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Quality of mangosteen juice colored with mangosteen pericarp

*Manurakchinakorn, S., Chainarong, Y. and Sawatpadungkit, C.

School of Agricultural Technology, Walailak University, Nakhon Si Thammarat 80160, Thailand

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Abstract

This study aimed at production of mangosteen juice using mangosteen pericarp as a natural colorant. Furthermore, quality changes of the mangosteen juice during refrigerated storage were investigated. Formula of mangosteen juice was developed based on flavor and color by addition of sucrose and mangosteen pericarp, respectively. Mangosteen juice adjusted to 18°Brix and added with 0.2% mangosteen pericarp obtained the highest sensory scores of quality attributes for flavor, color and overall liking. Subsequently, the mangosteen juice was pasteurized at 90°C for 5 min and stored at 4°C for 5 weeks. L^*, a^*, b^*, pH, ascorbic acid, anthocyanin, total phenolic compounds and antioxidant capacity of the mangosteen juice decreased ($p<0.05$), whereas an increase in titratable acidity was observed during the storage ($p<0.05$). Total soluble solids of the mangosteen juice remained stable throughout the storage period. In addition, bacteria and yeast and mold counts of the mangosteen juice stored for 5 weeks were still acceptable. The results indicate that the shelf life of mangosteen juice developed in this study was at least 5 weeks at 4°C.

Introduction

Mangosteen (*Garcinia mangostana* L.) is an important economic fruit crop in Thailand. The mangosteen fruit is renowned for its soft, sweet and slightly acid flesh with pleasant flavor when ripe. The flesh of mangosteen has been reported as a good source of antioxidants such as ascorbic acid and phenolic compounds (Leong and Shui, 2002; Lim *et al.*, 2007). Mangosteen is a climacteric fruit and maturity stage of the fruit can be classified by pericarp color into six stages: yellowish white or yellowish white with light green (stage 0), light greenish yellow with 5-50% scattered pink spots (stage 1), light greenish yellow with 51-100% scattered pink spots (stage 2), spots not as distinct as in stage 2 or reddish pink (stage 3), red to reddish purple (stage 4), dark purple (stage 5) and purple black (stage 6) (Palapol *et al.*, 2009). Color development of fruit pericarp during ripening has been shown to closely correlate with an increase in anthocyanin content. The highest anthocyanin content in mangosteen pericarp was found at the final color stage (Palapol *et al.*, 2009). Many studies have demonstrated that the dark purple pericarp of mangosteen fruit contain a variety of bioactive secondary metabolites such as anthocyanin and xanthone (Fu *et al.*, 2007; Ji *et al.*, 2007). Medicinal and antioxidant properties of the mangosteen pericarp have been extensively reviewed (Pedraza-Chaverri *et al.*, 2008; Suttirak and Manurakchinakorn, 2014). In addition, potential utilization of mangosteen pericarp extract as food colorant has been reported (Suttirak and Manurakchinakorn, 2012).

Mangosteen fruit at ripeness stage 6 (purple black pericarp) has a very limited storage life and deteriorate rapidly. The pericarp color is a major criterion used for grading of mangosteen fruit, in addition to freshness of stem and calyx, size and smoothness of the pericarp. Small fruit with dotted and dark purple pericarp is generally not marketable even though the flesh quality is still acceptable. Therefore, the objectives of this study were to add value of unmarketable as fresh mangosteen fruit by development of mangosteen juice using the mangosteen pericarp as a natural colorant, and monitor changes in some important physical, chemical and microbiological qualities of the pasteurized mangosteen juice during storage at 4°C for 5 weeks.

Materials and Methods

Preparation of mangosteen juice

Mangosteen fruit at stage 6 of maturity (Palapol *et al.*, 2009) was purchased from local growers in Nakhon Si Thammarat province. The fruit was washed with tap water, and then drained prior to processing. Mangosteen flesh was manually separated from the fruit and the juice was extracted using a hydraulic press (Model A2, Sakaya).

*Corresponding author.
Email: *schinakorn@yahoo.com*
Tel: +6675672356; Fax: +6675672302

Development of mangosteen juice formula

Mangosteen juice formula was developed based on flavor and color. Adjustment of flavor to various final total soluble solids including 18, 20 and 22°Brix, was conducted using sucrose, prior to sensory assessment. Sensory quality of the mangosteen juice focusing on flavor, by 9-point hedonic scale using 30 taste panelists was evaluated. Thereafter, the color of selected juice formula was enhanced by adding inner flesh of mangosteen pericarp, prepared by mixing the inner mangosteen pericarp with mangosteen juice and mashing with a spoon, at different levels including 0.2 and 0.4% (w/v). Sensory quality, in terms of color, flavor and overall liking, of the mangosteen juice was assessed. Subsequently, the developed mangosteen juice was subjected to pasteurization at 90°C for 5 min, prior to filling into bottles with screw caps and storage at 4°C for 5 weeks.

Quality evaluation of mangosteen juice

During the cold storage, physical, chemical and microbiological properties of the mangosteen juice were monitored every week. Color (L^*, a^*, b^*) measurement of the juice was executed using a HunterLab chromameter (Model ColorFlex, Hunter Associates Laboratory). Total soluble solids and pH were determined using a hand refractometer (Model ATC-1E, Atago) and a pH meter (Model MP 220, Mettler-Toledo), respectively. Titratable acidity was measured by potentiometric titration with 0.1N NaOH (James, 1995). Titratable acidity was expressed as g citric acid per 1000 ml of mangosteen juice. Ascorbic acid was measured by titrimetric assay with 2,6-dichloroindophenol (AOAC, 1995). Ascorbic acid content was expressed as mg per 1000 ml of mangosteen juice. Anthocyanin was assessed by pH-differential method modified from Cinquanta *et al*. (2002). Anthocyanin content was expressed as mg cyanidin-3-glucoside per 1000 ml of mangosteen juice (molar extinction coefficient of cyanidin-3-glucoside = 26,900). Total phenolic compounds were determined using Folin-Ciocalteau reagent assay (Singleton and Rossi, 1965). Total phenolic compounds content were expressed as mg gallic acid equivalent per 1000 ml of mangosteen juice. Antioxidant capacity was measured using DPPH free radical scavenging assay (Brand-Williams *et al*., 1995). Antioxidant capacity was expressed as mg ascorbic acid equivalent per 1000 ml of mangosteen juice. Total plate count and yeast and mold count of the mangosteen juice during the storage period were assessed using plate count agar and potato dextrose agar, respectively (AOAC, 1995).

Statistical analysis

The experiments were realized in triplicate. Statistical analysis was conducted using SPSS. An analysis of the variance was processed using the general linear model procedure. Mean comparisons were performed using Duncan's multiple range test.

Results and Discussion

Formula of mangosteen juice

Sensory scores, in terms of flavor and overall liking, of the mangosteen juice adjusted to various levels of final total soluble solids were demonstrated in Table 1. The color (L^*, a^*, b^*) and pH of the manogsteen juice were not affected by addition of sucrose (data not shown). Flavor and overall liking scores of 3 different total soluble solids juice were not significantly different. Considering the production cost, mangosteen juice adjusted to 18°Brix was selected for the following experiment.

Color has been considered to have a key role in food choice, food preference and acceptability, and may even influence taste thresholds, sweetness perception and pleasantness (Clydesdale, 1993). The addition of mangosteen pericarp resulted in enhancing color of mangosteen juice due to anthocyain present in the pericarp. The major anthocyanins found in the mangosteen pericarp were cyanidin-3-sophoroside and cyanidin-3-glucoside (Palapol *et al*., 2009). Furthermore, flavor of the mangosteen juice might be affected by some phenolic compounds containing in the mangosteen pericarp showing bitterness and/or astringency (Cheynier, 2012). Results from the sensory evaluation showed that the mangosteen juice with 0.2% additional pericarp obtained the highest color, flavor and overall liking scores ($p<0.05$) (Table 2). Therefore, the mangosteen juice adjusted to 18°Brix and added with 0.2% mangosteen pericarp was the selected formula for further study,

Quality of mangosteen juice during storage

Color

Product color is one of the most important quality factors of the mangosteen juice. Color parameters, in terms of L^*, a^* and b^*, of the mangosteen juice significantly decreased ($p<0.05$) as the storage time increased (Table 3). The decreases in L^* and b^* might be attributed to non-enzymatic and enzymatic browning of the mangosteen juice. The non-enzymatic browning occurred during the storage could be ascribed to oxidation of ascorbic acid, leading to development of furfural and melanoidin (Gregory III, 2008). The enzymatic browning

Table 1. Sensory scores of mangosteen juice adjusted to different levels of total soluble solids

Total soluble solids (°Brix)	Flavor	Overall liking
18	7.77±0.86[a]	7.76±0.77[a]
20	7.63±0.85[a]	7.73±1.05[a]
22	7.67±1.30[a]	7.73±1.36[a]

All value givens are means±standard deviations. Means in column with different letters are significantly different ($p<0.05$).

Table 2. Sensory scores of mangosteen juice added with different levels of mangosteen pericarp

Mangosteen pericarp (%)	Color	Flavor	Overall liking
0	6.20±1.24[a]	7.00±1.51[a]	6.67±1.74[a]
0.2	7.20±1.47[b]	7.27±1.53[b]	7.26±1.62[b]
0.4	7.16±1.58[b]	7.40±1.02[b]	6.63±1.56[a]

All value givens are means±standard deviations. Means in column with different letters are significantly different ($p<0.05$).

could be occurred due to reactivation of polyphenol oxidase during the storage, leading to the formation of melanin. The decreased a^* during the storage indicated loss of redness of the mangosteen juice. The redness of mangosteen juice was mainly attributed to the anthocyanin present in the mangosteen pericarp (Palapol *et al*., 2009). Destruction of anthocyanin, caused by structural transformation, hydrolyzation or condensation reactions, and occurrence of browning reactions during storage have been reported to result in a color change from natural red or purple to a more dull brownish color (Schwartz *et al*., 2008).

Total soluble solids, pH and titratable acidity

In addition to sweetness indicated by total soluble solids, sourness plays an important role in flavor attributes and sensory acceptability of the mangosteen juice. The main organic acids regarding flavor notes for most fruits are citric acid, malic acid, tartaric acid, succinic acid and quinic acid (Kays, 1991). Changes in total soluble solids, pH and titratable acidity of the mangosteen juice during storage for 5 weeks at 4°C were demonstrated in Table 3. No significant change in total soluble solids of the mangosteen juice was observed throughout the storage period. During the first 2 weeks, pH of the mangosteen juice gradually decreased ($p<0.05$), thereafter no significant difference in pH of the mangosteen juice was detected. On the other hand, titratable acidity significantly increased ($p<0.05$) throughout the storage period. Degradation of some major organic acids in the mangosteen juice such as citric and malic acids (Lee *et al*., 2013) might occur during the storage. However, the inconsistent change in pH with the change in titratable acidity was probably caused by the effect of buffer capacity of the fruit juice. Rocha *et al*. (1995) observed that pH and titratable acidity were not directly related in fresh-cut oranges during 10 days of storage. Lamikanra *et al.* (2000) also demonstrated the stable level in pH of fresh-cut cantaloupes during 14 days of storage. On the contrary, gradual decrease in pH and increase in titratable acidity of Bearss Seedless lime juice was noticed during storage at 5°C (Ziena, 2000).

Ascorbic acid

Ascorbic acid is a bioactive compound commonly found in fruit. Mangosteen flesh has been reported to contain 4.1±1.2 (Leong and Shui, 2002) or 5.8±0.8 mg ascorbic acid/100 g fresh weight (Lim *et al*., 2007). Changes of ascorbic acid content in mangosteen juice in this study were shown in Table 3. The initial ascorbic acid content in pasteurized mangosteen juice (4.04±0.05 mg/1000 ml juice) was not high, compared with that in pasteurized orange juice (424.6±2.59 mg/1000 ml juice) (Esteve *et al*., 2005). Ascorbic acid content of the mangosteen juice tended to decrease during the storage. Significant decrease ($p<0.05$) in ascorbic acid content was detected after 2 weeks of the storage. However, no significant difference of the ascorbic acid content of mangosteen juice was found between week 0 and 1, and week 4 and 5. Ascorbic acid is a reactive compound particularly vulnerable to storage conditions. It can be degraded by oxidative processes, which are stimulated in the presence of oxygen, light and enzymes such as ascorbate peroxidase (Davey *et al*., 2000). In our work, the pasteurized mangosteen juice was filled into glass bottles with screw caps. Thus, the transparent packages might promote undesirable chemical reactions, leading to a depletion of ascorbic acid of the mangosteen juice during the storage. Chemical degradation of ascorbic acid primarily involves oxidation to dehydroascorbic acid, followed by hydrolysis to 2,3-diketogulonic acid and further oxidation (Gregory III, 2008). Gradual decrease in ascorbic acid of Bearss Seedless lime juice stored in glass bottle under refrigeration (5°C) was also observed (Ziena, 2000). Sánchez-Moreno *et al.* (2006) congruently reported that stability of ascorbic acid in pasteurized tomato juice during storage could be affected by the type of container.

Table 3. Physico-chemical properties of mangosteen juice during storage at 4°C

Properties	Storage time (week)					
	0	1	2	3	4	5
L*	40.84±0.04[a]	39.76±0.02[b]	38.89±0.08[c]	38.77±0.02[d]	38.46±0.04[e]	37.83±0.04[f]
a*	2.97±0.02[a]	2.90±0.04[b]	2.76±0.03[c]	2.45±0.04[d]	2.16±0.03[e]	1.94±0.01[f]
b*	0.56±0.03[a]	-0.17±0.02[b]	-0.77±0.02[c]	-0.97±0.02[d]	-1.04±0.02[e]	-1.39±0.02[f]
Total soluble solid (°Brix)	20.0±0.00[a]	20.0±0.00[a]	20.0±0.00[a]	20.0±0.06[a]	19.9±0.06[a]	19.9±0.06[a]
pH	3.34±0.02[a]	3.29±0.01[b]	3.17±0.02[c]	3.12±0.01[d]	3.11±0.02[e]	3.09±0.02[e]
Titratable acidity (g citric acid/1000 ml juice)	6.03±0.04[a]	6.15±0.02[b]	6.25±0.02[c]	6.29±0.02[d]	6.35±0.02[e]	6.41±0.02[f]
Ascorbic acid (mg/1000 ml juice)	4.04±0.05[a]	3.90±0.05[a]	3.19±0.11[b]	2.12±0.02[c]	1.13±0.08[d]	0.94±0.08[e]
Anthocyanin (mg cyanidin-3-glucoside/1000 ml juice)	0.83±0.00[a]	0.83±0.00[a]	0.70±0.48[ab]	0.63±0.21[ab]	0.36±0.10[b]	0.28±0.19[b]
Total phenolic compounds (g gallic acid/1000 ml juice)	1.85±0.02[a]	1.66±0.01[b]	1.63±0.01[c]	1.59±0.02[d]	1.57±0.02[e]	1.54±0.01[f]
Antioxidant capacity (mg ascorbic acid/1000 ml juice)	8.12±0.03[a]	5.96±0.06[b]	5.22±0.04[c]	3.32±0.07[d]	2.42±0.07[e]	1.36±0.04[f]

All value givens are means±standard deviations. Means in row with different letters are significantly different ($p<0.05$).

Anthocyanin

Anthocyanins are plant pigments responsible for the orange, red and blue colors of various fruits and vegetables. Redness of the mangosteen juice was mainly attributed to the anthocyanin present in mangosteen pericarp. It has been demonstrated that mangosteen pericarp contain a variety of anthocyanin pigments. Major anthocyanins found in the mangosteen pericarp were reported to be cyanidin-3-glucoside and cyanidin-3-sophoroside (Palapol *et al*., 2009). After 3 weeks of storage, anthocyanin content of the mangosteen juice was not significantly different, thereafter significant decreases ($p<0.05$) were detected in week 4 and 5, compared with the initial anthocyanin content. It is generally recognized that light accelerates degradation of anthocyanin (Schwartz *et al*., 2008). During the storage at 4°C, structural transformation of anthocyanin from flavylium cation (red) to chalcone (colorless), an unstable form, could be occurred. The degradation of anthocyanin could also be due to hydrolyzation of 3-glycoside structure, which has a protective effect in unstable anthocyanin (Laleh *et al*., 2006). Furthermore, destruction of anthocyanin may probably caused by condensation reactions involving covalent association of anthocyanin with other flavanols present in fruit juice, leading to the formation of a new pyran ring by cycloaddition (Rivas-Gonzalo *et al*., 1995). Chemical compounds derived from these condensation reactions are responsible for changes in the color of red wine towards brown or orange (Hayasaka and Asenstorfer, 2002).

Total phenolic compounds

Phenolic compounds are secondary metabolites, ubiquitous in plants and plant derived foods and beverages. Phenolic compounds share some common properties inherent to the phenol ring as summarized by Quideau *et al.* (2011). Total phenolic compounds in mangosteen flesh were reported to be 54±7 (Lim *et al*., 2007) or 85±4.9 mg gallic acid equivalent/100 g fresh weight (Patthamakanokporn *et al*., 2008). On the other hand, total phenolic compounds in mangosteen pericarp extract, using water for the extraction, were reported to be 884.84±9.55 mg gallic acid equivalent/100 g fresh weight (Suttirak and Manurakchinakorn, 2009). A variety of phenolic compounds containing in the mangosteen peel such as phenolic acids (Zadernowski *et al*., 2009), tannins (Pothitirat *et al*., 2009), xanthones (Zarena and Udaya Sankar, 2009) and anthocyanins (Palapol

Table 4. Microbial property of mangosteen juice during storage at 4°C

Microorganism	Storage time (week)					
	0	1	2	3	4	5
Total plate count (CFU/ml)	Nd	Nd	Nd	11	13	24
Yeast and mold (CFU/ml)	Nd	Nd	Nd	Nd	17	23

Nd means not detected.

et al., 2009) has been extensively reported. In this study, total phenolic compounds of the mangosteen juice progressively decreased ($p<0.05$) with the increase in storage time (Table 3). Similarly, decrease in total phenolic compounds in orange juice during storage was demonstrated (Klimczak *et al.*, 2007). Possible degradation pathways of the phenolic compounds may be related to their oxidation, hydrolysis or isomerization (Chang *et al.*, 2006), leading to the decreased total phenolic compounds in the mangosteen juice during the storage. Moreover, reactivation of polyphenol oxidase in the mangosteen juice might occur, affecting the destruction of phenolic compounds served as substrates for enzymatic browning. Enzymatic oxidation of phenolic compounds catalyzed by polyphenol oxidase results in formation of brown pigments (Parkin, 2008).

Antioxidant capacity

Antioxidants are substances that can delay or prevent the oxidation process by acting through several mechanisms. Mangosteen fruit is well recognized as a good source of antioxidant (Leong and Shui, 2002; Lim *et al.*, 2007; Patthamakanokporn *et al.*, 2008). *In vitro* antioxidant properties of mangosteen peel extract has also been reviewed (Suttirak and Manurakchinakorn, 2014). As shown in Table 3, antioxidant capacity of the mangosteen juice progressively decreased ($p<0.05$) during the storage period. Antioxidant capacity of the mangosteen juice can be mainly contributed by ascorbic acid present in the mangosteen flesh (Leong and Shui, 2002; Lim *et al.*, 2007), in addition to anthocyanin and other phenolic compounds containing in the mangosteen pericarp (Pedraza-Chaverri *et al.*, 2008; Palapol *et al.*, 2009). Therefore, the loss in antioxidant capacity could be highly attributed to the loss of ascorbic acid, anthocyanin and total phenolic compounds of mangosteen juice during the storage (Table 3).

Microbiology

Fruit juice is a fertile environment for microorganisms to grow due to the high amount of moisture and sugar present. Pasteurization can be done for temporary preservation of fruit juice. However, some heat-resistant microorganisms such as Blastomyces and thermoacidophilic bacteria are capable of surviving pasteurization and causing spoilage to the fruit juice (Vantarakis *et al.*, 2011). In this study, no bacteria, and yeast and mold were detected during 2 and 3 weeks of storage, respectively (Table 4). At the end of the storage period, the total bacteria and yeast and mold counts did not exceed the legal standard of fruit juice (Thai Industrial Standards Institute, 2004). Growth of the survival microorganisms during storage can be affected by many factors including pH and storage temperature. These results indicated that the low pH of mangosteen juice (Table 3) and cold storage at 4°C might effectively restrict the proliferation of the microorganisms during 5 weeks of storage. Therefore, the pasteurized mangosteen juice can be considered microbiologically acceptable during the storage for 5 weeks at 4°C.

Conclusion

The optimum formula of mangosteen juice could be developed by adding sucrose to obtain 18°Brix of sweetness and 0.2% mangosteen pericarp to enhance color. Although there were some changes in color and some chemical qualities such as the loss of ascorbic acid, anthocyanin and total phenolic compounds leading to the decreased antioxidant capacity, the microbial safety of the pasteurized mangosteen juice was still acceptable during the storage at 4°C for 5 weeks.

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References

AOAC. 1995. Official Methods of Analysis. 16th Ed., Association of Official Analytical Chemists International. Virginia, USA.

Brand-Williams, W., Cuvelier, M. E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Science and Technology 28: 25-31.

Chang, Q., Zuo, Z., Chow, M. S. S. and Ho, W. K. K. 2006. Effect of storage temperature on phenolics stability in hawthorn (*Crataegus pinnatifida* var. major) fruits and hawthorn drink. Food Chemistry 98: 426-430.

Cheynier, V. 2012. Phenolic compounds: from plants to foods. Phytochemistry Reviews 11: 153-177.

Cinquanta, L., Matteo, M. D. and Esti, M. 2002. Physical pre-treatment of plums *(Prunus domestica)*. part 2. Effect on the quality characteristics of different prune cultivars. Food Chemistry 79: 233-238.

Clydesdale, F. M. 1993. Color as a factor in food choice. Critical Reviews in Food Science and Nutrition 33(1): 83-101.

Davey, M. W., Van Montagu, M., Inzé, D., Sanmartín, M., Kanellis, A., Smirnoff, N., Benzie, I. J., Strain, J. J., Favell, D. and Fletcher, J. 2000. Plant L-ascorbic: chemistry, function, metabolism, bioavailability and effects of processing. Journal of the Science of Food and Agriculture 80(7): 825-860.

Esteve, M. J., Frígola, A., Rodrigo, C. and Rodrigo, D. 2005. Effect of storage period under variable conditions on the chemical and physical composition and color of Spanish refrigerated orange juices. Food and Chemical Toxicology 43: 1413-1422.

Fu, C., Loo, A. E., Chia, F. P. and Huang, D. 2007. Oligomeric proanthocyanidins from mangosteen pericarps. Journal of Agricultural and Food Chemistry 55: 7689-7694.

Gregory III, J. F. 2008. Vitamins. In Damodaran, S., Parkin, K. L. and Fennema, O. R. (Eds). Fennema's Food Chemistry. 4th edn., p. 439-521. Florida: CRC Press.

Hayasaka, Y. and Asenstorfer, R. E. 2002. Screening for potential pigments derived from anthocyanins in red wine using nanoelectrospray tandem mass spectrometry. Journal of Agricultural and Food Chemistry 50(4): 756-761.

James, C. S. 1995. Analytical Chemistry of Foods. Glasgow: Blackie Academic and Professional.

Ji, X., Avula, B. and Khan, I. A. 2007. Quantitative and qualitative determination of six xanthones in *Garcinia mangostana* L. by LC-PDA and LC-ESI-MS. Journal of Pharmaceutical and Biomedical Analysis 43: 1270-1276.

Kays, S. J. 1991. Postharvest Physiology of Perishable Plant Products. Athens: Exon Press.

Klimczak, I., Małecka, M., Szlachta, M. and Glíszczyńska-Świgło, A. 2007. Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices. Journal of Food Composition and Analysis 20: 313-322.

Laleh, G. H., Frydoonfar, H., Heidary, R., Jameei, R. and Zare, S. 2006. The effect of light, temperature, pH and species on stability of anthocyanin pigments in four Berberis species. Pakistan Journal of Nutrition 5(1): 90-92.

Lamikanra, O., Chen, J. C., Banks, D. and Hunter, P. A. 2000. Biochemical and microbial changes during the storage of minimally processed cantaloupe. Journal of Agricultural and Food Chemistry 48: 5955-5961.

Lee, P. R., Tan, R. M., Yu, B., Curran, P. and Liu, S. Q. 2013. Sugars, organic acids, and phenolic acids of exotic seasonable tropical fruits. Nutrition and Food Science 43: 267-276.

Leong, L. P. and Shui, G. 2002. An investigation of antioxidant capacity of fruits in Singapore markets. Food Chemistry 76: 69-75.

Lim, Y. Y., Lim T. T. and Tee, J. J. 2007. Antioxidant properties of several tropical fruits: a comparative study. Food Chemistry 103: 1003-1008.

Palapol, Y., Ketsa, S., Stevenson, D., Cooney, J. M., Allan, A. C. and Ferguson, I. B. 2009. Color development and quality of mangosteen (*Garcinia mangostan*a L.) fruit during ripening and after harvest. Postharvest Biology and Technology 51: 349-353.

Parkin, K. L. 2008. Enzymes. In Damodaran, S., Parkin, K. L. and Fennema, O. R. (Eds). Fennema's Food Chemistry. 4th edn., p. 331-435. Florida: CRC Press.

Patthamakanokporn, O., Puwastien, P., Nitithamyong, A. and 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. and Pérez-Rojas, J. M. 2008. Medicinal properties of mangosteen *(Garcinia mangostana).* Food and Chemical Toxicology 46: 3227-3239.

Pothitirat, W., Chomnawang, M. T., Supabphol, R. and Gritsanapan, W. 2009. Comparison of bioactive compounds content, free radical scavenging and anti-acne inducing bacteria activities of extracts from the mangosteen fruit rind at two stages of maturity. Fitoterapia 80: 442-447.

Quideau, S., Deffieux, D., Douat-Casassus, C. and Pouységu, L. 2011. Plant polyphenols: chemical properties, biological activities, and synthesis. Angewandte Chemie International Edition 50: 586-621.

Rivas-Gonzalo, J. C., Bravo-Haro, S., Santos-Buelga, C. 1995. Detection of compounds formed through the reaction of malvidin-3-monoglucoside and catechin in the presence of acetaldehyde. Journal of Agricultural and Food Chemistry 43: 1444-1449.

Rocha, A. M. C. N., Brochado, C. M., Kirby, R. and Morais, A. M. M. B. 1995. Shelf-life of chilled cut orange determined by sensory quality. Food Control 6: 317-322.

Sánchez-Moreno, C., Plaza, L., de Ancos, B. and Cano, M. P. 2006. Nutritional characterization of commercial traditional pasteurized tomato juices: carotenoids, vitamin C and radical-scavenging capacity. Food Chemistry 98: 749-756.

Schwartz, S. J., von Elbe, J. H. and Giusti, M. M. 2008. Colorants. In Damodaran, S., Parkin, K. L. and Fennema, O. R. (Eds). Fennema's Food Chemistry. 4th edn., p. 571-638. Florida: CRC Press.

Singleton, V. L. and Rossi, J. A. 1965. Colorimetric of total phenolics with phosphomolybdicphosphotungstic acid reagent. American Journal of Enology and Viticulture 16: 144-158.

Suttirak, W. and Manurakchinakorn, S. 2009. Total phenolic contents and antioxidant activities of mangosteen peel extracts. Proceedings of the 35th Congress on Science and Technology of Thailand, p. H_H0003. Chonburi,

Thailand.
Suttirak, W. and Manurakchinakorn, S. 2012. Effect of dipping conditions on colorant properties of mangosteen peel extract. Proceedings of the 4th Walailak Research Conference, p. 246. Nakhon Si Thammarat, Thailand. (in Thai)
Suttirak, W. and Manurakchinakorn, S. 2014. In vitro antioxidant properties of mangosteen peel extract. Journal of Food Science and Technology 51(12): 3546-3558.
Thai Industrial Standards Institute. 2004. Thai Community Product Standard 275/2547: Orange Juice. Downloaded from h*ttp://app.tisi.go.th/otop/pdf_file/tcps275_47.pdf.*
Vantarakis, A., Affifi, M., Kokkinos, P., Tsibouxi, M. and Papapetropoulou, M. 2011. Occurrence of microorganisms of public health and spoilage significance in fruit juices sold in retail markets in Greece. Anaerobe 17: 288-291.
Zadernowski, R., Czaplicki, S. and Naczk, M. 2009. Phenolic acid profiles of mangosteen fruits *(Garcinia mangostana)*. Food Chemistry 112: 685-689.
Zarena, A. S. and Udaya Sankar, K. 2009. Screening of xanthone from mangosteen (*Garcinia mangostana* L.) peels and their effect on cytochrome c reductase and phosphomolybdenum activity. Journal of Natural Products 2: 23-30.
Ziena, H. M. S. 2000. Quality attributes of Bearss Seedless lime (*Citrus latifolia* Tan) juice during storage. Food Chemistry 71: 167-172.