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Effect of carbonation sources and its addition levels on carbonated mango juice

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Abstract

The present study was aimed to investigate the effect of carbonation sources (carbonated water or dry ice) and its supplementation levels on the physiochemical, microbial and sensorial qualities of carbonated mango juice. Experimental results revealed that the overall qualities of carbonated mango juice, especially sensory properties, obtained from the addition of dry ice were higher than those of carbonated water. Higher levels of carbonated water significantly decreased total acidity and ascorbic acid content of the carbonated mango juice ($p<0.05$). On the other hand, different levels of dry ice addition did not significantly affect the physicochemical properties of the carbonated mango juice ($p>0.05$). All of the carbonated mango juice samples had a low microbial number, which was not affected by the carbonation method and levels of the carbonation source.

Introduction

Mango (*Mangifera indica* L.) is one of the most popular and abundant tropical fruits in Southeast Asia (Li *et al*., 2012). In 2012, Thailand produced 2,650,000 MT of mangoes, mangosteens and guavas, which increased by 1.92% from the previous year (FAO, 2013). Although the fruit can grow in warm and humid climates, it tends to ripe over a very short period, causing it to be in a great supply for a short time and unavailable at other times (Coleman *et al*., 1980). Chok Anan is a major mango cultivar in the northern of Thailand that is popular for local and export market (Loelillet, 1994; Kienzle *et al*., 2011). The mango fruit flesh has rich luscious, aromatic flavor and a delicious taste in which sweetness and acidity delightfully blended (Loelillet, 1994). This characteristic allows the fruit to be processed into different products, including juice, nectars, puree, pickles and canned slices (Loelillet, 1994; Kienzle *et al*., 2012). Although mango flesh is dominated by moisture content and carbohydrate, mainly sucrose, glucose and fructose, the flesh is still rich with ascorbic and dehydroascorbic acids, β-carotene and phenolic compounds (Reddy and Reddy, 2005; Ribeiro and Schieber, 2010).

Fruit juice can be recognized as a drink that is prepared from fruit material either with or without any additional ingredient. The product can be used as a refreshing source of liquid and the fruit raw material usually contains minor ingredients, particularly vitamins and minerals, which are transferred to the final product (Ashurst, 2005). The juice will be a better alternative than carbonated soft drinks that are identified as a beverage typically containing water, sweetening agent and flavoring. The carbonated soft drinks have been associated with overweight and obesity (French *et al*., 2013). Nevertheless, Roethenbaugh (2005) reported that in 2003, bottled water and soft drinks were the second most popular beverage, after tea as the world's most popular drink. This trend was contributed from major soft drink producing companies that adjusted their products with consumer lifestyles, high marketing budgets and sophisticated distribution systems.

Carbonation is the impregnation of a liquid with carbon dioxide gas (Steen, 2005). The process has gained its popularity for its enjoyable taste and has become an important ingredient of sparkling drinks (Sternini, 2013). Consumption of beverage containing carbon dioxide produces an experience of "pleasurable and sought after" sensation, although the beverage can cause irritation or even painful for some group of people (Descoins *et al*., 2006). Carbonation for soft drinks is responsible for flavor enhancement and refreshing sensation (Saint-Eve *et al.,* 2009). The carbonation process can be carried out by a domestic carbonation unit (Barker *et al*., 2002) or a carbonator (Saint-Eve *et al*., 2009) or an addition

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of dry ice (Cheng *et al*., 2007). The last workers also stated that the presence of carbon dioxide in liquid could reduce surface tension and create more nuclei for cavitation.

To increase customer choices and product diversification, this project proposed a development of carbonated mango juices. A carbonated fruit based beverage is a new concept, which can provide nutritional elements of the fruit along with its natural pigments and flavor as well as a unique sparkle or effervescence effect (Lederer *et al*., 1991). A previous work of Cheng *et al.* (2007) about sonication and carbonation of guava juice showed that carbonation produced guava juice with higher ascorbic acid content, lower clarity and higher polyphenoloxidase activity. Another work by Lederer *et al.* (1991) displayed that a high carbonation level (1.42 CO_2 volumes) enhanced sourness, astringency, bitterness and chalkiness of flavored milk beverages. The aim of this project was to investigate the effect of carbonated water and dry ice at different addition levels on the physicochemical, microbial and sensorial qualities of carbonated mango juice.

Materials and Methods

Mango Juice

Fresh ripe mango fruit variety of Chok Anan was purchased from Muang Mai market in Chiang Mai, Thailand. The fruit that had yellow peel color, indicating as ripen fruit (Nordey *et al*., 2014), and a total soluble solid of 16±1 ºBrix was selected to be used in the experiment. The fruit was washed with municipal water supply, dried at room temperature and peeled with a sharp knife. After removing the seed of the fruit, the mango flesh was blended together with a blender (Philips, Japan). The mango puree was added with 0.25 g ascorbic acid (Union Science, Thailand) for each kg of the puree. The addition of the ascorbic acid was aimed to reduce browning reaction in the puree that could affect the color of the final product (Guerrero-beltran *et al*., 2004). To make the mango juice, 1000 g of mango puree was homogenously mixed with 3500 g of drinking water, 500 g of sugar (Lin, Thailand), 10 g of citric acid (Union Science, Thailand) and 6 g of salt (Prung Thip, Thailand). The addition of water, sugar, citric acid and salt in the mango puree was aimed to adjust the taste of the juice, which was determined from a preliminary experiment. The final mango juice that had a total soluble solid of 14±1 ºBrix was filtered with a muslin cloth to remove coarse particles of mango flesh. The mango juice was then subjected to a pasteurization treatment at 95ºC for 30 s (McLellan and Padilla-Zakour, 2004), cooled down immediately and stored in sterile glass bottles at 4ºC for a carbonation process.

Carbonation process

The carbonation process of mango juice was done by supplementing the juice with carbonated water (Chang, Thailand) or dry ice (Chiang Mai dry ice, Thailand). The carbonated water was added at 3 different ratios of 1:2.5, 2:2.5 and 3:2.5 (v/v) (Kim, 2014) for water and mango juice, respectively. For the dry ice, it was added at ratios of 1:1, 1.5:1 and 2:1 (w/v) (Cheng *et al*., 2007). The carbonation process was carried out in sterile juice bottles at a capacity of 100 ml and then capped tightly.

Physicochemical analyses

Color of carbonated mango juices in the term of L^* (lightness), a^* (redness/greenness) and b^* (yellowness/blueness) values was measured by a colorimeter (Minolta Chroma meter CR-300, Japan). Total soluble solids (TSS) of the sample juices that was expressed in ºBrix were determined using a digital refractometer (Atago 0~32 ºBrix, Japan). For pH value of carbonated mango juices, it was examined by a pH meter (Consort C830 T, Belgium). Total titratable acidity of mango juices was analyzed by a titration method. Briefly, 10 ml of mango juices was titrated with standardized 0.1 M sodium hydroxide (Merck, Germany) in the presence of a phenolphthalein indicator (Merck, Germany) until a definite faint pink color that persisted for more than 15 s. The volume of sodium hydroxide used in the titration was converted to the percentage of citric acid according to the following equation (AOAC, 2000);

Total acidity (%) = (volume of 0.1 M NaOH (ml) x 0.07 x 100)/ volume of juice sample (ml)

Determination of ascorbic acid content in carbonated mango juice was carried out by titrating the sample against a standard solution of 2,6-dichlorophenol-indophenol (Fluka, Switzerland) based on an AOAC method no. 967.21 (AOAC, 2000). The results obtained were expressed as mg of ascorbic acid per 100 ml sample, using the following equation:

Ascorbic acid (mg/100 ml) = (X-15) x (0.2/E) x (V/Y)

Where X was average ml for test solution titration; E was number of ml assayed; V was volume initial test solution and Y was volume test solution titrated.

The volume of carbon dioxide in the carbonated mango juice was determined using a pressure gauge (Ashcroft, USA) and a thermometer (SK Sato, Japan). At a constant measurement temperature of 28±0.5ºC, the pressure reading was then converted to the volume of carbon dioxide using a carbonation chart (Jacobs, 1959). The reading result was recognized as volume of carbon dioxide per juice volume, which described the amount of gas in ml that a given volume of water would absorb at atmospheric pressure (Jacobs, 1959).

Microbiological analyses

Carbonated mango juice was subjected to several microbial analyses, including total microbial count, a total number of yeast and mold and coliform, according to the AOAC method no. 966.23 (AOAC, 2000). An amount of 1 ml mango juice sample or its diluent using 9 ml of Maximum Recovery Diluent (Oxoid, UK) was placed on sterile petri dishes and added with an appropriate medium for each microbial group. The total microbial count was cultivated with Plate Count Agar (Difco, USA), while the number of yeast and mold was determined using Potato Dextrose Agar (Difco, USA). After the medium solidified, the petri dishes of total microbial count were incubated at 37±1ºC for 48 h, while the petri dishes for yeast and mold were kept at 30±1ºC for 72 h before enumeration of each microbial group was carried out. Determination of coliform in the carbonated mango juice was done using three tubes of a Most Probable Number method. Juice samples of 1 ml, 0.1 ml and 0.01 ml were transferred into 3 tubes containing 10 ml Brilliant Green Lactose Bile Broth (Difco, USA), mixed properly and incubated at 37±1ºC for 48 h prior to the observation of microbial growth.

Sensory analysis

Mango juice samples were evaluated for their sensory attributes in the terms of color, odor, sweetness, sourness, bitterness, sparkling sensation and overall acceptance (Pattaragulwanit, 1999). The test panel consisted of 50 untrained panelists, which were the undergraduate and postgraduate students of the Division of Food Science and Technology, Faculty of Agro-Industry, Chiang Mai University, Thailand. The examination was carried out for 2 times on different examination days. The panelists gave their preference on a 9-point hedonic scale, in which 9 was represented for extremely like and 1 was extremely dislike (Lawless and Heymann, 1998).

Statistical analysis

All collected data were subjected to a statistical analysis using Analysis of Variance by applying a Completely Randomized design. The analysis was performed using a SPSS statistics base 17.0 for Windows serial number 5068035 (SPSS Inc., Chicago, USA). Differences between the treatment means were determined by Duncan's Multiple Range Test. Statistical significance between sample treatments was defined at $p<0.05$.

Results and Discussion

Physicochemical properties of carbonated mango juice

Table 1 showed the physicochemical characteristics of carbonated mango juice produced with carbonated water. It could be seen clearly that higher addition levels of carbonated water significantly decreased color values of L^* and b^*, total soluble solid, total acidity and ascorbic acid of the mango juice ($p<0.05$). This finding could be affected by higher levels of water in the final juice product. The color of the mango juice in this study was closer to the color values of fresh cut Tommy Atkins mango cubes (Siddiq *et al*., 2013) compared to the color values of Chok Anan mango juice reported by Santhirasegaram *et al.* (2014). In the last study, Santhirasegaram *et al.* (2014) showed that the color values of the mango juice were 70.28±0.05, 5.00±0.03 and 54.45±0.04 for its L^*, a^* and b^* values, respectively. Higher color values of the mango juice in the last study might be affected by different processing steps and the absence of additional ingredients. Besides that, ripening stage of the fresh mango used in different studies could also affect the physicochemical properties of the subsequent juice product (Padda *et al.*, 2011). This could be noticed from different pH values informed in different studies. In this study, the pH of carbonated mango juice was 3.40±0.01, while the work of Santhirasegaram *et al.* (2014) found a pH value of 4.62±0.02. The pH value of mango juice in this study was closer to the pH of Langra mango fruit at the late stage of its maturity (110 days after fruit setting) described by Baloch and Bibi (2012). The amount of ascorbic acid in the carbonated mango juice at a ratio of 1:2.5 (Table 1) was similar to the report of Santhirasegaram et al. (2013) for Chok Anan mango juices that had passed pasteurization processes at 90±1ºC for 30 and 60 s. Although higher levels of carbonated water reduced several physicochemical properties of the mango juice, the increasing quantity of the water in the juice could significantly raise the juice volume of carbon dioxide ($p<0.05$), which might affect the juice sensory properties (Lederer *et al.*, 1991).

When dry ice was used to carbonate the mango juice, some physicochemical properties of the juice

Table 1. Physicochemical properties of carbonated mango juice affected by the addition levels of carbonated water

Ratio of carbonated water to mango juice	Color			Total soluble solid (°Brix)	pH	Total acidity (% citric acid)	Ascorbic acid content (mg/100 ml)	Volume of carbon dioxide per juice volume
	L*	a*	b*					
1:2.5	21.96±0.14[a]	-0.79±0.06[a]	2.15±0.01[a]	10.43±0.05[a]	3.40±0.01[b]	0.18±0.01[a]	3.42±0.01[a]	0.74±0.01[c]
2:2.5	21.84±0.05[b]	-0.60±0.06[b]	1.97±0.01[b]	7.85±0.07[b]	3.50±0.01[a]	0.14±0.01[b]	2.38±0.01[b]	0.96±0.01[b]
3:2.5	21.44±0.09[c]	-0.48±0.02[c]	1.82±0.01[c]	7.20±0.01[c]	3.50±0.01[a]	0.10±0.01[c]	2.38±0.01[b]	1.08±0.02[a]

[a-c] Values followed by different letters within the same column are significantly different ($p<0.05$).

Table 2. Physicochemical properties of carbonated mango juice affected by the addition levels of dry ice

Ratio of dry ice to mango juice	Color			Total soluble solid (°Brix)[ns]	pH[ns]	Total acidity (% citric acid)	Ascorbic acid content (mg/100 ml)[ns]	Volume of carbon dioxide per juice volume
	L*[ns]	a*	b*					
1:1	22.50±0.05	-1.11±0.01[b]	2.62±0.04[a]	14.00±0.01	3.20±0.01	0.37±0.01[a]	3.59±0.01	1.29±0.02[c]
1.5:1	22.55±0.06	-1.05±0.01[a]	3.56±0.01[b]	14.00±0.01	3.20±0.01	0.36±0.01[b]	3.59±0.01	1.34±0.01[b]
2:1	22.57±0.05	-1.05±0.01[a]	2.49±0.02[c]	14.00±0.01	3.20±0.01	0.36±0.01[b]	3.59±0.01	1.39±0.01[a]

[a-c] Values followed by different letters within the same column are significantly different ($p<0.05$).
[ns] Not significant.

that was not significantly affected were L^* value, total soluble solid, pH and ascorbic acid content ($p>0.05$; Table 2). This finding was mainly affected by the fact that the dry ice was a solid form of carbon dioxide, which did not make a watering effect on mango juice components. A similar finding had been reported for the carbonation of guava juice (Cheng *et al*., 2007). The supplementation of dry ice that produced a carbonated mango juice with higher total soluble solid and total acidity compared to those added with carbonated water (Table 1) might influence the sensory perception of the juice perceived by sensory panelists. The volume of carbon dioxide in the carbonated mango juice produced by dry ice was higher than those of the juices supplemented with carbonated water. The first mango juice also significantly had higher levels of carbon dioxide as greater amount of dry ice was incorporated in the juice ($p<0.05$).

Microbiological qualities of carbonated mango juice

The microbiological analyses of carbonated mango juice, including total microbial count and a total number of yeast and mold demonstrated that the mango juice did not have any detectable microorganisms (within a limitation of pour plate count used in this study) directly after the production process of the juice (data not shown). The number of coliform of all of the carbonated mango juice samples, irrespectively to the carbonation sources, was also less than 3 MPN/ml juice. This result was closed to the standard of Thailand Ministry of Public Health for beverage in sealed container that stated coliform bacteria should be less than 2.2 MPN/100 ml (Food and Drug Administration Thailand, 2013). The microbial finding in this study was mainly affected by the pasteurization treatment at 95ºC for 30 s that was applied to the juice during its production process (data not shown) compared to the presence of carbon dioxide in the juice. Similar results had also been reported by Santhirasegaram *et al.* (2013) for Chok Anan mango juices that were pasteurized at 90±1ºC for 30 and 60 s and Rivas *et al.* (2006) for a blended orange and carrot juice heated at 98ºC for 21 s.

Table 3. Sensory properties of carbonated mango juice affected by the addition levels of carbonated water

Ratio of carbonated water to mango juice	color	odor[ns]	sweetness	sourness	bitterness	Sparkling sensation	Overall acceptance
1:2.5	6.46±0.08[a]	5.66±1.22	5.87±0.32[a]	5.70±0.29[a]	5.94±0.11[a]	4.63±0.33[a]	5.66±0.21[a]
2:2.5	6.16±0.30[b]	5.57±0.53	5.53±0.05[ab]	5.26±0.14[b]	5.68± 0.19[b]	4.56±0.05[ab]	5.27±0.07[b]
3:2.5	5.84±0.36[c]	5.46±0.05	5.07±0.46[b]	4.79±0.16[c]	5.32±0.14[c]	4.26±0.24[b]	4.79±0.28[c]

[a-c] Values followed by different letters within the same column are significantly different ($p<0.05$).
[ns] Not significant.

Table 4. Sensory properties of carbonated mango juice affected by the addition levels of dry ice

Ratio of dry ice to mango juice	color	odor[ns]	sweetness	sourness[ns]	bitterness [ns]	sparkling sensation	overall acceptance[ns]
1:1	6.71±0.01[b]	6.50±0.28	6.44±0.25[b]	6.66±0.02	6.64±0.02	6.74±0.42[b]	6.84±0.28
1.5:1	6.99±0.23[a]	6.61±0.07	6.50±0.39[ab]	6.63±0.52	6.65±0.19	7.10±0.25[a]	6.84±0.05
2:1	6.98±0.24[a]	6.68±0.07	6.82±0.39[a]	6.81±0.52	6.70±0.19	7.30±0.25[a]	7.06±0.05

[a-b] Values followed by different letters within the same column are significantly different ($p<0.05$).
[ns] Not significant.

Sensory characteristics of carbonated mango juice

In the sensory evaluation of the carbonated mango juice, it was found that sensory panelists could perceive more discrepancies in the mango juice sensory attributes when different levels of carbonated water were supplemented to the juice compared to those of dry ice (Tables 3 and 4). Higher levels of carbonated water in the mango juice significantly decreased the sensory attributes of color, sweetness, sourness, bitterness, sparkling sensation and overall acceptance of the juice ($p<0.05$). The finding that could mainly be affected by the watering effect of carbonated water was well corresponded with the results of chemical assessments (Table 1). On the other hand, higher levels of dry ice in the mango juice significantly increased the sensory properties of the juice in the term of color, sweetness and sparkling sensation ($p<0.05$). A similar finding for the sweetness had been described by Yau *et al.* (1989). Higher levels of carbon dioxide in the juice produced with dry ice (Table 2) and higher sparkling sensation could contribute to higher odor and overall acceptance of the carbonated mango juice. These results were in an agreement with the report of Karagül-Yüceer *et al.* (1999), who found that carbonation in yogurt increased flavor and acceptance preference of expert and consumer panelists. Saint-Eve *et al.* (2009) also stated that carbon dioxide in soft drinks was responsible for flavor enhancement. In addition, Cuomo *et al.* (2009) reviewed that a correct carbonation level was important for a balance flavor. Between the two carbonation sources studied in this research, it was revealed that the sensory panelists had a higher preference for the dry ice source with the highest overall acceptance of 7.06 from 9.0 score (the carbonated mango juice with a ratio of 2:1). This overall acceptance score was in the similar preference range of flavored carbonated milk beverages sweetened by sucrose and high fructose corn syrup (Yau *et al.*, 1989).

Conclusion

Results from this study clearly demonstrated that carbonation of mango juice with carbonated water affected more physicochemical and sensorial attributes of the juice compared to those added with dry ice. All of the carbonated mango juices had a low number of microbial content directly after their production. A high preference of sensory panelists towards the carbonated mango juice supplemented with dry ice created an opportunity to improve the consumption of fruit juice. The carbonated fruit juice might be a good response from the food industry to provide consumer with a healthy food product that corresponds to customer's lifestyles.

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