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Evaluation of Fruit Characters, Xanthones Content, and Antioxidant Properties of Various Qualities of Mangosteens (*Garcinia mangostana* L.)

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ABSTRACT

Xanthone in mangosteen fruit hull has antioxidant activities. The objective of this experiment was to determine xanthones content, physical and chemical characters, and antioxidant potentials of several groups of mangosteens qualities. The experiment was carried out from January 2008 to August 2008. The research used a randomized complete block design with four replications. The treatments were four physical fruit conditions: large size mangosteens (≥ 100 g), small size mangosteens (min. 50 g), yellow sap dotted fruits, and scabbed fruit. The parameters being observed were physical and chemical characteristics, xanthone content, and radical scavenging activity of mangosteen fruit hull extract. The results demonstrated that the physical condition of fruit significantly affected physical fruit hull characters and chemical fruit characters. Characters of fruit hull, thickness, fresh weight, and dry weight, differed among fruit qualities. The physical condition of fruit hull also significantly influenced total soluble solid and vitamin C content, but did not affect total titrable acid and degree of acidity of the fruits. Fruit hulls of all groups of mangosteen qualities had similar antioxidant properties with the IC_{50} value of 5.57-6.11 ppm.

Keywords: benzophenone, scab, vitamin C, yellow sap

INTRODUCTION

Mangosteen (*Gracinia mangostana* L.) is one of main exported fruits from Indonesia. Fruit physical appearance, rather than chemical properties, is the major factor determining mangosteen marketability, both for domestic and international markets (Suyanti *et al*., 1999). Hence, physical qualities of mangosteen fruits determine consumers' acceptability and mangosteen's market price. The important physical characters of mangosteen's fruits include the dotless hull surface, the presence of scabs and yellow sap dotted hulls. Scabbed fruits and yellow sap dotted fruits are not attractive for consumers, due to their faded and dirty images. The yellow sap dotted fruits on their hull's outer surface, or lead to the inside fruit and fruit flesh are categorized as low quality fruits, have low consumers' acceptability and economic values.

In addition to fruit physical appearances, fruit weight or size determines fruit marketability. Based on fruit weight, mangosteens can be classified into 5 classes: Super (≥ 125 g $fruit^{-1}$), A (100–111 g $fruit^{-1}$), B (76.9-90.9 g $fruit^{-1}$), C (62-66.7 g $fruit^{-1}$), D (50-55.5 g $fruit^{-1}$) (Waluyo, 2003). Generally, consummers prefer large mangosteen therefore small fruits are cheaper than the large ones.

Efforts to increase mangosteen farmers' income are not only by improving cultivation technology but also by increasing the added values of low quality fruits, such as fruits with scabs and yellow sap dotted fruits. Since mangosteen's hull has a relatively large unedible portion to the total fruit's weight, making use of the hulls will be advantageous to reduce wastes as well as to add values of the unmarketable mangosteens. Processing mangosteen hulls has a great economical potential since the hulls contain xanthones, a bioactive phenols that have been reported to have antibacterial properties (Suksamrarn *et al*., 2003), antiinflamation, antioxidant, and anticancer properties (Hartati, 2000; Moongkarndi *et al.,* 2004; Cahyana, 2006). Xanthone was reported to have more than only vitamin E and vitamin C. So far, biosynthesis of xanthone in mangosteen tree are rarely studied, so biological functions of xanthone in mangosteen trees have not been completely explained. On the other hand, research on xanthones isolation and bioactivities has been widely conducted (Parveen and Ud-Din Khan, 1988; Chairungsrilerd *et al.,* 1996; Gopalakrishnan and Balaganesan, 2000). Hence, there are gaps between xanthone research in the field of agronomy and in chemistry or pharmachology.

Report pertaining availability of antioxidant activity on mangosteen's hull provides an inspiration to carry out a study on antioxidant potency from various groups of mangosteen's quality. Mangosteen's hull is one of potential antioxidant sources because it is the biggest portion of mangosteen fruit. Searching for natural antioxidant source is important because several synthetic antioxidants and some that are usually used have negative effect to people's health.

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It is not only very important to prevent various degenerative diseases, but antioxidant has also been utilized in industries for long time.

The exploitation of mangosteen's hull potential can be derived from mangosteen fruits having low consumers' acceptance, such as low quality mangosteen fruits or infeasible fruits for export. This effort is also an important point, considering that many non-producer countries have tried to develop xanthones in phytopharmaca industries and Indonesia as a producer has great chance to develop this industry. The exploitation of potential of mangosteen's xanthone as antioxidant has also great prospect for phytopharmaca and food industries. Therefore, research pertaining xanthones content evaluation on mangosteen's hull related to fruits' physical condition, including its antioxidant activity evaluation is required.

Research was aimed at studying physical and chemical characters of mangosteen fruits particularly in the xanthone content and antioxidant properties potential.

MATERIALS AND METHODS

Research was carried out in Bogor from January to August 2008 using mangosteens harvested from Leuwiliang Mangosteen Orchard. Analysis of fruit characters were conducted in Ecophysiology Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, IPB. Analysis of fruits quality were done in Center of Tropical Fruit Laboratory, IPB. Antioxidant activity assay was carried out in Laboratory of Research Group on Crop Improvement (RGCI), Department of Agronomy and Horticulture, Faculty of Agriculture, IPB. Xanthones and benzophenone content analysis were carried out in Integrated Laboratory, Faculty of Agriculture, IPB.

The experiment used randomize block design with four replications to test a single factor of classification of morphological quality of mangosteens, using 20 fruits for each classification. Fruits were purchased from the fruit collector (Head of Farmers Group) immediately after the fruits were harvested. Fruits were harvested 4 times in a three days interval.

Sample fruits were classified into four types of physical conditions as treatment, namely scabbed fruits (i.e. fruits with coverage of scab less than 90%), yellow sap dotted fruits on their outer surface of fruits (i.e. fruits with coverage of yellow dots of 90%), big size dotless fruits (weight ≥ 100 g fruit^{-1}, without dot and yellow sap dots on the outer hull surface), and small size dotless fruits (weight ≤ 100 g fruit^{-1}, without scab and yellow sap dots on the outer hull surface).

Fruit physical characters observed in this study were fruit weight, aril hull weight, thickness of fruit hull, weight of aril and seed, dry weight of hull, and hull firmness. Data on fruit physical characters were displayed in the form of percentage of hull's fresh weight to fruit weight, percentage of weight of aril and seed to fruit weight, percentage of hull's dry weight to aril hull weight, and percentage of hull's dry weight to fruit weight.

Measurement on chemical characters were conducted on Total Soluble Solid (TSS), Total Titratable Acidity (TTA), degree of flesh acidity, content of xanthones and benzophenone, and activity of free radical scavengers. Total soluble solid was measured using hand refractometer. and stated in ^{o}Brix. Total titratable acidity was observed on filtrate from the following preparation procedure. Fruit flesh was refined, 10 g of the paste was taken and put into the glassware before water was added, shaken and then filtered. The filtrate was added with phenolphthalein indicator, then titrated with NaOH 0.1 N until pink color appeared. Degree of flesh acidity was measured by using pH meter.

Content of ascorbic acid was measured by the following procedure. Ten gram of fruit flesh paste was put into a 100 mL measuring cylinder, then added with water and shaken. The homogenized solution was filtered. The filtrate was then added with indicator of 1% amylum solution, and titrated with 0.01 N iodium.

Content of xanthones and benzophenone were measured using following procedures. Extraction was conducted to dried mangosteen's hull in the form of powder, then as much as 100 g powder was extracted with 100 mL methanol solution (p.a). Analysis of xanthones and benzophenone was carried out by using methanol eluent and formic acid, and they were detected at wave length of 234 nm (Teixiera *et al*., 2003). The activity of free radical scavengers was measured using DPPH (2,2-diphenyl-1-picrylhidrazyl) method. As much as 1 mL of 0.4 mM DPPH and 3.9 mL of ethanol were added into 100 µL of extract in various test concentrations. The absorbance was measured using spectrophotometer UV-VIS (Rohman and Riyanto, 2005). The antioxidant potential were presented in the form of IC_{50}.

Data were analysed using F Test at level α = 5%, and further test was carried out by Duncan Multiple Range test at level α = 5%.

RESULTS AND DISCUSSION

Fruit Characters

The physical character of mangosteen affected the percentage of hull fresh weight and affected the percentage of aril + seed and hull dry weight (Table 1). The increase in fruit size is simultaneously followed by the increase of hull weight because mangosteen fruit weight mostly comes from hulls, whereas the edible portion of mangosteen fruit is around 36% (Gunawan, 2007). The highest percentage of hull dry weight came from the yellow sap dotted fruits. These suggested that large size mangosteen contained more water in their hulls whereas scabbed fruits and yellow sap dotted fruits had lower water content.

Fruit physical condition influenced the thickness of fruit hull. Scabbed fruits and yellow sap dotted fruits had thicker hull and a lower water content so they had higher hull dry weight. Fruits in small size and dotless appearance had thin hull, with average thickness of 7.7 mm (Tabel 2). Fruit size is one of the important fruit qualities that can be

Table 1. Percentage of hull weight to fruit weight, aril and seed weight to fruit weight, and percentage of hull dry weight to hull fresh weight

Fruit physical condition	Hull fresh weight to fruit weight	Aril and seed weight to fruit weight	Hull dry weight to aril hull weight	Hull dry weight to fruit weight
	....	.... %	....	....
Yellow sap dotted	68.17a	35.47a	36.68c	27.09a
Scabbed	65.47ab	33.07b	37.71bc	25.57b
Small size	66.45ab	27.65c	39.84a	25.06b
Large size	64.23b	30.15bc	38.60ab	23.72c
F-test	*	*	**	**

Note: Number followed by the same letter at the same column is not significantly different based on DMRT at level α = 5%; *, ** = significant at α = 5% and α = 1%, respectively

improved by increasing carbohydrate availability for fruits or improving sink capacity of fruits. Techniques that had been applied to increase fruit size includes girdling on orange, application of fruit thinner agent, and application of fruit enhancer agent (Agusti *et al*., 2002). Fruit size was also determined by fruit's sink power at fruit growth which is determined by physiological condition (Yamaki, 2010). Although mangosteen size becomes an important factor determining fruit quality, no study foccusing on how to enlarge mangosteen fruit size is reported.

Yellow sap-dotted mangosteen fruits had the highest value of fruit's firmness of 0.89 kg sec^{-1} but this value did not significantly differ from other fruit groups (Table 2). This might be caused by water lost in the yellow sap dotted fruits and scabbed fruits. Because of relatively low water content in yellow sap dotted fruit's hull, this group had harder hull and the fruits were more difficult to peel.

Chemical Characters

Physical properties of mangosteen's outer surface affected the TSS value. Scabbed fruits had the highest TSS of 20.23 ^{o}Brix and differed only with small-dotless fruits (Table 3). Mangosteen fruits from five mangosteen production centers in Java had TSS ranged between 14.74-17.96 ^{o}Brix and TTA between 0.59-1.20%, with value of

Table 2. Physical characters of mangosteen hull

Fruit physical condition	Hull thickness (cm)	Hull's fresh weight (g)	Hull's dry weight (g)	Firmness (kg sec^{-1})
Yellow sap dotted	0.99a	68.39b	27.1b	0.89
Scabbed	0.90ab	71.65b	28.0b	0.86
Small size	0.77b	57.20c	21.6c	0.85
Large size	0.92a	87.00a	32.3a	0.88
F test	*	**	*	ns

Note: Number followed by the same letter at the same column is not significantly different based on DMRT at level α = 5%; *, ** = significant at α = 5% and α = 1%, respectively; ns = not significant at α = 5%

Table 3. Chemical qualities of mangosteen fruit on various fruit physical conditions

Fruit physical condition	Total Soluble Solid (^{o}Brix)	Total Tetratable Acidity (%)	pH	Vitamin C (mg (100 g)$^{-1}$)
Yellow sap dotted	19.19ab	0.39	3.51	34.76b
Scabbed	20.23a	0.34	3.55	37.06b
Small size	18.63b	0.36	3.49	32.65b
Large size	19.10ab	0.37	3.52	42.75a
F test	*	ns	ns	*

Note: Number followed the same letter at the same column is not significantly different based on DMRT at level α = 5%; * = significant at α = 5%; ns = not significant at α = 5%

TSS and TTA for Leuwiliang Plants 14.74 ^{o}Brix and 1.16% , respectively (Gunawan, 2007). However, fruits quality and nutrition content might vary referring to production system and season (Pieper and Barrett, 2009).

Mangosteen fruit scabs might be caused by attacks of aphids when fruits were still young and small or when flowers were blooming (Verheij, 1997), friction among fruits while the fruits are still on the trees or fruits with leaves at young periods that caused injury and then enlarged simultaneously as the fruits were developing (Tirtawinata, 2002). So far, there was no information on the relationship between pathogen attack and fruit's soluble solids.

Fruit size influenced the content of vitamin C, with large fruits had the highest content of vitamin C. Hanamura *et al*. (2008) reported there was difference of vitamin C content on Acerola fruits (*Malpighia emarginata* DC.) between cultivars, planting regions, and fruit maturity levels. So far, there was no report on mechanism explaining relationship between fruit size and vitamin C content. Davey *et al*. (2000) stated that vitamin C in cell did not only take a role as antioxidant, but also as cofactor for several enzymes and contributed to cell division and enlargement.

Xanthones and Benzophenone Content

Xanthones and benzophenone content differed significantly among fruit condition groups (Table 4). There were significant different in the content of xanthone and benzophenone among fruit groups, except between groups of yellow sap fruits and scabbed fruits. Benzophenone is an intermediate compound for forming various xanthone types, so it is possible that if intermediate compound in xanthones formation was at high concentration then final compound produced would increase, assuming other factors influencing its biosynthesis were similar.

No study explaining the mechanisms of scab formation on mangosteens was reported. Scab formation can be classified into two groups, based on the the nature of the scab, i.e. scabs due to pest attacks and due to physical damages. If xanthone function is taken into account, scab formation might act as a defend mechanism against pathogen attacks since it caused an increase of xanthone accumulation.

Role of xanthones in mangosteen plants had been rarely reported. A research on mango showed mangoes resistent to malformation contained high mangiferin (1,3,6,7-tetrahydroxy xanthone-C2-ß-D-glucoside). Malformation is abnormal inflorescence syndrome that was affected by physiological problems and by pathogen attack such as *Fusarium moniliforme* var. *subglutinans*. Mangiferin mechanism in malformation prevention improves antifungal compound and checks hormone balance so malformation can be prevented (Singh, 2006). Franklin *et al*. (2009) reported that in *Hypericum perforatum*, xanthone played a role as phytoalexin that repressed pathogen growth when cells were experiencing biotic stresses. Xanthone function on mangosteen plant has not been reported. However, considering studies on mangiferin, xanthone might also play a role in preventing biotic stresses condition.

Antioxidant Properties

Antioxidant properties of mangosteen's hull extract did not differ significantly among fruit groups, with value of IC_{50} ranged between 15,289-23,544 µg g^{-1} crude extract (CE) methanol of mangosteen's hull (Table 4). DPPH methods, in this research was defined as concentration of materials that were required to prevent formation of DPPH radical as much as 50%.

Franklin *et al.* (2009) stated that xanthones served not only as phytoalexin, but xanthones in cell culture of *Hypericum perforatum* also functioned as antioxidant. Role of antioxidant in cell culture was to protect cell from damages due to existence of ROS (Radical Oxygen Species). Other antioxidant resources from plants that has been reported are leaf of orange jasmine (*Murraya paniculata* L.) with IC_{50} value of 126.17 µg mL^{-1} (Rohman and Riyanto, 2005), and cherry fruit (*Cornus mas* L.) with IC_{50} value of 0.29–0.69 mg mL^{-1} (Tural and Koca, 2008). Within natural phenolic groups, compounds that had been reported to have an antioxidant activity other than xanthones are flavonoid and tannin (Karthikumar *et al*., 2007).

Drogoudi *et al*. (2008) reported that there were differences in levels of antioxidant activities in apple polyphenol played a major role as antioxidant in apple

Table 4. Content of xanthone and benzophenone and free radical scavangers activity on various fruit physical conditions

Fruit physical condition	Xanthone	Benzophenone	IC_{50}-DPPH (ppm)
	……………………(µg g^{-1} CE)	……………………	
Yellow sap dotted	15,289b	2,190b	6.11
Scabbed	23,544a	12,149a	5.58
Small size	20,434ab	8,301ab	6.60
Large size	18,502ab	7,048ab	6.48
F test	*	*	ns

Note: Number followed the same letter at the same column is not significantly different based on DMRT at level α = 5%; * = significant at α = 5%; ns = not significant at α = 5%

hulls, while vitamin C had a less significant role. Celik *et al*. (2008) reported that antioxidant capacity of cranberry fruits was affected by fruit maturity stages, whereas Roussos *et al*. (2007) reported that phenol content and antioxidant potential were affected by plant's growth environment.

CONCLUSION

Physical condition of mangosteen fruits affected the thickness of mangosteen's hull, hull's fresh- and dry-weight, but did not influence firmness of fruit hull. Group of large fruits had the highest content of vitamin C. Scabbed fruits had significantly higher xanthone and benzophenone content compared to yellow sap dotted fruits, but these levels were similar to those of other fruit groups. Antioxidant potential of mangosteen's hull extract in free radical scavenger for all fruit groups were similar with IC_{50} value ranged between 5.57-6.11 ppm.

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