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Original Article

Anti-acne inducing bacteria activity and α-mangostin content of *Garcinia mangostana* fruit rind extracts from different provenience

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Abstract

The fruit rind of *Garcinia mangostana* Linn. has been traditionally used for treatment of skin infection, wounds, dysentery, and diarrhea. α-Mangostin, a major constituent of the fruit rind, was reported to possess a strong inhibitory effect against *Propionibacterium acnes* and *Staphylococcus epidermidis*, which is involved in acne development. This study was conducted to quantitative analyze the content of α-mangostin in the fruit rind of this plant collected from 13 locations in the South and East of Thailand by validated TLC-densitometric method. Antibacterial activity against *P. acnes* and *S. epidermidis* of the extracts was also determined. α-Mangostin contents in the fruit rinds and in the 95 % ethanolic extracts were found in the ranges of 3.39-5.68 and 11.83-23.11 % dry weight, respectively. The samples from the South showed higher contents of α-mangostin (average 17.64 % w/w in the extract and 4.85 % w/w in the dried powder) than the eastern samples. The MIC values of all extracts against *P. acnes* and *S. epidermidis* were in the range of 7.81-15.63 and 15.63-31.25 μg/mL, respectively, while the MBC values were in the range of 15.63-31.25 and 62.50-125.00 μg/mL, respectively. The antibacterial activity and α-mangostin content of the samples from different locations were significantly different (p<0.05). The average MIC and MBC values indicate that the samples from the South of Thailand (MIC = 13.02 μg/mL, MBC = 15.63 μg/mL for *P. acne* and MIC = 23.44 μg/mL, MBC = 83.33 μg/mL for *S. epidermidis*) promoted stronger antibacterial effect than the samples from the East. The results suggest that the α-mangostin content in the extract of *G. mangostana* fruit rind correlates with the anti-acne inducing bacteria activity. The fruit rinds of *G. mangostana* cultivated in the South seemed to be the appropriate source in terms of higher α-mangostin content and better anti-acne property.

Keywords: α-mangostin, Guttiferae, mangosteen, *Propionibacterium acnes*, *Staphylococcus epidermidis*, TLC-densitometry

1. Introduction

Mangosteen (*Garcinia mangostana* Linn.) is a tropical fruit tree of the family Guttiferae. The fruit of this plant is known as the "Queen of fruits" due to its pleasant flavor (Martin, 1980). Mangosteen originates in Southeast Asia and can be found in several tropical countries, especially in the southern and eastern parts of Thailand, where it represents an important exported product. The fruit rind of mangosteen has been used as a traditional medicine for treatment of skin infection, wounds, dysentery, and diarrhea (Gritsanapan and Chulasiri, 1983; Nakatani *et al*., 2002). It contains xanthones, tannins, and other bioactive substances (Sen *et al*., 1980; Fransworth and Bunyapraphatsara, 1992; Yu *et al*., 2007). α-Mangostin was reported to be a major constituent of the fruit rind (Walker, 2007) (Figure 1). It possess antibacterial (Sakagami *et al*., 2005), anti-inflammatory (Chomnawang *et al*., 2007), antihistamine (Chairungsrilerd *et al*., 1996), and anti-HIV properties (Chen *et al*., 1996). It was also reported to inhibit *Propionibacterium acnes* and *Staphylococcus*

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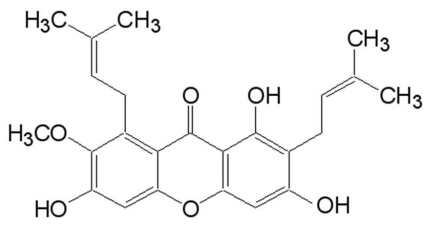

Figure 1. Chemical structure of α-mangostin

epidermidis, which is involved in acne development (Chomnawang *et al*., 2005). Thus, the fruit rind of this plant is an interesting source for anti-acne properties. Recently, mangosteen fruit rind extract has been used in several commercial nutritional supplements and herbal cosmetics. One problem of these applications is that most of the extracts did not have standardization. So, quality of the extract in each batch was different. This study was undertaken to determine α-mangostin content in 95 % ethanolic extracts of the fruit rinds of *G. mangostana* collected from different locations in Thailand using the validated TLC-densitometric method. Antibacterial activity of these extracts against *P. acnes* and *S. epidermidis* were also determined. The results could be used as a medicinal plant database of the country and also as a guidance for further standardization of *G. mangostana* fruit rind extracts that has not been reported. Thin layer chromatographic fingerprints and TLC-densitograms of the crude extracts were also performed.

2. Materials and Methods

2.1 Chemicals

The reference standard of α-mangostin was purchased from Chroma Dex Inc. (Santa Ana, CA). Other chemicals and solvents used in this experiment were analytical grade, which were purchased from Labscan Asia (Bangkok, Thailand).

2.2 Microorganisms and media

P. acnes (ATCC 6919) and *S. epidermidis* (ATCC 14990) were used as the test organisms in this study. These bacteria were obtained from the American Type Culture Collection, USA. Brain heart infusion (BHI) and tryptic soy broth (TSB) were obtained from DIFCO (Detroit, USA).

2.3 Plant materials

The ripe fruits of *G. mangostana* were collected from 13 different locations in the South and East of Thailand during June to August 2006 (Table 1). The samples were identified by Dr. Wandee Gritsanapan, Faculty of Pharmacy, Mahidol University. The voucher specimens (WGM0106 - WGM1306) were deposited at the Department of Pharmacognosy, Faculty of Pharmacy, Mahidol University, Bangkok, Thailand.

The fresh fruits were cleaned and the edible aril parts were removed. The fruit rinds were cut into small pieces and dried in a hot air oven at 50°C for 72 h. The dried samples were ground into powder, passed through a sieve with mesh number 20. The powdered samples were kept in air tight containers protected from light until used.

2.4 Preparation of *G. mangostana* fruit rind extract

Each sample (10 g) was placed into a trimble and extracted with 400 mL of 95 % ethanol in a soxhlet apparatus. Extraction was carried out for 15 h with approximatly 5 cycles/h. The extract was filtered through a Whatman no. 1 filter paper. The filtrate was concentrated under reduced pressured at 50°C using a rotary vacuum evaporator. The crude extract was then evaporated on a boiling water bath

Table 1. *G. mangostana* fruit collected from different locations in Thailand.

No.	Code	Source	Region
1	GM01	Subdistrict Thung Khwai Kin, District Klaeng, Rayong	East
2	GM02	Subdistrict Nong Taphan, District Ban Khai, Rayong	East
3	GM03	Subdistrict Phlapphla, District Mueang, Chanthaburi	East
4	GM04	Subdistrict Song Phi Nong, District Tha Mai, Chanthaburi	East
5	GM05	Subdistrict Wang Krachae, District Mueang, Trat	East
6	GM06	Subdistrict Khao Saming, District Mueang, Trat	East
7	GM07	Subdistrict Thung Nonsi, District Khao Saming, Trat	East
8	GM08	District Lang Suan, Chumphon	South
9	GM09	Subdistrict Ratchakrut, District Mueang, Ranong	South
10	GM10	Subdistrict Khao Wong, District Ban Ta Khun, Surat Thani	South
11	GM11	Subdistrict Tha Di, District Lan Saka, Nakhon Si Thammarat	South
12	GM12	District Panare, Pattani	South
13	GM13	District Sukhirin, Narathiwat	South

until a constant weight was obtained and the extract ratio (crude drug : extract) was calculated. The extraction of each sample was done in triplicate.

2.5 Instrumentation and analytical condition of TLC-densitometric method

Thin layer chromatography was performed on a precoated silica gel aluminium plate GF_{254} (20×10 cm, 0.2 mm thickness, E. Merck, Germany) using a Camag Linomat 5 syringe. The sample solution was spotted in form of a band of length 6.0 mm using a nitrogen aspirator. A constant application rate of 150 nl/s was employed, while the space between each band was 8.7 mm. The slit dimension was kept at 5.00 mm × 0.45 mm while 20 mm/s scanning speed was employed. The mobile phase, consisting of dichloromethane and methanol in a 96 : 4 ratio, was used. Linear ascending development was carried out in a 20×10 cm twin trough glass chamber (Camag, Muttenz, Switzerland) saturated with the mobile phase. The length of each chromatogram run was 8 cm. After developing, the TLC plate was dried using an air dryer. Densitometric scanning was performed on Camag TLC scanner 3 in the reflectance-absorbance mode at 320 nm, operated by winCATS 1.2.6 software (Camag, Muttenz, Switzerland). The source of radiation utilized was a deuterium lamp (Pothitirat and Gritsanapan, 2008a).

2.5.1 Preparation of standard solution

A stock solution of α-mangostin reference standard was prepared by dissolving 10 mg of α-mangostin in 10 mL of methanol in a volumetric flask. This solution (1 mL) was transferred to a 10 mL volumetric flask and adjusted to volume with methanol (100 μg/mL). Various amounts of stock solution were spotted on the TLC plate to obtain final concentrations of 100, 200, 300, 400, and 500 ng/spot.

2.5.2 Preparation of sample solutions

Accurately weighted 100 mg of the dried extracts of each sample was transferred to a 100 mL volumetric flask and dissolved in methanol (final concentration of 1,000 μg/mL). An aliquot of this solution (500 μL) was diluted with methanol to make a concentration of 50 μg/mL.

2.6 TLC-fingerprints and TLC-densitograms

TLC-fingerprints were performed on a precoated aluminium plate of silica gel $60F_{254}$ (20×10 cm) using dichloromethane : methanol (96 : 4) as a mobile phase. The developing distance was 8.0 cm. After removing the plate from the chamber, the plate was dried using an air dryer and sprayed with 10 % sulfuric acid in ethanol, followed by heating at 110°C for 10 min. The plate was examined under ultraviolet light (366 nm). The hRf values of the main components were determined comparing with the hRf value of α-mangostin standard. Video densitometry of the chromatoplate was carried out using Camag Reprostar 3 with cabinet cover and mounted digital camera.

TLC-densitograms were performed on Camag TLC scanner 3 by scanning the plate at 320 nm before spraying with 10 % sulfuric acid in ethanol.

2.7 Quantitative analysis of α-mangostin content in *G. mangostana* fruit rind extracts

A volume of sample solution (5 μL) was applied on a TLC plate and analyzed by the proposed method. The content of α-mangostin was calculated using its calibration curve regarding to the dilution factor and expressed as gram per 100 g of the extract and of the dried powder. Each analysis was done in triplicate.

2.8 Antibacterial susceptibility test

2.8.1 Inoculum preparation

P. acnes was incubated in brain heart infusion medium (BHI) for 72 h at 37°C under anaerobic condition while *S. epidermidis* was incubated in tryptic soy broth (TSB) for 24 h at 37°C and adjusted to yield approximately 10^8 CFU/mL.

2.8.2 Determination of minimal inhibitory and bactericidal concentrations

The minimal inhibitory concentration (MIC) was determined by twofold serial microdilution assay (Sahin *et al*., 2003). The extract was dissolved in DMSO and was incorporated into medium to get a concentration of 1000 μg/mL and serially diluted to achieve 500, 250, 125, 62.50, 31.25, 15.63, 7.81, 3.91, 1.95, 0.98, 0.49, and 0.24 μg/mL, respectively. The standardized suspension (10 μL) of each tested organism were transferred to each well. The broth cultures of *S. epidermidis* and *P. acnes* were incubated for 24 h and 72 h, respectively. The MIC defined as the lowest concentration of the compound that inhibits the microorganisms was determined. The minimal bactericidal concentration (MBC), defined as the lowest concentration of the compound that kills the microorganism, was also recorded. This showed the lowest concentration of the compound that showed no visible growth after the subculture of each clear well onto a new plate containing suitable media.

2.9 Statistical analysis

Each experiment was done in triplicate. The results were expressed as mean and standard deviation (SD). The average of α-mangostin content, MIC and MBC values of the samples from different locations were statistically analyzed using one way ANOVA with LSD by SPSS 11.5 Program. The average content of α-mangostin, MIC and MBC values

of the samples from each region were statistically analyzed using *t*-test by MS Excel software. The statistical probability (*p*-value) less than 0.05 indicated a statistical significant difference between groups.

3. Results and Discussion

Samples of *G. mangostana* fruits for this study were collected from the East and South of the Thailand, the main cultivation areas for this plant. In our previous study, we found that the soxhlet extraction with 95 % ethanol was appropriate for extraction of *G. mangostana* fruit rind to yield highercontentof anti-acne α-mangostin components (Pothitirat and Gritsanapan, 2007). Therefore, the soxhlet extraction with 95 % ethanol was used to extract all samples. The extract ratio (crude drug : extract) of thirteen samples collected from the Southern and Eastern Thailand was 3-5 : 1 (Table 2). The variation of α-mangostin content in the extracts of *G. mangostana* fruit rinds collected from different locations was demonstrated by the validated TLC-densitometric method. This method provided good reproducibility, accuracy, and selectivity for quantitative analysis of α-mangostin in the extracts of *G. mangostana* (Pothitirat and Gritsanapan, 2008a). The contents of α-mangostin in the thirteen extracts of *G. mangostana* fruit rinds collected from different locations were significantly different ($p<0.05$), ranged from 3.39±0.03 to 5.68±0.03 % w/w in the dried powder and 11.83±0.17 to 23.11±0.06 % w/w in the extracts (Table 2). The average content of α-mangostin in all dried powder samples and in 95 % ethanolic extracts was found to be 4.58±0.75 % w/w and 16.85±3.95 % w/w, respectively. The results showed that the samples from the South contained higher amounts of α-mangostin (average 17.64±3.89 % w/w in the extracts and 4.85±0.83 % w/w in the dried powder) than the samples from the East (average 16.43±3.69 % w/w in the extracts and 4.35±0.60 % w/w in the dried powder) (Table 2). This information supports our former report that *G. mangostana* grown in the Southern part of Thailand contains high content of α-mangostin (Pothitirat and Gritsanapan, 2008b). The variation in the amount of the active component, α-mangostin, in *G. mangostana* fruit rind might occur from geographical differences between the South and the East concerning temperature, rainfall, length of day, quality of light, and altitude (Baker, 2002). It might also relate to the genetic background of the plants.

TLC-densitograms of α-mangostin and other constituents in the extracts of *G. mangostana* fruit rind are shown in Figure 2. All samples gave 6 peaks, appeared at hRf values 14, 29, 40 (α-mangostin), 52, 77, and 88. A major peak in all samples was α-mangostin, related to a maximum absorption of 320 nm. This wavelength was used for analysis. For TLC fingerprints, using silica gel GF_{254} as a stationary phase and dichloromethane : methanol (96 : 4) as a mobile phase, the system gave a good resolution of the α-mangostin at hRf = 40. Fluorescent spots were detected under the UV light at 366 nm after the plate was sprayed with 10% sulfuric acid in ethanol and heated at 110°C for 10 min. TLC of all extracts of *G. mangostana* fruit rind showed the same pattern and

Table 2. Content of α-mangostin in *G. mangostana* fruit rinds collected from different locations in Thailand determined by TLC-densitometric method

Region	Sample	Extract ratio (g of crude drug: 1 g of extract)	α-mangostin content (%w/w)[1]			
			In extract [2]	Average [3]	In dried powder [2]	Average [3]
East	GM01	3.66±0.04	14.61±0.06 [h]	16.43±3.69 [a]	3.96±0.02 [i]	4.35±0.60 [a]
	GM02	2.93±0.14	11.83±0.17 [k]		3.91±0.06 [i]	
	GM03	3.85±0.32	18.00±0.06 [d]		4.39±0.02 [h]	
	GM04	3.69±0.13	19.63±0.03 [c]		5.18±0.01 [d]	
	GM05	3.84±0.21	16.54±0.09 [e]		4.47±0.02 [g]	
	GM06	4.22±0.24	22.32±0.04 [b]		5.09±0.01 [e]	
	GM07	3.47±0.03	12.08±0.16 [j]		3.47±0.04 [j]	
South	GM08	4.17±0.01	23.11±0.06 [a]	17.64±3.89 [b]	5.57±0.01 [b]	4.85±0.83 [b]
	GM09	3.73±0.06	12.49±0.10 [i]		3.39±0.03 [k]	
	GM10	3.08±0.08	14.91±0.15 [g]		4.76±0.05 [f]	
	GM11	3.56±0.16	15.96±0.15 [f]		4.34±0.04 [h]	
	GM12	3.99±0.08	23.00±0.11 [a]		5.68±0.03 [a]	
	GM13	2.78±0.06	14.61±0.10 [h]		5.35±0.04 [c]	
	Average	3.61±0.45 (3-5)	16.85±3.95		4.58±0.75	

[1] Expressed as mean ± SD (n = 3)
[2] Different letters in each column indicate significantly different at $p<0.05$ in one-way ANOVA
[3] Different letters in each column indicate significantly different at $p<0.05$ in *t*-test

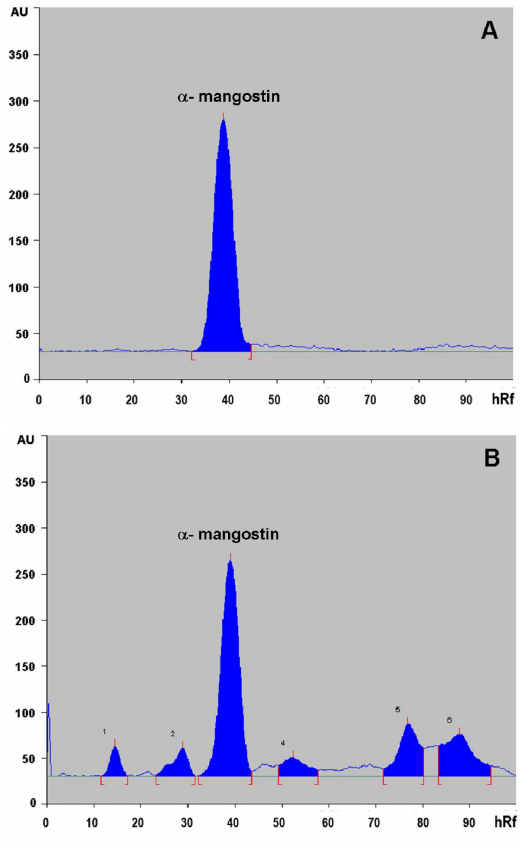

Figure 2. TLC-densitograms of α-mangostin standard and of the fruit rind extract of *G. mangostana*: A. α-mangostin standard, B. the fruit rind extract of *G. mangostana*

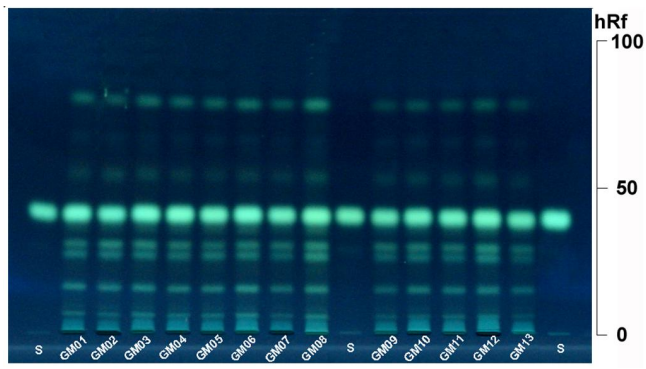

Figure 3. TLC-fingerprints of the extracts of *G. mangostana* fruit rinds collected from several locations. Stationary phase: silica gel GF_{254}; Mobile phase: dichrolomethane: methanol 96 : 4, v/v; Detection: sprayed with 10% sulfuric acid in ethanol, heat at 110°C for 10 min and observed under UV 366 , S = α-mangostin standard.

α-mangostin was a major spot (Figure 3).

On the basis of the broth dilution method, the antibacterial activity of the extracts of *G. mangostana* fruits rinds collected from different locations was significantly different (p<0.05). The MIC values of all crude extracts against *P. acnes* and *S. epidermidis* were in the range of 7.81-15.63 and 15.63-31.25 μg/mL, respectively, while the MBC values were in the range of 15.63-31.25 and 62.50-125.00 μg/mL, respectively. The average MIC values of all extracts against *P. acnes* and *S. epidermidis* were found to be 13.22 and 24.04 μg/mL, respectively, while the average MBC values were 16.83 and 86.54 μg/mL, respectively. Based on MIC and MBC values, the samples from the South promoted a stronger antibacterial effect (MIC = 13.02 μg/mL, MBC = 15.63 μg/mL for *P. acne* and MIC = 23.44 μg/mL, MBC = 83.33 μg/mL for *S. epidermidis*) than the samples from the East. α-Mangostin showed a good inhibitory effect on *P. acnes* (MIC = MBC = 1.95 μg/mL) and *S. epidermidis* (MIC = MBC = 3.91 μg/mL) (Table 3). Therefore, α-mangostin was an active antibacterial agent against *P. acnes* and *S. epidermidis* and was used for quality assurance of the *G. mangostana* extract and its products for anti-acne. The extract of fruit rind of *G. mangostana* and α-mangostin were shown to be good sources for anti-acne inducing bacteria agent. The result confirms a former report that *G. mangostana* fruit rind extract revealed strong antibacterial activity against *P. acnes* and *S. epidermidis* (Chomnawang *et al.*, 2005).

4. Conclusion

The extracts of *G. mangostana* fruit rinds obtained from different locations in the South and East of Thailand showed a high variation of α-mangostin content and anti-acne inducing bacterial potency, whereas their TLC-fingerprints and TLC-densitograms showed similar patterns. α-Mangostin was the major and active component, which was used as a marker for the quality assurance of the extract. Two of seven samples from the East (samples GM04 and GM06) and two of six southern samples (samples GM08 and GM12) were found to contain higher yields of α-mangostin (> 5 % w/w in dried powder, and > 19 % w/w in the extract), and higher antibacterial activity against *P. acnes* (MIC = 7.81 μg/mL). The MBC of each extract (except sample GM05) against *P. acnes* was not different (15.63 μg/mL), while the MIC and MBC against *S. epidermidis* were higher and seemed to be not relate with α-mangostin content. In average, the samples from the South contained higher yield of α-mangostin and promoted stronger antibacterial activity against *P. acnes* and *S. epidermidis* than the samples from the East. Thus, *G. mangostana* cultivated in the South was seemed to be a good source of α-mangostin and anti-acne inducing bacteria activity. This is the first time to report the variation in content of α-mangostin in *G. mangostana* fruit rind from various locations of Thailand determined by TLC-densitometry. TLC-densitometric method was appropriate for routine analysis of α-mangostin content in raw materials and products of *G. mangostana*. It provided good accuracy, less time and solvents consumed. The data will be useful for finding appropriate locations in Thailand where *G. mangostana* fruit rinds have higher α-mangostin contents. It can also be used as a guidance for further standardization of *G.*

Table 3. The MIC and MBC values of the fruit rind extracts of *G. mangostana* collected from different locations in Thailand against *P. acnes* and *S. epidermidis*

Region	Sample	Susceptibility of bacteria to *G. mangostana* fruit rind extracts[1]							
		P. acnes				*S. epidermidis*			
		MIC[2] (μg/mL)	Average[3] (μg/mL)	MBC[2] (μg/mL)	Average[3] (μg/mL)	MIC[2] (μg/mL)	Average[3] (μg/mL)	MBC[2] (μg/mL)	Average[3] (μg/mL)
East	GM01	15.63 [a]	13.39 [a]	15.63 [b]	17.86 [a]	31.25 [a]	24.55 [a]	62.50 [b]	89.29 [a]
	GM02	15.63 [a]		15.63 [b]		31.25 [a]		125.00 [a]	
	GM03	15.63 [a]		15.63 [b]		31.25 [a]		125.00 [a]	
	GM04	7.81 [b]		15.63 [b]		15.63 [b]		62.50 [b]	
	GM05	15.63 [a]		31.25 [a]		31.25 [a]		62.50 [b]	
	GM06	7.81 [b]		15.63 [b]		15.63 [b]		62.50 [b]	
	GM07	15.63 [a]		15.63 [b]		15.63 [b]		125.00 [a]	
South	GM08	7.81 [b]	13.02 [a]	15.63 [b]	15.63 [a]	31.25 [a]	23.44 [a]	62.50 [b]	83.33 [a]
	GM09	15.63 [a]		15.63 [b]		31.25 [a]		125.00 [a]	
	GM10	15.63 [a]		15.63 [b]		15.63 [b]		125.00 [a]	
	GM11	15.63 [a]		15.63 [b]		15.63 [b]		62.50 [b]	
	GM12	7.81 [b]		15.63 [b]		15.63 [b]		62.50 [b]	
	GM13	15.63 [a]		15.63 [b]		31.25 [a]		62.50 [b]	
	Average	13.22		16.83		24.04		86.54	
	α-mangostin	1.95		1.95		3.91		3.91	

MIC = Minimal inhibitory concentration
MBC = Minimal bactericidal concentration
[1] Each experiment was done in triplicate
[2] Different letters in each column indicate significantly different at $p<0.05$ in one-way ANOVA
[3] Different letters in each column indicate significantly different at $p<0.05$ in *t*-test

mangostana fruit rinds and the extracts used in pharmaceutical and cosmetic productions.

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References

Baker, R. 2002. Production of crude drugs. In Trease and Evans Pharmacognosy, Saunders, Philadelphia, WB.

Chairungsrilerd, N., Furukawa, K., Ohta, T., Nozoe, S. and Ohizumi, Y. 1996. Pharmacological properties of α-mangostin, a novel histamine H1 receptor antagonist. European Journal of Pharmacology. 314(3), 351-356.

Chen, S. X., Wan, M. and Loh, B. N. 1996. Active constituents against HIV-1 protease from *Garcinia mangostana*. Planta Medica. 62(4), 381-382.

Chomnawang, M. T., Surassmo, S., Nukoolkarn, V. S. and Gritsanapan, W. 2005. Antimicrobial effects of Thai medicinal plants against acne-inducing bacteria. Journal of Ethnopharmacology. 101(1-3), 330-333.

Chomnawang, M. T., Surassmo, S., Nukoolkarn, V. S. and Gritsanapan, W. 2007. Effect of *Garcinia mangostana* on inflammation caused by *Propionibacterium acnes*. Fitoterapia. 78(6), 401-408.

Fransworth, N. R. and Bunyapraphatsara, N. 1992. Thai Medicinal plants: Recommended for primary health care system, Prachachon Co. Ltd, Bangkok, Thailand.

Gritsanapan, W. and Chulasiri, M. 1983. A preliminary study of antidiarrheal plants: I. antibacterial activity. Mahidol University Journal of Pharmaceutical Science. 10(4), 119-122.

Martin, F. W. 1980. Durian and Mangosteen In: Tropical and Subtropical Fruits: Composition, Properties and Uses, The AVI Publishing Company, Inc, Westport, CT.

Nakatani, K., Nakahata, N., Arakawa, T., Yasuda, H. and Ohizumi, Y. 2002. Inhibition of cyclooxygenase and prostaglandin E2 synthesis by gamma-mangostin, a xanthone derivative in mangosteen, in C6 rat glioma cells. Biochemical Pharmacology. 63(1), 73-79.

Pothitirat, W. and Gritsanapan, W. 2007. Different extraction methods for high content of biologically active components from mangosteen fruit rind. Thai Journal of Pharmaceutical Sciences. 31(Suppl), 5.

Pothitirat, W. and Gritsanapan, W. 2008a. Thin layer chro-

matography densitometric analysis of α-mangostin content in *Garcinia mangostana* fruit rind extracts. Journal of AOAC International. 91(5), 1145-1148.

Pothitirat, W. and Gritsanapan, W. 2008b. Quantitative analysis of total mangostins in *Garcinia mangostana* fruit rind. Journal of Health Research. 22(4), 161-166.

Sahin, F., Karaman, I., Gulluce, M., Ogutcu, H., Sengul, M., Adiguzel, A., Ozturk, S., Kotan, R. 2003. Evaluation of antimicrobial activities of *Satureja hortensis* L. Journal of Ethnopharmacology. 87, 61-65.

Sakagami, Y., Iinuma, M., Piyasena, K. G. N. P. and Dharmaratne, H. R. W. 2005. Antibacterial activity of α-mangostin against vancomycin resistant Enterococci (VRE) and synergism with antibiotics. Phytomedicine. 2(3), 203-208.

Sen, K. A., Sarkar, K. K., Mazumder, C. P., Banerji, N., Uusvuori, R. and Hase, T. A. 1980. A xanthone from *Garcinia mangostana*. Phytochemistry. 14(10), 2223-2225.

Walker, E. B. 2007. HPLC analysis of selected xanthones in mangosteen fruit. Journal of Separation Science. 30, 1229 –1234.

Yu, L., Zhao, M., Yang, B., Qiangzhong, Z. and Jiang, Y. 2007. Phenolics from hull of *Garcinia mangostana* fruit and their antioxidant activities. Food Chemistry. 104, 176-181.