compounds. Supplementation of diets with exotic fruits positively affects plasma lipid profile and antioxidant activity in rats fed cholesterol-containing diets.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

There is convincing evidence that fruits and vegetables are playing a beneficial role in the prevention and even treatment of different diseases (Aramwit, Bang, & Srichana, 2010; Borochoy-Neori et al., 2008; Nakamura, Nagata, Oba, Takatsuka, & Shimizu, 2008; Takachi et al., 2008; Ou et al., 2002).

There has also been a great interest in the potential health benefits of exotic fruits due to their antioxidant content and bioactive compounds.

Higher synergistic activity is shown when combinations of natural antioxidants were used (Hait-Darshan, Grossman, Bergman, Deutsch, & Zurgil, 2009). Among the exotic fruits durian (*Durio zibethinus* Murr.) is less investigated than the snake fruit (*Salacca edulis* Reinw) and mangosteen (*Garcinia mangostana*) (Arancibia-Avila et al., 2008; Gorinstein et al., 2009). Therefore, it was decided to compare durian with two other exotic fruits (snake fruit and mangosteen) and with the wide consumed mango (*Mangifera indica* L.), kiwifruit (*Actinidia chinensis*) and avocado (*Persea americana*). It has been shown that the above-mentioned fruits possessed high nutritional and bioactive properties (Aralas, Mohamed, & Bakar, 2009; Khoo, Ismail, Mohd-Esa, & Idris, 2008; Masibo & He, 2008; Pedraza-Chaverri, Cárdenas-Rodríguez, Orozco-Ibarra, & Pérez-Rojas, 2008; Ribeiro, Barbosa,

* Corresponding author. Tel.: +972 2 6758690; fax: +972 2 6757076.
E-mail address: gorin@cc.huji.ac.il (S. Gorinstein).

Queiroz Knödler, & Schieber, 2008; Terasawa, Sakakibara, & Murata, 2006). However, these data were determined using different antioxidant methods (Leontowicz, Leontowicz, Drzewiecki, et al., 2007; Leontowicz, Leontowicz, Jastrzebski, et al., 2007; Toledo et al., 2008; Park et al., 2009). In recent studies (Ikram et al., 2009; Isabelle et al., 2010; Leong & Shui, 2002) the characterization and comparison of the exotic fruits was based on the Singapore market, where the majority of the fruits were imported from Malaysia. Oppositely in this research the origin of exotic fruits was from Thailand. In order to obtain reliable results all samples of the studied fruits were investigated at the same stage of ripeness using unified methods for determination of the antioxidant potential. In our previous investigation the antioxidant potential (AP) was determined only by two assays: [2, 2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid)] (ABTS) with Trolox equivalent antioxidant capacity (TEAC) and 1, 1-diphenyl-2-picrylhydrazyl radical (DPPH) (Haruenkit et al., 2007). In the present report two additional assays were used: Ferric-reducing/antioxidant power (FRAP) and Cupric reducing antioxidant capacity (CUPRAC) and also the previous two assays to analyze the exotic and conventional fruits of the new harvest. FT-IR and 3D fluorimetry were used in this study as additional analytical tools to characterize bioactive compounds of the different extracts.

Antihypercholesterolemic effects of different fruits were studied *in vivo* studies on animal models. Savithri, Appian, and Natesan Shanmugam (2009) investigated the reaction of *Averrhoa bilimbi* Linn. fruit and its extracts using Triton-induced hypercholesterolemia in rats as a model. Gallaher and Gallaher (2009) tested dried plums as a part of diet in lowering of lipids in rats. Valcheva-Kuzmanova et al. (2007) used as a part of a rat's diet *Aronia melanocarpa* juice which is rich in anthocyanins. Beppu et al. (2009) have studied the hypolipidemic effects of ethanol extracts of *Citrus depressa* and *Annona atemoya* on KKAY mice fed with moderately high-fat diet. In spite of the reviewed data, it was interesting to compare the exotic fruits as supplementation of the diets in the present study. Therefore *in vivo* studies were carried out with the *in vitro* experiments.

As far as we know, no results of such comparative investigation of rare exotic fruits, mango, kiwifruit and avocado have been published.

2. Materials and methods

2.1. Chemicals

6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,2-azinobis (3-ethyl-benzthiazoline-6-sulfonic acid) (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH), Folin-Ciocalteu reagent (FCR), lanthanum(III) chloride heptahydrate, $\text{FeCl}_3 \times 6\text{H}_2\text{O}$, $\text{CuCl}_2 \times 2\text{H}_2\text{O}$, 2,9-dimethyl-1,10-phenanthroline (neocuproine) were purchased from Sigma Chemical Co., St Louis, MO, USA. 2, 4, 6-Tripyridyl-s-triazine (TPTZ) was purchased from Fluka Chemie, Buchs, Switzerland. All reagents were of analytical grade. Deionized and distilled water was used throughout.

2.2. Samples and preparation

Durian (*D. zibethinus* Murr. cv Mon Thong), snake fruit (*S. edulis* Reinw, cv Sumalee), mangosteen (*G. mangostana*) and mango (*M. indica* L., cv Nam Dok Mai No. 4) were harvested from a 25-year-old Mon Thong commercial durian orchard, in Chantaburi Province, eastern Thailand in 2009 and were at the same stage of ripeness. Kiwifruit (*A. chinensis*, cv 'Hayward') cultivar at its commercial maturity stage was harvested in the orchard (Heanam County, Jeonnam Province, Korea, 2009). Avocado (*P. americana*) was donated by Mehadrin Tnuport Export (MTEX) L.P, Be'erot Yitzhak, Israel. All fruits were cleaned with tap water and dried, using about 1 kg of fruits with five replicates. The edible parts of the above-mentioned fruits were prepared for this investigation manually without using steel knives.

The peeled fruits were weighed, chopped and homogenized under liquid nitrogen in a high-speed blender (Hamilton Beach Silex professional model).

A weighed portion (50–100 g) was then lyophilized for 48 h (Virtis model 10-324), and the dry weight was determined. The samples were ground to pass through a 0.5 mm sieve and stored at -20°C until the bioactive substances were analyzed.

2.3. Determination of dietary fibers and microelements

Dietary fibers in the selected samples were analyzed by the modified AOAC method. The samples were treated with heat stable α -amylase, protease, and amyloglucosidase, followed by centrifugation (15 min, 3000 g) to separate the soluble and insoluble fractions and dialysis against water, which substituted ethanol precipitation of soluble dietary fiber (Prosky, Asp, Schweizer, De Vries, & Furda, 1992; Mañas, Bravo, & Saura-Calixto, 1994).

Determination of minerals (Na, K, Mg, and Ca) and trace elements (Fe, Cu, Zn, and Mn) was done as follows. Lyophilized fruit samples (0.8 g) were mineralized in a microwave oven with concentrated HNO_3 . The concentrations of elements were estimated by a Perkin-Elmer 5100 ZL atomic absorption spectrometer (Perkin-Elmer Ltd., Beaconsfield, Buckinghamshire, U.K.), using the flame method for Na, K, Mg, Ca, Fe, Cu, and Zn and the flameless method for Mn.

2.4. Determination of the contents of the main bioactive compounds, Fourier Transform Infrared (FT-IR) spectra of polyphenols and fluorimetry

The presence of polyphenols in the investigated fruit samples was studied by Fourier Transform Infrared (FT-IR) spectroscopy. A Bruker Optic GmbH Vector FT-IR spectrometer (Bruker Optic GmbH, Attingen, Germany) was used to record IR spectra. A potassium bromide microdisk was prepared from finely ground lyophilized powder of 2 mg of fruit samples with 100 mg of KBr (Sinelli, Spinardi, Di Egidio, Mignani, & Casiraghia, 2008).

Two-dimensional fluorescence measurements (2D-FL) were done using a model FP-6500, Jasco Spectrofluorometer, serial N261332, Japan. Fluorescence emission spectra for all fruit samples at a concentration of 0.25 mg/mL were taken at emission wavelength (nm) of 330, and recorded from wavelength of 265 to a wavelength of 310 nm, at emission wavelengths of 685 nm from 300 to 750 nm; and at excitation of 350 nm from 370 to 650 nm. Standard of 0.01 mM catechin or quercetin in methanol was used. The three-dimensional spectra (3D-FL) of water extracts of the investigated fruits were collected with subsequent scanning emission spectra from 270 to 750 nm at 1.0 nm increments by varying the excitation wavelength from 260 to 350 nm at 10 nm increments. The scanning speed was set at 1000 nm/min for all measurements. All measurements were performed with emission mode and with intensity up to 1000 (Wulf, Geyer, Nicolai, & Zude, 2005; Yin, Li, Ding, & Wang, 2009).

Phenols were extracted from lyophilized fruits with 100% methanol, acetone, hexane and water (concentration 25 mg/mL) at room temperature twice during 3 h. Lyophilized fruit samples were also extracted from a 50-mg aliquot with 5 mL of 60% methanol/water with heating at 90°C for 3 h for unconjugated polyphenols (UCP) and under the same conditions with 5 mL of 1.2 M HCl in 60% methanol/water for conjugated polyphenols (CP) with some modifications. The samples were cooled, diluted to 10 mL with methanol and centrifuged for 5 min at $4000 \times g$ to remove solids (Hertog, Hollman, & Venema, 1992; Gorinstein et al., 2008; Perez-Jimenez & Saura-Calixto, 2005; Vinson, Su, Zubic, & Bose, 2001).

The polyphenols were determined by Folin-Ciocalteu method with measurement at 750 nm with spectrophotometer (Hewlett-Packard, model 8452A, Rockville, USA). The results were expressed as mg of gallic acid equivalents (GAE) per g DW (Singleton, Orthofer, &

Lamuela-Raventos, 1999). Flavonoids, extracted with 5% NaNO₂, 10% AlCl₃ × 6H₂O and 1 M NaOH, were measured at 510 nm. The total flavanols were estimated using the *p*-dimethylaminocinnamaldehyde (DMACA) method, and then the absorbance at 640 nm was read. The extracts of condensed tannins (procyanidins) with 4% methanol vanillin solution were measured at 500 nm. (+)-Catechin served as a standard for flavonoids, flavanols, and tannins, and the results were expressed as catechin equivalents (CE). Total ascorbic acid was determined by CUPRAC assay (Ozyurek, Guclu, Bektasoglu, & Apak, 2007) in water extract (100 mg of lyophilized sample and 5 mL of water). The absorbance of the formed bis (Nc)-copper (I) chelate was measured at 450 nm.

Carotenoids were extracted with acetone and measured by HPLC. The total anthocyanins were carried out by a pH differential method. Absorbance was measured in a Beckman spectrophotometer at 510 nm and at 700 nm in buffers at pH 1.0 and 4.5, using $A = [(A_{510} - A_{700})_{pH1.0} - (A_{510} - A_{700})_{pH4.5}]$. Results were expressed as mg of cyanidin-3-glucoside equivalent (CGE)/g of DW (Cheng & Breen, 1991).

2.5. Determination of antioxidant potential

The AP was determined by four complementary assays:

- (1) 2, 2-Azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt (ABTS^{•+}) method for the screening of antioxidant activity is reported as a decolorization assay applicable to both lipophilic and hydrophilic antioxidants, including flavonoids, hydroxycinnamates, carotenoids, and plasma antioxidants. The pre-formed radical monocation ABTS is generated by oxidation of ABTS with potassium persulfate and is reduced in the presence of such hydrogen-donating antioxidants. The influences of both the concentration of antioxidant and duration of reaction on the inhibition of the radical cation absorption are taken into account when determining the antioxidant activity. ABTS^{•+} radical cation was generated by the interaction of ABTS (7 mM/L) and K₂S₂O₈ (2.45 mM/L). This solution was diluted with methanol until the absorbance in the samples reached 0.7 at 734 nm (Re et al., 1999).
- (2) Ferric-reducing/antioxidant power (FRAP) assay measures the ability of the antioxidants in the investigated samples to reduce ferric-tripiridyltriazine (Fe³⁺–TPTZ) to a ferrous form (Fe²⁺), which absorbs light at 593 nm (Benzie & Strain, 1996).
- (3) Cupric reducing antioxidant capacity (CUPRAC): This assay is based on utilizing the copper(II)–neocuproine [Cu(II)–Nc] reagent as the chromogenic oxidizing agent. The absorbance at 450 nm was recorded against a reagent blank (Apak, Guclu, Ozyurek, & Karademir, 2004).
- (4) Scavenging free radical potentials were tested in a methanolic solution of 1, 1-Diphenyl-2-picrylhydrazyl method (DPPH). The degree of decoloration of the solution indicates the scavenging efficiency of the added substance. In its radical form, DPPH has an absorption band at 515 nm which disappears upon reduction by antiradical compounds. DPPH solution (3.9 mL, 25 mg/L) in methanol was mixed with the sample extracts (0.1 mL), then the reaction progress was

monitored at 515 nm until the absorbance was stable (Brand-Williams, Cuvelier, & Berset, 1995).

2.6. Animal study

The Animal Care Committee of the Warsaw University of Life Sciences (SGGW), Warsaw, Poland had approved this study. The experiments were done on young growing 3–4 weeks old Wistar male rats (n = 25) with the mean weight of 111 g at the beginning of the trial. During the experiment the feed intake was about 4.4 g per day × 30 days of the period of the experiment = 111 g + 132 g = 243 g. At the end of the experiment the rats were about 7–8 weeks old. The rats were divided into 5 groups of 5 in each group and were named Control, Chol, Chol/Snake, Chol/Mangosteen, Chol/Durian. However the diet groups containing mango, kiwi and avocado were not investigated in *in vivo* studies, because of the similarity to the exotic fruits.

2.7. Diets

During 30 days of the experiment the rats of all 5 groups were fed basal diet (BD), which included wheat starch, casein, soybean oil, vitamin and mineral mixtures. The rats of the Control group were fed only the BD. The BD of the other 4 groups was supplemented with 1% of nonoxidized cholesterol (NOC) of analytical grade (Chol group), 1% of NOC and 5% of lyophilized following fruits: snake fruit (Chol/Snake), mangosteen (Chol/mangosteen), durian (Chol/durian). In most of the experiments *in vivo* cellulose was used as control fiber (Anderson, Jones, & Riddell-Mason, 1994). In Control groups animals were supplemented with a percentage of cellulose similar to the percentage of supplementation with fruit in the other groups. At the end of the experiment, the rats were anaesthetized using diethyl ether, and the blood samples were taken from the left atrium of the heart and plasma was prepared according to test regulations and used for laboratory tests, which included the determination of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG) and plasma antioxidant activity (PAA). Also liver and aorta histopathology was examined.

ABTS, DPPH and FRAP were adopted for the determination of plasma antioxidant activity.

2.8. Statistical analysis

The results of this investigation *in vivo* are means ± SD, n = 5. 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.

3. Results and discussion

3.1. Dietary fibers and microelements

The contents of total, insoluble and soluble dietary fibers in durian, snake fruit, mangosteen, mango and kiwifruit differ minimally (Table 1, P > 0.05), and in avocado was significantly higher than in

Table 1
Contents of dietary fibers in the studied fruits (g/100 g FW).

Compounds	Durian	Snake fruit	Mangosteen	Mango	Kiwi	Avocado
Total dietary fiber	3.2 ± 0.3 ^a	3.0 ± 0.3 ^a	3.0 ± 0.3 ^a	2.9 ± 0.2 ^a	2.9 ± 0.2 ^a	6.2 ± 0.5 ^b
Soluble fiber	1.3 ± 0.1 ^a	1.2 ± 0.1 ^a	1.2 ± 0.1 ^a	1.2 ± 0.1 ^a	1.2 ± 0.1 ^a	2.1 ± 0.2 ^b
Insoluble fiber	1.9 ± 0.1 ^a	1.8 ± 0.1 ^a	1.8 ± 0.1 ^a	1.7 ± 0.1 ^a	1.7 ± 0.1 ^a	4.1 ± 0.3 ^b

Values are means ± SD of 5 measurements. Means in rows without superscript letters in common differ significantly (P < 0.05).

Table 2
Contents of minerals and trace elements in the studied fruits (mg kg⁻¹ DW).

Compounds	Durian	Snake fruit	Mangosteen	Mango	Kiwifruit	Avocado
Na	220.2 ± 11.1 ^a	254.3 ± 12.2 ^a	242.5 ± 12.1 ^a	289.1 ± 14.1 ^a	250.2 ± 12.1 ^a	231.2 ± 11.6 ^a
K	15,942 ± 42 ^b	12,473 ± 37 ^a	13,159 ± 39 ^a	14,181 ± 41 ^a	18,686 ± 49 ^c	15,292 ± 42 ^b
Mg	691.2 ± 29.7 ^a	668 ± 29.2 ^a	624 ± 27.2 ^a	545 ± 23.2 ^a	834 ± 31.9 ^b	684 ± 29.5 ^a
Ca	199.8 ± 10.1 ^a	242.8 ± 12.1 ^a	316.7 ± 14.9 ^b	273.1 ± 12.7 ^a	1637 ± 42.1 ^c	343 ± 12.1 ^b
Fe	6.71 ± 0.3 ^a	13.22 ± 0.6 ^c	14.19 ± 0.7 ^c	10.95 ± 0.5 ^b	12.32 ± 0.6 ^b	10.78 ± 0.5 ^b
Mn	8.26 ± 0.4 ^b	11.44 ± 0.5 ^b	30.58 ± 1.5 ^d	7.63 ± 0.3 ^b	21.67 ± 1.3 ^c	4.62 ± 0.2 ^a
Zn	4.92 ± 0.3 ^a	11.41 ± 0.6 ^c	12.54 ± 0.7 ^c	9.02 ± 0.3 ^b	11.44 ± 0.6 ^c	8.91 ± 0.4 ^b
Cu	4.92 ± 0.3 ^c	3.71 ± 0.3 ^b	1.63 ± 0.3 ^a	5.12 ± 0.3 ^c	1.09 ± 0.3 ^a	3.96 ± 0.3 ^b

Values are means ± SD of 5 measurements. Means in rows without superscript letters in common differ significantly ($P < 0.05$).

Table 3
Fluorimetric data of different fruit extracts.

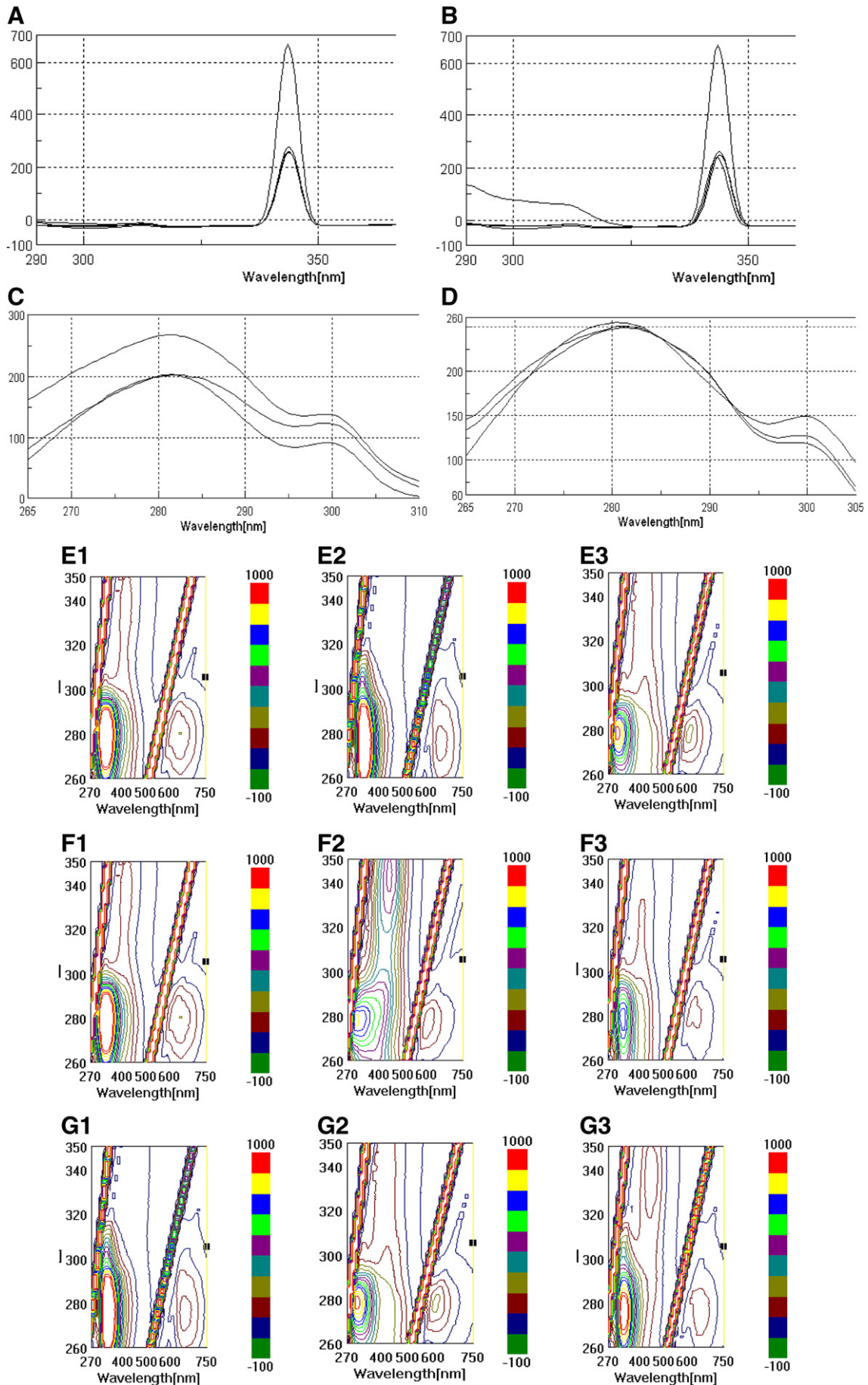
Range the peak Fluorescence intensity	Durian λ _{em} /ex, nm Position of the peak	Mangosteen λ _{em} /ex, nm Position of the peak	Snake fruit λ _{em} /ex, nm Position of the peak	Mango λ _{em} /ex, nm Position of the peak	Avocado λ _{em} /ex, nm Position of the peak	Kiwifruit λ _{em} /ex, nm Position of the peak
λ ex 265–305 FI	330/282.5 202.41	330/282 484.01	330/280.5 255.66	330/281.5 268.55	330/281.5 203.41	330/281 251.60
λ ex 265–305 FI	330/300 122.68	330/300 137.70	330/300 149.29	330/300 137.70	330/300 90.07	330/300 127.15
λ em 370–650 FI	390.5/350 48.81	390.5/350 54.37	391/350 60.44	391/350 67.12	391.5/350 77.25	391/350 75.06
λ em 370–650 FI	448/350 11.07	427/350 37.95	437/350 53.96	429/350 45.23	423.5/350 69.96	430/350 68.31
λ ex 290–400 FI	685/344 255.93	685/344 241.75	685/343 240.14	685/343.5 276.58	685/343.5 258.49	685/344 249.11
λ ex 300–750 FI	740/371 239.46	740/372 261.77	–	740/371.5 364.36	740/371 239.46	740/372 216.17
λ ex 300–750 FI	740/739.5 55.33	740/739.5 58.43	–	740/739.5 125.77	740/739.5 –	740/739.2 43.14
λ ex 280/380 FI	–	450/342.5 25.89	450/340.5 55.92	450/359 37	450/303 33.05	–
λ ex 280/380 FI	–	–	450/285 25.81	–	450/346 48.49	–

the other five fruits ($P < 0.05$). Other authors showed similar results in the amount of dietary fibers (Mahattanatawee et al., 2006), where fourteen tropical fruits from south Florida including green and ripe mangoes were studied. It was found that total dietary fiber changed from 0.9 to 7.2 g/100 g FW, which is higher than the data shown in Table 1. The content of Na in all 6 studied fruits was different (Table 2), but not significant ($P > 0.05$). The significantly highest content of K, Mg and Ca was registered in kiwifruit ($P < 0.05$). The content of Fe and Mn in mangosteen was significantly higher than that in the other five fruits ($P < 0.05$). Also the content of Zn in mangosteen was higher than that in the other five fruits but not significantly ($P > 0.05$). The content of Cu in mango and durian was significantly higher than in the other four fruits ($P < 0.05$). From multidimensional pattern recognition techniques (Poovarodom et al., 2010), the factor analysis (FA) was involved in the mineral composition of fruits. The results of FA of durian, avocado and mango fruits, as well as snake fruit, mangosteen and kiwifruit, based on the content of macro- and microelements K, Ca, Mg, Na, Fe, Mn, Cu, Zn, are depicted on a score plot of factors. Avocado and mango are more similar on the element profile than durian when compared with avocado or mango (Poovarodom et al., 2010). The potassium/magnesium ratio for snake fruit was 21.10 and for kiwifruit: 20.16; and the magnesium/calcium ratio for snake fruit was 2.76 and for kiwifruit 0.50. The obtained present results on minerals and microelements in the new harvest of the investigated fruits (Table 2) are in agreement with our previous data on the same fruits which were collected two years ago (Gorinstein et al., 2010; Haruenkit et al., 2007; Haruenkit et al., 2010; Poovarodom et al., 2010). As was found in this investigation, the content of the minerals in the studied fruits vary significantly

($P < 0.05$). K has the significantly highest content among the studied minerals ($P < 0.05$). Among the fruits the significantly highest content of minerals ($P < 0.05$) was in kiwifruit and mangosteen: of K, Mg and Ca and Fe and Mn, respectively.

3.2. Bioactive compounds

Fluorimetric measurements showed (Table 3) the following peaks (nm) with the fluorescence intensity units (FIU): durian, mangosteen, snake fruit, mango, avocado and kiwifruit with the range of the spectra λ ex (290–400 nm) with emission of 685 and a peak of 343–344 nm and the lowest of 240.14 FIU for snake fruit and the highest of 276.58 for mango (Fig. 1A, B). Catechin of 0.001 mM as a standard for flavonoids was measured at the same conditions and showed the same peak as the fruit extracts at 343.5 nm with a higher FIU of 666.83 (Fig. 1A, B). At excitation wavelength of 350 nm with the range of the spectra λ ex (370–650 nm) the following peaks appeared: the first peak appeared at 390.5–391.5 nm with FIU in the range from 48.8 to 77.3. A shift appeared in the second peak for the fruits: from 423.5 nm to 448 nm and FIU from 11.1 for durian to 70.0 for avocado. Catechin showed one peak at 390.5 with FIU of 35.1. At emission of 330 nm the recording was for all fruits with the shift of the main peak, detected between 280.5 and 282.5 nm with 202.4 and 484.0 for avocado and mangosteen, respectively. The second peak was measured exactly at the same wavelength of λ ex 300 nm with 90.1 for avocado and the highest was for snake fruit of 149.3, respectively. Catechin showed one peak at 282 with FIU of 700.4 (Fig. 1A, B). At emission of 450 nm for mangosteen, snake fruit, mango and avocado one peak in the range between 303 and 359 appeared with 33.07 and 37 FIU for avocado and



mango, respectively. The second peak was only in snake fruit, avocado and catechin at 286 nm with 9.72 FIU. At emission of 740 nm the following data were shown: the main peak was detected at 371, 371.5 and 372 for all fruits except snake fruit, with FIU from 239.5 for durian and 364.4 for mango (Table 3) and the second peak was at 739.5 nm and 739.2 with 43.14 for kiwifruit and 125.8 for mango. Catechin showed two peaks at 371.5 and 739.5 with 590.86 and 311.90.

In three-dimensional fluorescence spectra the excitation and the emission (Fig. 1E, F, G) wavelengths and the fluorescence intensity were used as the axes in order to investigate the information of the fruit samples, and the contour spectra provided more information. The x-axis represents the emission spectra from 270 to 750 nm, while the y-axis is the excitation spectra from 260 to 350 nm for: E1, E2, and E3 (durian, snake fruit, and mangosteen); F1, F2, and F3 (durian, avocado, and mango); G1, G2, and G3, (snake fruit, mangosteen, and kiwifruit), respectively. The result shows that the three-dimensional fluorescence cross maps of fruits in comparison with standards (catechin and gallic acid) are obviously different (Gorinstein et al., 2010; Poovarodom et al., 2010). One main peak and one minor can easily be observed at the approximate location for durian (Fig. 2 E1, F1, $\lambda_{em}/\lambda_{ex}$ 340/275 nm with FIU 737.6 and $\lambda_{em}/\lambda_{ex}$ 650/275 nm with FIU 105); snake fruit (Fig. 2 E2, G1, $\lambda_{em}/\lambda_{ex}$ 340/275 nm with FIU 979.3 and $\lambda_{em}/\lambda_{ex}$ 660/275 nm with FIU 120.9); mangosteen (Fig. 1 E3, G2, $\lambda_{em}/\lambda_{ex}$ 330/275 nm with FIU 480 and $\lambda_{em}/\lambda_{ex}$ 620/275 nm with FIU 85.3); avocado (Fig. 1 F2, $\lambda_{em}/\lambda_{ex}$ 320/275 nm with FIU 999 and $\lambda_{em}/\lambda_{ex}$ 610/275 nm with FIU 67.3); mango (Fig. 1 F3, $\lambda_{em}/\lambda_{ex}$ 340/275 nm with FIU 539.8 and $\lambda_{em}/\lambda_{ex}$ 640/275 nm with FIU 65.4); kiwifruit (Fig. G3, $\lambda_{em}/\lambda_{ex}$ 340/275 nm with FIU 705.2 and $\lambda_{em}/\lambda_{ex}$ 660/275 nm with FIU 94.5). As can be seen the polyphenol spectra in water extracts are similar among these fruits, but differ from the methanol extracts.

3.2.1. FT-IR spectra

The comparison of three exotic fruits durian, snake fruit and mangosteen showed more intensive bands in durian (Fig. 2A, a) than the other samples (Fig. 2A, b and c). The main bands in durian sample were from 1700 to 800 cm^{-1} (1637, 1415, 1137, 1103, 1056, 995 and 923 cm^{-1}). The other two samples were similar and overlaid in the same area. Fig. 2B presents three spectra of durian (a), avocado (b) and mango (c). The bands were in the same region, and some additional bands were detected in the overlaying, such as 1595, 1453 and 1262 cm^{-1} . The same bands appeared in these three samples. Fig. 2C shows the comparison between snake fruit (a), mangosteen (b), and kiwifruit (c). One additional band was detected at 1725 cm^{-1} . The wavelength numbers of FT-IR spectra for catechin at 831, 1040, 1112, 1144, 1285, 1478, 1512 and 1611 cm^{-1} were assigned to C–H alkenes, C–O alcohols, C–O–H alcohols, –OH aromatic, C–O alcohols, C–H alkanes, C=C aromatic ring and C=C alkenes, respectively. Gallic acid showed the following wavelength numbers (cm^{-1}): 866, 1026, 1237, 1451, 1542 and 1619. A shift in the difference between the standards and the investigated samples can be explained by the method of extraction of the main polyphenols. FT-IR and 3 D fluorimetry were used as rapid methods for comparison of methanol extracts from the studied fruits as an additional indicator of similarity or difference between the studied fruits, based on the bands and peaks in the polyphenol region. These analytical techniques can be recommended for any plant extracts.

The contents of total polyphenols (mg GAE g^{-1} DW) were in range from 2.58 to 8.46 in water extracts for durian, avocado, mango, for

kiwifruit, mangosteen and snake fruit ($P < 0.05$, Figs. 3, 4, Table 4). These data are similar to the cited results on bioactive compounds (Arancibia-Avila et al., 2008; Gorinstein et al., 2009; Gorinstein et al., 2010; Leontowicz, Leontowicz, Drzewiecki, et al., 2007; Leontowicz, Leontowicz, Jastrzebski, et al., 2007) and other authors (Corral-Aguayo, Yahia, Carrillo-Lopez, & Gonzalez-Aguilar, 2008; Rocha Ribeiro, Queiroz, Lopes Ribeiro de Queiroz, Milagres Campos, & Pinheiro Sant'Ana, 2007; Wolfe et al., 2008). The contents of total flavonoids (mg CE g^{-1} DW, Table 4) in water extracts were in the range from 1.523 to 0.163 for durian, snake fruit, mangosteen, avocado, kiwifruit and mango. These results on flavonoids are corresponding with the cited literature (Park et al., 2008, 2009; Robles-Sanchez et al., 2009; Toledo et al., 2008). Luximon-Ramma, Bhorun, and Crozier (2003) found that the content of flavonoids in eleven exotic fruits commonly consumed in Mauritius was from 21 to 712 $\mu\text{g g}^{-1}$ FW. The contents of flavanols ($\mu\text{g CE/g DW}$, Table 4) for water extracts were in the range from 67.05 to 2.11 for durian, avocado, mango, snake fruit, mangosteen and kiwifruit, respectively ($P < 0.05$). These results are in agreement with our previous published data (Arancibia-Avila et al., 2008; Haruenkit et al., 2007; Toledo et al., 2008) and other cited reports (Seeram, 2008), where some tropical fruits and among them mangosteen were investigated for phenolic phytochemicals such as, anthocyanins, flavonols, flavanols, proanthocyanidins, ellagitannins, gallotannins, xanthones, and coumarins. The contents of anthocyanins (mg CGE/g DW, Table 4) for water extracts were in range from 17.12 to 2.51 for all 6 investigated fruits, respectively ($P < 0.05$). The obtained anthocyanin contents are in agreement with our previous published data (Arancibia-Avila et al., 2008; Toledo et al., 2008) and data of other authors (Luximon-Ramma et al., 2003). These authors found that the content of proanthocyanidins in eleven commonly consumed exotic fruits from Mauritius was from 7 to 2561 $\mu\text{g g}^{-1}$ FW.

The contents of ascorbic acid (mg g^{-1} DW, Table 4) for water extracts were in the range from 2.52 to 15.25 for investigated samples, respectively ($P < 0.05$). The contents of ascorbic acid in investigated samples were higher than determined by others: for kiwifruit 1.88–3.00 (Tavarini, Degl'Innocenti, Remorini, Massai, & Guidi, 2008), 2.06 (Amodio, Colelli, Hasey, & Kader, 2007), and 1.69 mg g^{-1} FW (Jung, Lee, Bae, & Choi, 2007). It was found that the content of vitamin C was in the range from 8 to 1426 $\mu\text{g g}^{-1}$ FW in analyzed eleven commonly consumed exotic fruits from Mauritius (Luximon-Ramma et al., 2003).

The contents of tannins (mg CE g^{-1} DW, Table 4) for water extracts were in the range from 0.27 to 6.48 for the investigated samples. Total carotenoids and β -carotene ($\mu\text{g/g}$) were from 1.47 to 15.18 and 0.38 to 13.62, respectively. The obtained results on tannins and carotenoids for the investigated fruits are in agreement with our previous published data (Gorinstein et al., 2010; Park et al., 2009; Poovarodom et al., 2010). As can be seen, the contents of the bioactive compounds in water extracts in the studied fruits differ significantly. The higher content of polyphenols and tannins was in snake fruit, flavonoids, flavanols and anthocyanins – in durian, vitamin C – in kiwifruit, total carotenoids and β -carotenoids – in mango. Most of the bioactive compounds in exotic and conventional fruits were comparable ($P > 0.05$). Durian contains the significantly highest contents of flavonoids, flavanols and anthocyanins followed by snake fruit – the significantly highest content of polyphenols and tannins ($P < 0.05$ in both cases).

Fig. 1. Above, two-dimensional fluorimetric emission spectra (2D-FL) of methanol fruit extracts (0.25 mg/mL) for A) emission wavelength 685 nm recorded over the frequency ranges from the excitation wavelength at 290 nm to 400 nm, for catechin, mango and avocado from upper line to lower line; B) same conditions than A for catechin, kiwifruit and snake fruit from upper line to lower line; C) emission at 330 nm and recording from 265 to 310 nm for mango, durian and avocado from upper line to lower line; and D) same conditions than C for snake fruit, kiwifruit and durian from upper line to lower line. Below, three-dimensional fluorescence (3D-FL) contour map of water extracts (0.001 mg/mL) of: durian, snake fruit and mangosteen (E1, E2 and E3); durian, avocado and mango (F1, F2 and F3); snake fruit, mangosteen and kiwifruit (G1, G2 and G3). The 3D-FL were run emission mode and fluorescence intensity up to 1000, emission wavelengths from 270 to 750 nm and excitation wavelengths from 260 to 350 nm; scanning speed was 1000 nm/min on A–D–F, excitation wavelength on x-axis and fluorescence intensity on y-axis; E–G, emission wavelength on x-axis and excitation wavelength on y-axis.

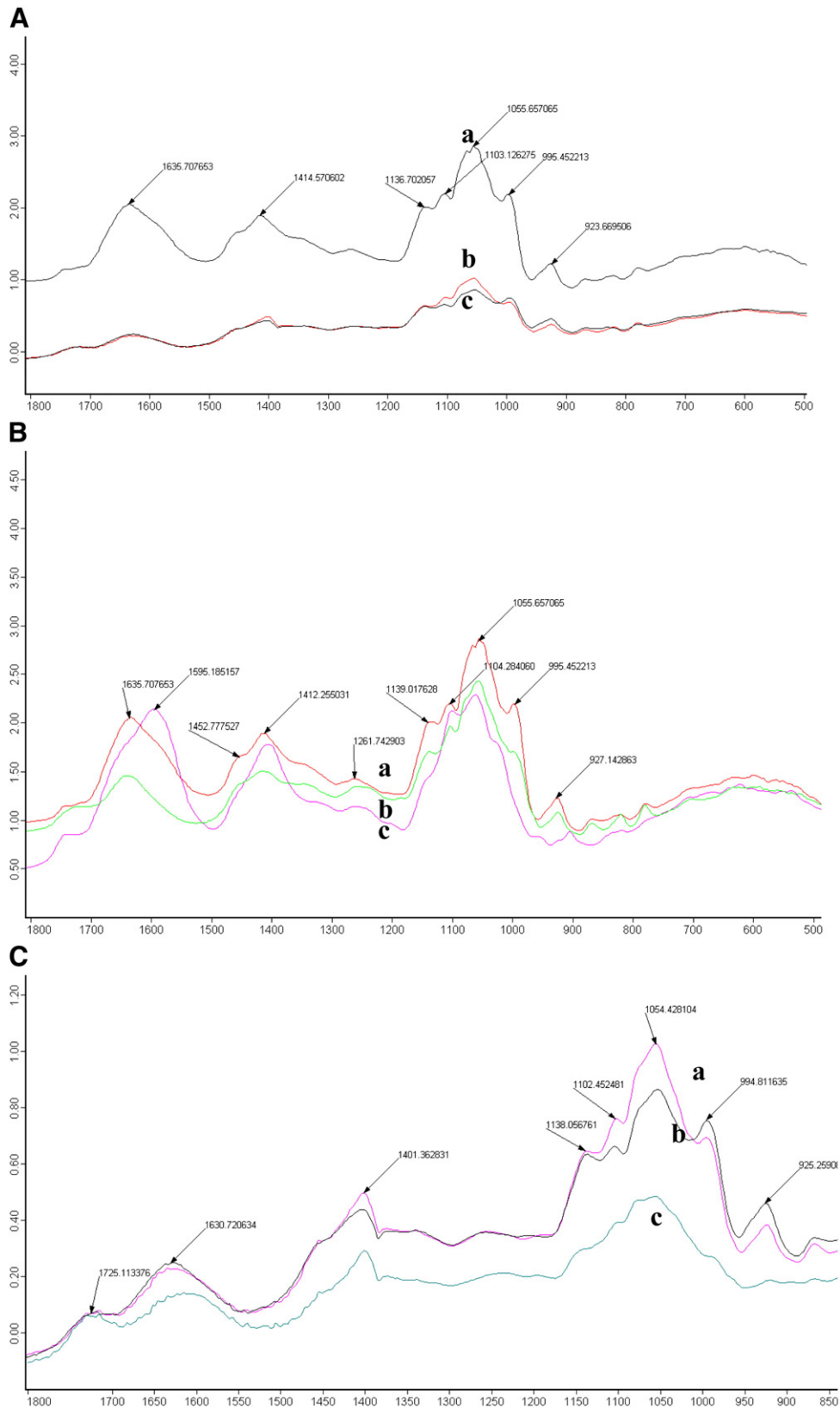


Fig. 2. FTIR spectra of lyophilized water extracts: A durian (a), snake fruit (b) and mangosteen (c); B: durian (a) avocado (b) and mango (c); C, snake fruit (a), mangosteen (b) and kiwifruit (c).

3.3. Fruits antioxidant activity

It was found that the 1) ABTS data were in range of 10.32 ± 1.6 to $19.78 \pm 2.1 \mu\text{MTE/g}$ for durian, avocado and mango ($P < 0.05$, Fig. 3); 2) FRAP data were in the range of 18.43 ± 1.8 to $22.65 \pm 2.3 \mu\text{MTE/g}$

for avocado, durian and mango ($P < 0.05$, Fig. 3); 3) CUPRAC data were in range of 15.62 ± 1.6 to $20.13 \pm 2.1 \mu\text{MTE/g}$ for durian, avocado and mango ($P < 0.05$, Fig. 3); 4) The obtained results of antioxidant values of the fruits are in agreement with our previous published data (Gorinstein et al., 2010; Haruenkit et al., 2010; Poovarodom et al.,

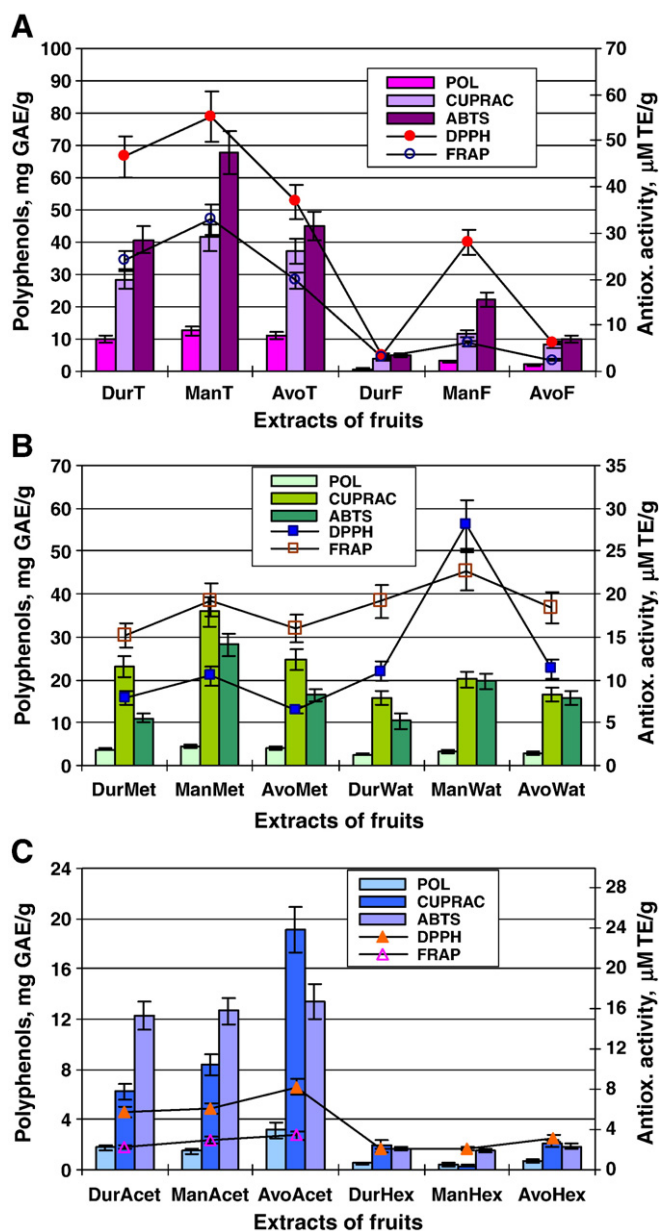


Fig. 3. Polyphenols and antioxidant activities of durian, mango and avocado extracts: A) Methanol (60%)–HCl extracts of conjugated polyphenols, and methanol (60%) extracts of unconjugated polyphenols; B) methanol polyphenols extracts, and water polyphenol extracts; C) acetone polyphenol extracts and hexane polyphenol extracts. Dur, Durango; Man, mango; Avo, avocado; CP, conjugated polyphenols; UCP, unconjugated polyphenols; POL, polyphenols; CUPRAC, cupric reducing antioxidant activity; ABTS, 2,2'-azinobis(3-ethyl-benzothiazoline-6-sulfonic acid)diammonium salt; DPPH, 1-diphenyl-2-picrylhydrazyl method; FRAP, ferric-reducing/antioxidant power; GAE, gallic acid equivalent; and Antiox, antioxidant. All data are calculated per gram dry weight.

2010) and the results of other authors (Corral-Aguayo et al., 2008; Jung et al., 2007; Mahattanatawee et al., 2006). The comparison of our data of durian, kiwifruit, mango and mangosteen was done according to recently published report of thirty-eight types of fruits commonly consumed in Singapore (Isabelle et al., 2010). Our obtained results differ from the cited ones, because of the country of origin of these fruits and the method of extraction of the bioactive compounds. In the present research the investigated fruits were from Thailand, Korea and Israel. In the cited research (Isabelle et al., 2010) the listed below exotic fruits were from Malaysia, and New Zealand. From the cited data (Isabelle et al., 2010) the highest amount of polyphenols and

antioxidant activity was in mangosteen, followed by kiwifruit and mango. Our data were slightly lower (Figs. 3, 4, Table 4).

Our data can be compared with another report (Barreto, Benassi, & Mercadante, 2009), where in 18 pulps from tropical fruits ascorbic acid, total phenolics, flavonoids, carotenoids and free radical scavenger activity evaluated by the ABTS assay were determined. Fruits showed a relatively high amount of bioactive compounds. Free radical scavenger showed a high correlation with total phenolic compounds ($r=0.99$) and flavonoids ($r=0.86$). However, the correlation was found to be very poor with ascorbic acid ($r=0.02$) and with total carotenoid levels ($r=0.08$). The same correlation coefficients were evaluated in our research only with slightly higher value for flavonoids ($r=0.92$), ascorbic acid ($r=0.56$), and carotenoids ($r=0.42$). Our results are in agreement with Vijaya Kumar Reddy, Sreeramulu, and Raghunath (2010), where fourteen commonly consumed fresh and ten dry fruits were studied. The antioxidant activity and polyphenols of both fresh and dry fruits showed marked variation, as it was shown in our data. Correlation analyzed between the polyphenols and antioxidant activity as assessed by the two methods showed that phenolics may contribute maximally to the ABTS ($r=0.84$) and to lesser extent to DPPH ($r=0.77$) in fresh fruits. Our data were slightly higher than the cited ones in the estimation of the correlation coefficients. The data in the literature is poor on the investigated exotic fruits, therefore our results were compared with a number of Brazilian exotic fruits, which were characterized in relation to their bioactive compounds and antioxidant capacity (Genovese, Da Silva Pinto, De Souza Schmidt Goncalves, & Lajolo, 2008). Camu-camu (*Myrciaria dubia*) presented the highest vitamin C and total phenolics contents (397 and 1797 mg/100 g FW, respectively) and the highest DPPH scavenging capacity. Coquinho (*Butia capitata*) also showed a significant vitamin C content (43 mg/100 g FW). A good correlation between total phenols and DPPH scavenging activity was found for fruits ($r=0.997$). Quercetin and kaempferol derivatives were the main flavonoids present in all samples. According to our results, camu-camu and araca can be compared with the snake fruit and might be sources of bioactive compounds. Our results were in agreement with the results of others (Ikram et al., 2009), where antioxidant activity and total phenolic acids were determined by two similar antioxidants assays (DPPH and FRAP). Their findings showed that the fruits from *Sallacca* and *Garcinia* had higher antioxidant capacity compared to other studied genera. *Durio* [total phenolics (TP), mg GAE/g DW, and antioxidant capacity (AC) based on β -carotene bleaching assay, %] showed different ranges of TP and AC from 1.56 to 7.52 and AC from 73.87 to 60.36, depending on the cultivar and genera as for *Durio zibenthinus* (Durian Tutong, TP=1.56 and AC=73.87) for *D. zibenthinus* (Durian Isu Oren, TP=4.32 and AC=64.86) and for *Durio kutejensis* (Durian Isu Kuning, TP=4.70 and AC=54.05). *Garcinia* showed as well differences in the polyphenols [total phenolics (TP), mg GAE/g DW, and antioxidant capacity (AC) based on β -carotene bleaching assay, %] from the lowest for *Garcinia atroviridis* (Assam Gelugor) – TP=3.49; middle of TP=4.89 for *Garcinia parvifolia* (Kundung Sarawak) and the highest – TP=85.10 for *Garcinia prainiana* (Cerapu) (Ikram et al., 2009). In Patthamakanokporn, Puwastien, Nitithamyong, and Sirichakwal (2008) the data for mangosteen were similar: polyphenols (TP, mg GAE/g DW) TP=4.15, ORAC and FRAP ($\mu\text{M TE/g DW}$) – 30.56 and 25.43, respectively. In Leong and Shui (2002) L-ascorbic acid equivalent antioxidant capacity (AEAC) calculated on dry weight (mg/g DW) was for snake fruit 17.16, followed by mangosteen of 7.65, kiwifruit – 7.60, mango – 6.48, and avocado of 4.16. The ranking orders of total antioxidant capacity were as follows: snake fruit>mangosteen>kiwifruit>mango>avocado (Leong & Shui, 2002).

Mango Nam Dok Mai (*M. indica* L.) was reported to have 5.2 mg GAE/g DW, ORAC and FRAP values ($\mu\text{M TE/g DW}$) of 96.6 and 36.8 (Patthamakanokporn et al., 2008). Mango Kiew-sa-weya had lower data: total polyphenols about 2.94, ORAC and FRAP of 30.56 and 26.43. In

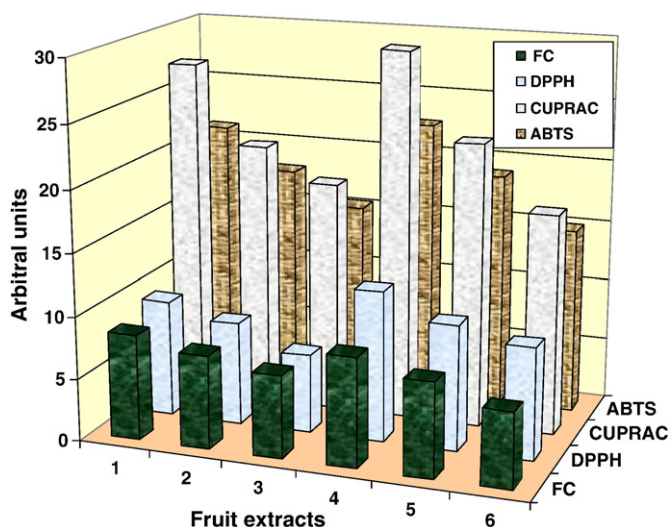


Fig. 4. Relationship between the polyphenols and antioxidant activities in different fruit extracts. Extracts 1–3, water extracts of snake fruit Sumalee, mangosteen, conventional kiwifruit ‘Hayward’; 4–6, methanol extracts of Snake fruit Sumalee, mangosteen, and conventional kiwifruit ‘Hayward’. FC, Folin–Ciocalteu method; DPPH, 1, 1-diphenyl-2-picrylhydrazyl radical; ABTS, 2, 2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt; and CUPRAC, Cupric reducing antioxidant capacity.

mangosteen values of polyphenols were 4.15, ORAC and FRAP – 122.74 and 31.78. The rank of ORAC and FRAP antioxidant activity values in fruits was different: phenols: mango (Nam Dok Mai) > mangosteen > mango (Kiew-sa-weya); FRAP: mango (Nam Dok Mai) > mangosteen > mango (Kiew-sa-weya); ORAC: mangosteen > mango (Nam Dok Mai) > mango (Kiew-sa-weya) (Patthamakanokporn et al., 2008). The values of polyphenols in *Mangifera foetida*, *Mangifera odorata* and *Mangifera pajang* (10.32–124.19 mg GAE/g DW) was higher in Ikram et al. (2009). The efficiency of extraction depends on different variables such as solvents, their concentration, temperature, time of extraction. From the obtained data from Table 1, Figs. 3 and 4 we can conclude that the highest yield of the bioactive compounds was evaluated in methanol extracts with hydrolysis, followed by methanol, water, acetone and hexane, what corresponded with others (Vinson et al., 2001; Hertog et al., 1992). The results of this report support the conclusions of Perez-Jimenez and Saura-Calixto (2005) that the most efficient antioxidant extraction was achieved by using successively acidic methanol/water (50:50 v/v, pH 2). The extraction with methanol/HCl is based on the data of others (Hertog et al., 1992), showing that under acid hydrolysis with 2.0 M HCl in boiling 50% aqueous methanol, flavonol 3-O-glucosides are hydrolyzed completely within a few minutes, whereas complete hydrolysis of flavonol 3,7- and 4'-O-glucuronides takes 60–250 min. Optimization of extraction and hydrolysis has shown that the highest yield was found using 1.2 M HCl and a reaction period of 2 h. It appeared that extraction was most efficient with 50% aqueous

methanol. The flavonoid glycosides were hydrolyzed to their corresponding aglycons by refluxing in 1.2 M HCl containing 40% MeOH so as to exert maximal reducing power towards scavenging radicals used in the antioxidant assays. Increasing acid concentration and reaction time led to a significant degradation of quercetin. Therefore, such extraction was suggested in this study for the extraction of total phenols. These results are exactly in line with Hertog et al. (1992), reporting that the extraction efficiency could thus depend on the water/methanol ratio (Hertog et al., 1992; Perez-Jimenez & Saura-Calixto, 2005; Gorinstein et al., 2008). The order of the investigated exotic fruits is not exactly the same as in the cited literature. Such difference depends on the year of collection, the cultivar, the post harvest conditions, the extraction of bioactive compounds and the applied assays for the antioxidant determination.

3.4. Investigation in vivo

One of the main risk factors of atherosclerosis is hypercholesterolemia. Decrease of LDL reduces the risk of this disease. Oxidized LDL cholesterol is the main contributor of the development of atherosclerotic lesions, because it stimulates macrophage cholesterol accumulation. Serum high-density lipoprotein (HDL) levels are inversely related to the risk of atherosclerosis. Fruits extracts of high antioxidative capacity and unique polyphenolic composition are reported to be beneficial in atherosclerosis prevention (Borochov-Neori et al., 2008), therefore the results with the exotic fruits in vivo are important for a better understanding of the bioactivity of the investigated fruits.

After the experiment in vivo diets supplemented with exotic and other fruits significantly hindered the rise in plasma lipids and hindered a decrease in the plasma antioxidant activity in rats fed cholesterol-containing diet. It was recorded that the level of plasma lipids in diet groups with investigated fruits vs. Chol group was significantly less (P<0.05): TC – 12.1–10.2%, LDL-C – 13.3–11.4%, HDL-C – 12.2–10.8% and TG – 14.1–13.2% (Fig. 5). A significant decrease was registered in the plasma antioxidant activity in all cholesterol fed vs. Control group (P<0.05). However, the decrease in the antioxidant activity in Durian/Chol vs. Chol Group was significantly less: by 16.9–14.7%, 21.9–20.8% and 11.8–10.5%, according to ABTS, DPPH and FRAP, respectively. The decrease in the plasma antioxidant activity was predictable. As was shown by Mahfouz and Kummerow (2000), cholesterol-rich diets have different effects on lipid peroxidation, cholesterol oxides, and antioxidant enzymes in rats and rabbits.

The above cited results of the present investigation which was conducted with the fruits collected from the new harvest are in agreement with our published data on the change in the plasma cholesterol spectrum and antioxidant activity with the exotic fruits from the previous harvest (Haruenkit et al., 2007; Leontowicz, Leontowicz, Drzewiecki, et al., 2007; Leontowicz, Leontowicz, Jastrzebski, et al., 2007). Our findings agree with those of Savithri et al. (2009), where A.

Table 4
Contents of bioactive compounds in water extracts of the studied fruits/g DW.

Compounds	Durian	Snake fruit	Mangosteen	Mango	Kiwifruit	Avocado
Pol, mgGAE	2.58 ± 0.1 ^a	8.46 ± 0.4 ^c	7.51 ± 0.3 ^b	3.42 ± 0.2 ^a	6.61 ± 0.3 ^b	2.86 ± 0.1 ^a
Flavo, mgCE	1.523 ± 0.07 ^c	0.313 ± 0.02 ^b	0.241 ± 0.01 ^b	0.163 ± 0.01 ^a	0.182 ± 0.01 ^a	0.194 ± 0.01 ^a
Flava, µgCE	67.05 ± 3.1 ^c	3.14 ± 0.2 ^a	2.88 ± 0.2 ^a	31.02 ± 1.5 ^b	2.11 ± 0.1 ^a	34.10 ± 1.7 ^b
Antho, mgGCE	17.12 ± 1.1 ^e	9.74 ± 0.5 ^d	6.82 ± 0.3 ^c	1.75 ± 0.08 ^a	2.51 ± 0.1 ^a	4.38 ± 0.2 ^b
Tannin, mgCE	1.37 ± 0.06 ^b	6.48 ± 0.3 ^d	2.81 ± 0.1 ^c	0.27 ± 0.01 ^a	2.34 ± 0.1 ^c	1.44 ± 0.07 ^b
Vit C, mgAA	5.65 ± 0.2 ^b	13.28 ± 0.7 ^c	12.35 ± 0.6 ^c	5.26 ± 0.2 ^b	15.2 ± 0.8 ^d	2.52 ± 0.1 ^a
TotCar, µg/g	7.26 ± 0.4 ^b	2.2 ± 0.1 ^a	1.47 ± 0.07 ^a	15.18 ± 0.8 ^c	9.4 ± 0.5 ^b	9.47 ± 0.5 ^b
β-Car, µg/g	4.94 ± 0.2 ^d	1.17 ± 0.05 ^b	0.38 ± 0.02 ^a	13.62 ± 0.7 ^e	2.6 ± 0.1 ^c	3.11 ± 0.1 ^c

Pol, polyphenols, flavo, flavonoids, Flava, flavanols, Antho, anthocyanins, Vit C, vitamin C, TotCar, total carotenoids, β-Car, β-Carotenoids, CE, catechin equivalent; GAE, gallic acid equivalent, and CGE, cyanidin-3-glucoside equivalent. Values are means ± SD. Means in rows without superscript letters in common differ significantly (P<0.05).

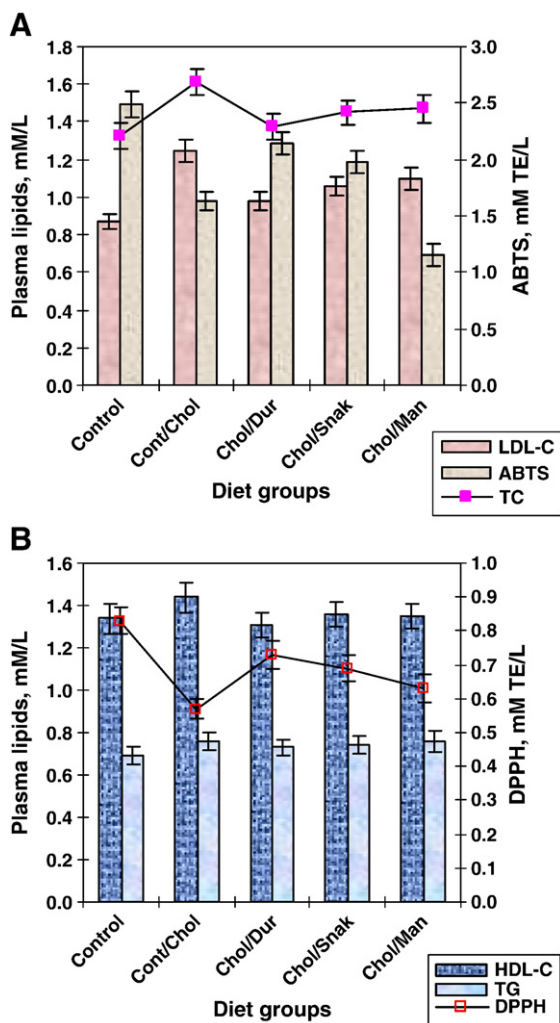


Fig. 5. Effects of supplementation to rats with exotic fruits in diets on: A) LDL-C, ABTS, TC; B) HDL-C, DPPH, TG. Cont, control diet; Cont/Chol, control diet with cholesterol; Chol/Dur, diet with cholesterol supplemented with durian; Chol/Snak, diet with cholesterol supplemented with snake fruit; Chol/Man, diet with cholesterol supplemented with mango; ABTS, 2,2'-azinobis(3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt; and DPPH, 1-diphenyl-2-picrylhydrazyl method.

bilimbi Linn. fruit in its water extract (50 mg/kg) was found to be effective in lowering lipids in the high-fat diet fed rats. Thus, this fruit can be used as a dietary ingredient to prevent as well as treat hyperlipidemia as investigated fruits in this research. The results obtained by Gallaher and Gallaher (2009) support as well our findings where the apoE-deficient mouse, which develops atherosclerotic lesions rapidly when fed cholesterol, was used to determine the ability of dried plums to reduce atherosclerosis.

Similarly, repeated oral administration of ethanol extracts of *C. depressa* and *A. atemoya* potently lowered the plasma triglyceride (TG) concentrations of KKAY mice fed a moderately high-fat diet for 4 weeks. Thus, reduced fatty acid mobilization from the adipose tissue by the *A. atemoya* extract may result in the reduction in TG synthesis in the liver (Beppu et al., 2009). Our results corresponded with this report on the hypolipidemic effects of *C. depressa* and *A. atemoya*. Our results were in agreement with Valcheva-Kuzmanova et al. (2007), where *A. melanocarpa* fruit juice (AMFJ) was applied orally for 30 days at doses of 5, 10 and 20 mL/kg. In rats fed the cholesterol-containing diets, AMFJ significantly hindered an increase in plasma lipids (total cholesterol, low-density lipoprotein cholesterol and triglycerides) because of cholesterol feeding. Body weight gains, liver weights and liver and aorta histopathology were not influenced either by high-

cholesterol diets or by AMFJ treatment. AMFJ showed lipid-lowering effects in rats with induced hyperlipidemia, and could be valuable in reducing lipidemia as a factor of cardiovascular risk. In our results when the fruits were tested for 30 days aorta histopathology was not observed, as in the cited research. Only experiments with 46 days feeding showed changes in the aorta histology on persimmon fruits (Gorinstein et al., 2011).

Based on the obtained and cited data it can be concluded that fruits are a rich source of diverse antioxidants, therefore the efforts in the promotion of variety fruits, especially exotic fruits, for health benefits (Barreto et al., 2009) have to be done.

4. Conclusions

The contents of bioactive compounds and the antioxidant potentials are relatively high in all studied exotic fruits, such as durian, snake fruit, and mangosteen and traditional ones such as avocado, mango and kiwifruit. The contents of total polyphenols (mg GAE g⁻¹ DW) were in the range from 2.58 to 8.46 in water extracts for durian, avocado, mango, for kiwifruit, mangosteen and snake fruit. DPPH antioxidant capacity values were in the range from 10.94 to 28.16 μMTE/g for durian, avocado and mango, respectively, and from 6.35 to 9.43 for kiwifruit, mangosteen and snake fruit, respectively. The supplementation of diets with these fruits positively affects plasma lipid profile and antioxidant activity in rats fed cholesterol-containing diets. The combination of *in vitro* with *in vivo* studies may allow to have a better information on the association between the content of bioactive compounds in the studied fruits and their effects on health.

Acknowledgements

Reviewer #1's enthusiasm and input are greatly valued. The authors are thankful to Post Harvest Technology Innovation Center, Chiang Mai University, Chiang Mai, Thailand, for partial financial support. The authors are thankful to the Chantaburi Salacca Grower Association, Chantaburi, Thailand, for partial financial support as well. The authors are also thankful to Mr Moshe Giladi (Mehadrin Tnuport Export (MTEX) L.P, Be'erot Yitzhak, Israel) for the donation of some fruit samples.

References

- Amodio, M. L., Colelli, G., Hasey, J. K., & Kader, A. A. (2007). A comparative study of composition and post harvest performance of organically and conventionally grown kiwifruits. *Journal of the Science of Food and Agriculture*, 87, 1228–1236.
- Anderson, J. W., Jones, A. E., & Riddell-Mason, S. (1994). Ten different dietary fibers have significantly different effects on serum and liver lipids of cholesterol fed rats. *Journal of Nutrition*, 124, 78–83.
- Apak, R., Guclu, K., Ozyurek, M., & Karademir, S. E. (2004). Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. *Journal of Agriculture and Food Chemistry*, 52, 7970–7981.
- Aralas, S., Mohamed, M., & Bakar, A. M. F. (2009). Antioxidant properties of selected salak (*Salacca zalacca*) varieties in Sabah, Malaysia. *Nutrition and Food Science*, 39, 243–250.
- Aramwit, P., Bang, N., & Srichana, T. (2010). The properties and stability of anthocyanins in mulberry fruits. *Food Research International*, 43, 1093–1097.
- Arancibia-Avila, P., Toledo, F., Park, Y. -S., Jung, S. -T., Kang, S. -G., Heo, B. -G., et al. (2008). Antioxidant properties of durian fruit as influenced by ripening. *LWT – Food Science and Technology*, 41, 2118–2125.
- Barreto, G. P. M., Benassi, M. T., & Mercadante, A. Z. (2009). Bioactive compounds from several tropical fruits and correlation by multivariate analysis to free radical scavenger activity. *Journal of the Brazilian Chemical Society*, 20, 1856–1861.
- Benzie, I. F. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of 'antioxidant power': The FRAP assay. *Analytical Biochemistry*, 239, 70–76.
- Beppu, F., Niwano, Y., Kyan, R., Yasura, K., Tamaki, M., Nishino, M., et al. (2009). Hypolipidemic effects of ethanol extracts of *Citrus depressa* and *Annona atemoya*, typical plant foodstuffs in Okinawa, Japan on KKAY mice fed with moderately high fat diet. *Food Science and Technology Research*, 15, 553–556.
- Borochov-Neori, H., Judeinstein, S., Greenberg, A., Fuhrman, B., Attias, J., Volkova, N., et al. (2008). Phenolic antioxidants and antiatherogenic effects of Marula

- (*Sclerocarya birrea* Subsp. *caffra*) fruit juice in healthy humans. *Journal of Agricultural and Food Chemistry*, 56, 9884–9891.
- Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *Food Science & Technology (London)*, 28, 25–30.
- Cheng, G. W., & Breen, P. J. (1991). Activity of phenylalanine ammonia-lyase (PAL) and concentrations of anthocyanins and phenolics in developing strawberry fruit. *Journal of American Society of Horticultural Science*, 116, 865–869.
- Corral-Aguayo, R. D., Yahia, E. N., Carrillo-Lopez, A., & Gonzalez-Aguilar, G. (2008). Correlation between some nutritional components and the total antioxidant capacity measured with six different assays in eight horticultural crops. *Journal of Agricultural and Food Chemistry*, 56, 10498–10504.
- Gallaher, C. M., & Gallaher, D. D. (2009). Dried plums (prunes) reduce atherosclerosis lesion area in apolipoprotein E-deficient mice. *British Journal of Nutrition*, 101, 233–239.
- Genovese, M. I., Da Silva Pinto, M., De Souza Schmidt Goncalves, A. E., & Lajolo, F. M. (2008). Bioactive compounds and antioxidant capacity of exotic fruits and commercial frozen pulps from Brazil. *Food Science and Technology International*, 14, 207–214.
- Gorinstein, S., Haruenkit, R., Poovarodom, S., Park, Y. -S., Vearasilp, S., Suhaj, M., et al. (2009). The comparative characteristics of snake and kiwifruits. *Food and Chemical Toxicology*, 47, 1884–1891.
- Gorinstein, S., Haruenkit, R., Poovarodom, S., Vearasilp, S., Ruamsuke, P., Namiesnik, J., et al. (2010). Some analytical assays for the determination of bioactivity of exotic fruits. *Phytochemical Analysis*, 21, 355–362.
- Gorinstein, S., Leontowicz, H., Leontowicz, M., Jesion, I., Namiesnik, J., Drzewiecki, J., et al. (2011). Influence of two cultivars of persimmon on atherosclerosis indices in rats fed cholesterol-containing diets: Investigation *in vitro* and *in vivo*. *Nutrition*, doi:10.1016/j.nut.2010.08.015.
- Gorinstein, S., Lojek, A., Ciz, M., Pawelzik, E., Delgado Licon, E., Medina, O. J., et al. (2008). Comparison of composition and antioxidant capacity of some cereals and pseudocereals. *International Journal of Food Science & Technology*, 43, 629–637.
- Hait-Darshan, R., Grossman, S., Bergman, M., Deutsch, M., & Zurgil, N. (2009). Synergistic activity between a spinach-derived natural antioxidant (NAO) and commercial antioxidants in a variety of oxidation systems. *Food Research International*, 42, 246–253.
- Haruenkit, R., Poovarodom, S., Leontowicz, H., Leontowicz, M., Sajewicz, M., Kowalska, T., et al. (2007). Comparative study of health properties and nutritional value of durian, mangosteen, and snake fruit: Experiments *in vitro* and *in vivo*. *Journal of Agricultural and Food Chemistry*, 55, 5842–5849.
- Haruenkit, R., Poovarodom, S., Vearasilp, S., Namiesnik, J., Sliwka-Kaszynska, M., Park, Y. -S., et al. (2010). Comparison of bioactive compounds, antioxidant and antiproliferative activities of Mon Thong durian during ripening. *Food Chemistry*, 118, 540–547.
- Hertog, M. G. L., Hollman, P. C. H., & Venema, D. P. (1992). Optimization of a quantitative HPLC determination of potentially anticarcinogenic flavonoids in vegetables and fruits. *Journal of Agricultural and Food Chemistry*, 40, 1591–1598.
- Ikram, E. H. K., Eng, K. H., Jalil, A. M. M., Ismail, A., Idris, S., Azlan, A., et al. (2009). Antioxidant capacity and total phenolic content of Malaysian underutilized fruits. *Journal of Food Composition and Analysis*, 22, 388–393.
- Isabelle, M., Lee, B. -L., Lim, M. -T., Koh, W. -P., Huang, D. -J., & Ong, C. -N. (2010). Antioxidant activity and profiles of common fruits in Singapore. *Food Chemistry*, 123, 77–84.
- Jung, C. H., Lee, W. J., Bae, S. H., & Choi, S. G. (2007). Chemical components and antioxidant activity of Korean gold kiwifruit. *Han'guk Sikp'um Yongyang Kwahak Hoehi*, 36, 859–865.
- Khoo, H., Ismail, A., Mohd-Esa, N., & Idris, S. (2008). Carotenoid content of underutilized tropical fruits. *Plant Foods for Human Nutrition*, 63, 170–175.
- Leong, L. P., & Shui, G. (2002). An investigation of antioxidant capacity of fruits in Singapore markets. *Food Chemistry*, 76, 69–75.
- Leontowicz, M., Leontowicz, H., Drzewiecki, J., Jastrzebski, Z., Haruenkit, R., Poovarodom, S., et al. (2007). Two exotic fruits positively affect rat's plasma composition. *Food Chemistry*, 102, 192–200.
- Leontowicz, M., Leontowicz, H., Jastrzebski, Z., Jesion, I., Haruenkit, R., Poovarodom, S., et al. (2007). The nutritional and metabolic indices in rats fed cholesterol-containing diets supplemented with durian at different stages of ripening. *Biofactors*, 29, 123–136.
- Luximon-Ramma, A., Bahorun, T., & Crozier, A. (2003). Antioxidant actions and phenolic and vitamin C contents of common Mauritian exotic fruits. *Journal of the Science of Food and Agriculture*, 83, 496–502.
- Mahattanatawee, K., Manthey, J. A., Luzio, G., Talcott, S. T., Goodner, K., & Baldwin, E. A. (2006). Total antioxidant activity and fiber content of select Florida-grown tropical fruits. *Journal of Agriculture and Food Chemistry*, 54, 7355–7363.
- Mahfouz, M. M., & Kummerow, F. A. (2000). Cholesterol-rich diets have different effects on lipid peroxidation, cholesterol oxides, and antioxidant enzymes in rats and rabbits. *Journal of Nutritional Biochemistry*, 11, 293–302.
- Mañas, E., Bravo, L., & Saura-Calixto, F. (1994). Sources of error in dietary fibre analysis. *Food Chemistry*, 50, 331–342.
- Masibo, M., & He, Q. (2008). Major mango polyphenols and their potential significance to human health. *Comprehensive Review of Food Science and Food Safety*, 7, 309–319.
- Nakamura, K., Nagata, C., Oba, S., Takatsuka, N., & Shimizu, H. (2008). Fruit and vegetable intake and mortality from cardiovascular disease are inversely associated in Japanese women but not in men. *Journal of Nutrition*, 138, 1129–1134.
- Ou, B., Huang, D., Hampsch-Woodill, M., Flanagan, J. A., & Deemer, E. K. (2002). Analysis of antioxidant activities of common vegetables employing oxygen radical absorbance capacity (ORAC) and ferric reducing antioxidant power (FRAP) assays: A comparative study. *Journal of Agriculture and Food Chemistry*, 50, 3122–3128.
- Ozyurek, M., Guclu, K., Bektasoglu, B., & Apak, R. (2007). Spectrophotometric determination of ascorbic acid by the modified CUPRAC method with extractive separation of flavonoids-La (III) complexes. *Analytica Chimica Acta*, 588, 88–95.
- Park, Y. -S., Jung, S. -T., Kang, S. -G., Heo, B. G., Arancibia-Avila, P., Toledo, F., et al. (2008). Antioxidants and proteins in ethylene treated kiwifruits. *Food Chemistry*, 107, 640–648.
- Park, Y. -S., Jung, S. -T., Kang, S. -G., Heo, B. -G., Lee, S. -H., Toledo, F., et al. (2009). Radical scavenging capacity of ethylene-treated kiwifruit. *Journal of Food Biochemistry*, 33, 674–692.
- Patthamakanokporn, O., Puwastien, P., Nitithamyong, A., & Sirichakwal, P. P. (2008). Changes of antioxidant activity and total phenolic compounds during storage of selected fruits. *Journal of Food Composition and Analysis*, 21, 241–248.
- Pedraza-Chaverri, J., Cárdenas-Rodríguez, N., Orozco-Ibarra, M., & Pérez-Rojas, J. M. (2008). Medicinal properties of mangosteen (*Garcinia mangostana*). *Food and Chemical Toxicology*, 46, 3227–3239.
- Perez-Jimenez, J., & Saura-Calixto, F. (2005). Literature data may underestimate the actual antioxidant capacity of cereals. *Journal of Agricultural and Food Chemistry*, 53, 5036–5040.
- Poovarodom, S., Haruenkit, R., Vearasilp, S., Namiesnik, J., Cvikrova, M., Martincova, O., et al. (2010). Comparative characterization of durian, mango and avocado. *International Journal of Food Science and Technology*, 45, 921–929.
- Prosky, L., Asp, N. G., Schweizer, T., De Vries, J. W., & Furda, I. (1992). Determination of insoluble and soluble dietary fiber in food and food products: Collaborative study. *Journal of AOAC International*, 75, 360–367.
- Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology & Medicine*, 26, 1231–1237.
- Ribeiro, S. M. R., Barbosa, L. C. A., Queiroz Knödler, J. H. M., & Schieber, A. (2008). Phenolic compounds and antioxidant capacity of Brazilian mango (*Mangifera indica* L.) varieties. *Food Chemistry*, 110, 620–626.
- Robles-Sanchez, R. M., Islas-Osuna, M. A., Astiazaran-García, H., Vazquez-Ortiz, F. A., Martin-Belloso, O., Gorinstein, S., et al. (2009). Quality index, consumer acceptability, bioactive compounds, and antioxidant activity of fresh-cut mangoes (*Mangifera indica* L.) as affected by low-temperature storage. *Journal of Food Science*, 74, S126–S134.
- Rocha Ribeiro, S. M., Queiroz, J. H., Lopes Ribeiro de Queiroz, M. E., Milagres Campos, F., & Pinheiro Sant'Ana, H. M. (2007). Antioxidant in mango (*Mangifera indica* L.) pulp. *Plant Foods for Human Nutrition*, 62, 13–17.
- Savithri, A., Appian, S., & Natesan Shanmugam, N. (2009). Studies on the antihyperlipidemic properties of *Averrhoa bilimbi* fruit in rats. *Planta Medica*, 75, 55–58.
- Seeram, N. P. (2008). *Bioavailability, metabolism and tissue distribution of fruit bioactives*. Abstracts of Papers, 235-th ACS National Meeting, New Orleans, LA, United States, April 6–10.
- Sinelli, N., Spinardi, A., Di Egidio, V., Mignani, I., & Casiraghi, E. (2008). Evaluation of quality and nutraceutical content of blueberries (*Vaccinium corymbosum* L.) by near and mid-infrared spectroscopy. *Postharvest Biology and Technology*, 50, 31–36.
- Singleton, V. L., Orthofer, R., & Lamuela-Raventos, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods of Enzymology*, 299, 152–178.
- Takachi, R., Inoue, M., Ishihara, J., Kurahashi, N., Iwasaki, M., Sasazuki, S., et al. (2008). Fruit and vegetable intake and risk of total cancer and cardiovascular disease. Japan Public Health Center-based Prospective Study. *American Journal of Epidemiology*, 167, 59–70.
- Tavarini, S., Degl'Innocenti, E., Remorini, D., Massai, R., & Guidi, L. (2008). Antioxidant capacity, ascorbic acid, total phenols and carotenoids changes during harvest and after storage of Hayward kiwifruit. *Food Chemistry*, 107, 282–288.
- Terasawa, N., Sakakibara, M., & Murata, M. (2006). Antioxidative activity of avocado epicarp hot water extract. *Food Science and Technology Research*, 12, 55–58.
- Toledo, F., Arancibia-Avila, P., Park, Y. -S., Jung, S. -T., Kang, S. -G., Heo, B. -G., et al. (2008). Screening of the antioxidant and nutritional properties, phenolic contents and proteins of five durian cultivars. *International Journal of Food Sciences and Nutrition*, 59, 415–427.
- Valcheva-Kuzmanova, S., Kuzmanov, K., Tsanova-Savova, S., Mihova, V., Krasnaliev, I., Borisova, P., et al. (2007). Lipid-lowering effects of *Aronia melanocarpa* fruit juice in rats fed cholesterol-containing diets. *Journal of Food Biochemistry*, 31, 589–602.
- Vijaya Kumar Reddy, C., Sreeramulu, D., & Raghunath, M. (2010). Antioxidant activity of fresh and dry fruits commonly consumed in India. *Food Research International*, 43, 285–288.
- Vinson, J. A., Su, X., Zubic, L., & Bose, P. (2001). Phenol antioxidant quantity and quality of foods: Fruits. *Journal of Agriculture and Food Chemistry*, 49, 5315–5321.
- Wolfe, K. L., Kang, X., He, X., Dong, M., Zhang, Q., & Liu, R. H. (2008). Cellular antioxidant activity of common fruits. *Journal of Agriculture and Food Chemistry*, 56, 8418–8426.
- Wulf, J. S., Geyer, M., Nicolai, B., & Zude, M. (2005). Non-destructive assessment of pigments in apple fruit and carrot by laser-induced fluorescence spectroscopy (LIFS) measured at different time-gate positions. *Acta Horticulturae*, 2, 1387–1393 (Proceedings of the 5th International Postharvest Symposium).
- Yin, C., Li, H., Ding, C., & Wang, H. (2009). Preliminary investigation on variety, brewery and vintage of wines using three-dimensional fluorescence spectroscopy. *Food Science and Technology Research*, 15, 27–38.