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Chemical properties, antioxidant activities and sensory evaluation of mango vinegar

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Abstract This study was carried out to examine the chemical properties, antioxidant activities and sensory scores of mango vinegar produced from five mango cultivars, namely 'Nam Dokmai', 'Kalon', 'Kaew', 'Chok Anan' and 'Maha Chanok'. Mango vinegars were produced via a two-stage (alcoholic and acetous) fermentation process. The initial soluble solid contents in the mango juice were adjusted to 22 °Brix use refractometer before the fermentation. Alcoholic fermentation was conducted using *Saccharomyces cerevisiae* as the inoculant while *Acetobacter pasteurianus* was used for acetous fermentation. As observed for all samples during the alcoholic fermentation the levels of soluble solids decreased continuously and the levels of alcohol were found to increase at the end of fermentation process. Notably, the wine produced from 'Nam Dokmai' cultivar exhibited the highest levels of alcohol (14.82%) and antioxidant activity (DPPH method) (80.21%). Similar results were observed for all samples during the acetous fermentation, in which the levels of alcohol dropped continuously and the levels of acetic acid were noted to elevate at the end of the fermentation process. The highest levels of acetic acid (6.96%) was detected in the vinegars produced from 'Kalon' cultivar while those produced form 'Maha Chanok' cultivar exhibited the highest levels of antioxidant activity (91%). Sensory evaluation based on the 9-point hedonic scales showed that the vinegars produced from 'Kaew' cultivar displayed the highest overall acceptability with an average score of 6.23, equivalent to the hedonic scale of 9, which indicated the slightly pleasant levels of the vinegar preference of the consumers.

Keywords: Antioxidant activity; Fermentation; Fruit vinegar; Mango; Sensory evaluation

Introduction

Vinegar is one of the most widely used seasoning in the world. In addition to being primarily used as food seasoning, vinegar plays an important role in the production of food products since it is applied in a wide variety of products, including sauces, ketchups and mayonnaise (Ho *et al.*, 2017). Moreover, vinegar has long been used in the treatment of many common

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ailments with claims of anti-infective, antitumor, and hyperglycemic properties (Johnston and Gaas, 2006).

The beneficial effects of vinegar might be due to bioactive substances such as amino acids, organic acids or phenolic compounds derived from its raw materials (Budak *et al.*, 2014; Ghosh *et al.*, 2016). Moreover, the bioactive compounds in vinegars can be produced and/or increased through the overall vinegar fermentation process (Solieri and Giudici, 2009), where phenolic compounds are transformed into new antioxidative molecules (Shahidi *et al.*, 2008).

Recently, the demand for fruit vinegars has increased due to their reputation as health food products, which help to promote different kinds of beneficial effects to consumers, such as having antidiabetic effects and lowering cholesterol levels in blood by inhibiting the oxidation of low density lipoproteins (LDLs), among other benefits (Chen *et al.*, 2017; Ho *et al.*, 2017). Owing to its excellent sensorial properties and nutritional compositions having different health-promoting properties, mainly from the antioxidant activities (Kim *et al.*, 2009), mango is an appealing ingredient for the production of vinegar. Mango (*Mangifera indica* L.) is rich of bioactive compound such as proteins (0.36 – 0.40) g 100 g^{-1} fresh weight (FW) of pulp, vitamin A (0.135 – 1.872) mg 100 g^{-1} FW pulp, vitamin C (7.8 – 172.0)mg 100 g^{-1} FW of pulp, carotenoids (0.78 – 29.34) µg g^{-1}FW of pulp; phenolic compounds, dietary fibre (DF), carbohydrates, minerals, and other anti-oxidants known to have medicinal, nutritional, and industrial benefits (Rymbai *et al.*, 2015).

For this purpose, this study was carried out to compare the chemical properties, antioxidant activities and sensory scores of the mango vinegars produced via a two-stage fermentation process from five cultivars, namely 'Nam Dokmai', 'Kalon', 'Kaew', 'Chok Anan' and 'Maha Chanok'. In this context, chemical properties were assessed in terms of alcohol contents, glucose and fructose contents, and acetic acid contents. Antioxidant activities were determined by DPPH radical assays and total phenolic contents. Sensory evaluation was performed based on the 9-point hedonic scale.

Materials and methods

Chemicals and reagents

2,2-diphenyl-1-picrylhydrazyl hydrate (DPPH) was purchased from Sigma–Aldrich (Steinheim, Germany). Folin-ciocalteau reagent was from Merck (Darmstadt, Germany) and sodium carbonate (anhydrous) from Univar (Downers Grove, IL, USA). All other chemicals and solvents were purchased from local manufacturers. Deionized water was prepared by a Milli-Q Water Purification system (Millipore, MA, USA).

Material and fermentation

Mango pulp of five cultivars, namely 'Nam Dokmai', 'Kalon', 'Kaew', 'Chok Anan' and 'Maha Chanok', was used for the production of mango vinegars via a two-stage (alcoholic and acetous) fermentation process. Mango pulp of each cultivar was crushed and mixed with water at a ratio of 1:1 to prepare mango juice. After adjustment of the pH to 4.5 by acetic acid and sugar content up to 22 °Brix by sugar, the mango juice was pasteurized for 30 min at 60 °C. Alcoholic fermentation was conducted for 8 days at room temperature under static conditions in plastic vessels containing 3 L of the mango juice inoculated with Lalvin ICV D-47 wine yeast, *Saccharomyces cerevisiae*, (Wine & Scientific Equipment Ltd., Part., Ratchaburi, Thailand) at a ratio of 0.75% (v/v). Preparation of yeast inoculum was carried out by mixing 5 g of yeast powder with 60 mL of warm water. At the end of the fermentation process, the obtained wine was separated from the sediment by allowing it to settle in glass bottles, followed by pasteurization for 30 min at 60 °C and clarification for 45 days at 10 °C. Prior to acetous fermentation, the alcohol content of the obtained wine was adjusted to 7% by sterile distill water. Acetous fermentation was performed for 15 days under the aforementioned conditions in glass vessels containing 135 mL of the mango wine inoculated with *Acetobacter pasteurianus* TISTR 521 at a ratio of 10% (v/v). Sampling was performed at given timepoints to collect the two-stage fermented mango vinegars by allowing them to settle in microtube and storage at 4 °C in microtubes before the analyses.

Chemical analysis

Analysis of alcohol, acetic acid, glucose and fructose contents was performed on a Shimadzu HPLC-RID system (Shimadzu, Japan) consisting of Shimadzu LC-20AD pumps and RID-10A refractive index detector. The analytical column was Aminex HPX-87H column (300 mm × 7.8 mm i.d., 9 µm, Bio-Rad Laboratories, Inc., USA) coupled to a cationic exchange precolumn (Bio-Rad Laboratories, Inc., USA). H_2SO_4 (5 mM) was used as the mobile phase. The injection volume was 20 mL with a flow rate of 0.6 mL/min. The column temperature was set at 45 °C.

Total phenolic contents

Total phenolic contents of the mango vinegars were determined using Folin-Ciocalteu reagent as described by (Singleton *et al.*, 1999). Briefly, 1 mL of each sample was diluted with 9.5 mL of distilled water and was then mixed with 0.5 mL of Folin-Ciocalteu reagent and 2 mL of 10% Na_2CO_3 solution. After 30-min incubation at room temperature, absorbance was measured at 765 nm using a Shimadzu UV-1700 spectrophotometer (Shimadzu, Japan). Results were expressed as mg gallic acid equivalents in 1 mL of sample (mg GAE/mL).

DPPH radical-scavenging activity

Antioxidant activities of the vinegars were evaluated by DPPH radical assay (Brand-Williams *et al.*, 1995), in which 2,2-diphenyl-1-picrylhydrazyl hydrate (DPPH) radical was used as a stable radical. In brief, 1.5 mL of each sample was added to 1.5 mL of 0.1 mM DPPH radical solution prepared in ethanol, and the mixture was incubated for 20 min at room temperature in the dark. After incubation, absorbance was measured at 517 nm using a Shimadzu UV-1700 spectrophotometer (Shimadzu, Japan), and the DPPH radical scavenging activities were expressed as the percentage of the DPPH radical elimination effect of vitamin C. Control solutions were prepared by dissolving 0.004 g of DPPH in 95% ethanol, followed by adjustment of the solutions to a final volume of 100 mL. DPPH radical scavenging capacity (RSC) was calculated using the equation $\%RSC = (1 - A_S/A_C) \times 100$, where A_C and A_S denote the absorbance of control and sample, respectively.

Sensory analysis

About 200 g of the mango vinegars were mixed with 150 g of honey and 150 g of water to make drinking vinegars and the obtained drinking vinegars were subjected to the sensory evaluation based on the 9-point hedonic scale by using 30 untrained panelists. The panelists were asked to rank the 9-point scale of affective tests of clearance, color, odor, taste and overall acceptance with the scale 9 representing like extremely, 5 representing neither like nor dislike and 1 representing dislike extremely.

Statistical analysis

A randomized block design, with three replicates and five samples per replicate, was used to compare the chemical properties, antioxidant activities and consumers' preference of the mango vinegars produced from five mango cultivars. The results are expressed as the mean ± one standard deviation (SD) of three replicates and data were analyzed using one-way analysis of variance (ANOVA) with Duncan's multiple range test (DMRT) to determine the significance between samples. In all cases, $p < 0.05$ was considered significant.

Results

Chemical properties of the mango juice, wines and vinegars

The mango wines produced from five mango cultivars via a 8-day alcoholic fermentation process using *Saccharomyces cerevisiae* as an inoculant were analyzed for their chemical compositions, and the results are presented in Fig. 1A. It was observed that at the end of the fermentation, high alcohol content was detected in all the mango wines, indicating that sugars in the mango juice were rapidly converted to alcohol. Acetic acid content of the mango wines was quite low but significantly increased at the end of the fermentation, ranging from 0.30% to 1.32% (Fig. 1D). The mango wine produced from 'Chok Anan' cultivar contained the highest level of acetic acid of 1.32 ± 0.47% while that from 'Maha Chanok' cultivar had the lowest acetic acid content of 0.30 ± 0.15%.

As given in Fig. 1B, glucose was rapidly utilized during the production of the mango wine as observed for all samples, with the most rapidly utilized glucose observed after 1 day of the fermentation in 'Kalon' cultivar. Notably, glucose was completely depleted in all the mango wine samples after 5 days of the fermentation. Fructose was likely to be utilized more slowly as compared to glucose (Fig. 1C). During an 15-day acetous fermentation process, the mango vinegars produced from the five mango wines using *A. pasteurianus* were analyzed for their chemical compositions, and the results are given in Fig. 2. As illustrated in Fig. 2A, all the mango vinegars showed a significant decrease in the alcohol content as it was converted to acetic acid by acetic acid bacteria, which was consistent with the increased acetic acid content, as depicted. On the other hand, at the end of a 15-day acetous fermentation process, acetic acid content was found to range from 4.88% to 6.96%, with the highest value of 6.96 ± 0.08% observed in the mango vinegar produced from 'Kalon' cultivar and the lowest 4.88 ± 0.00% in that produced from 'Nam Dokmai' cultivar (Fig. 2B).

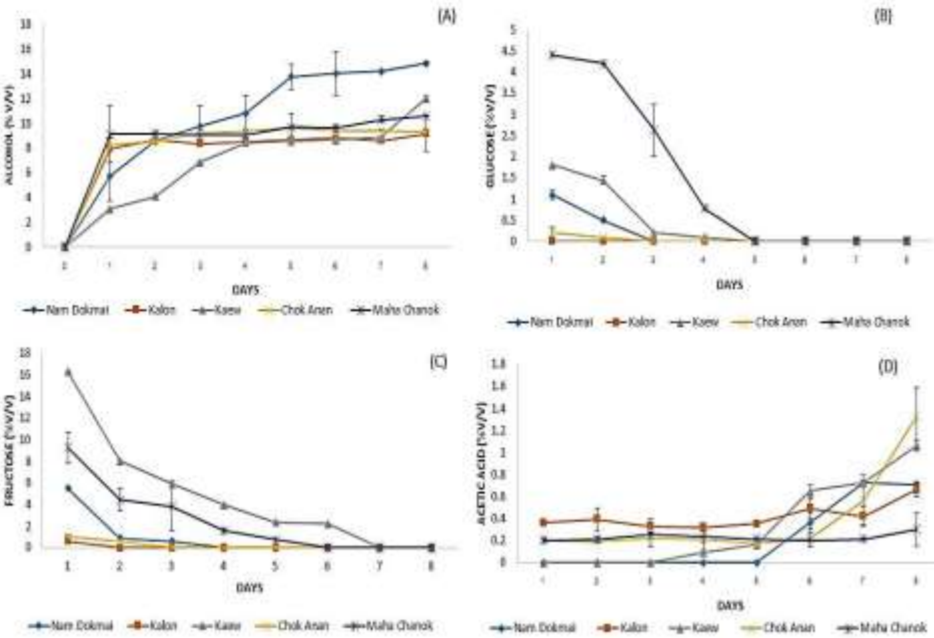

Figure 1. Physicochemical properties of mango wine during a 8-day fermentation process Alcohol (A) Glucose (B) Fructose (C) and Acetic acid (D)

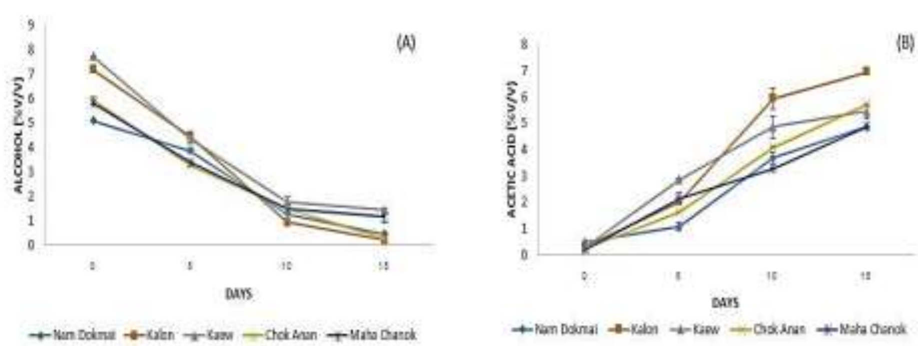

Figure 2. Physicochemical properties of mango vinegar during a 15-day fermentation process Alcohol (A) and Acetic acid (B)

Total phenolic contents and antioxidant activities

The levels of antioxidant activities of the mango vinegars are presented in Table 1. The results showed that the mango juice derived from ‘Kalon’ cultivar exhibited the highest antioxidant activity of 69.13 ± 0.07%. Meanwhile, the wine produced from 'Nam Dokmai' cultivar had the highest antioxidant activity of 84.16 ± 6.72%. On the other hand, the vinegar produced from 'Maha Chanok' cultivar was observed to exhibit the highest antioxidant activity of 91.00 ± 2.37%.

The levels of total phenolic contents detected in the mango vinegars produced from different mango cultivars via a two-stage fermentation process are given in Table 2. It was noted that the mango juice derived from 'Kaew' cultivar contained the highest levels (117.20 ± 0.48 mg/L) of total phenolics. Similar results were observed for the mango wine produced from the same cultivar, in which the wine measured at the end of alcoholic fermentation exhibited the highest total phenolic content of 94.30 ± 0.19 mg/L. On the other hand, the vinegar produced from 'Chok Anan' cultivar was found to contain the highest total phenolic content of 117.81 ± 2.48 mg/L.

Table 1. Antioxidant activities of the five mango vinegars produced via a two-stage fermentation process

Cultivars	**DPPH (% inhibition)**		
	Juice	**Wine**	**Vinegar**
Nam Dokmai	33.83 ± 0.07^{d}	84.16 ± 6.72^{b}	88.30 ± 5.32^{a}
Kalon	69.13 ± 0.07^{a}	58.29 ± 0.43^{b}	68.51 ± 2.66^{b}
Kaew	66.87 ± 1.40^{b}	54.88 ± 3.09^{b}	65.73 ± 3.09^{c}
Chok Anan	43.54 ± 0.29^{c}	43.44 ± 0.00^{c}	86.37 ± 4.60^{a}
Maha Chanok	66.58 ± 0.07^{b}	80.21 ± 2.23^{a}	91.00 ± 2.37^{a}

Values with different letters in the same column are significantly different according to Duncan's multiple range test ($p < 0.05$).

Table 2. Total phenolic contents of the five mango vinegars produced via a two-stage fermentation process

Cultivars	**Total phenolic content (mg/L)**		
	Juice	**Wine**	**Vinegar**
Nam Dokmai	92.74 ± 0.29	84.77 ± 0.10^{b}	71.46 ± 0.19^{c}
Kalon	98.82 ± 0.10	72.14 ± 0.19^{e}	82.47 ± 0.29^{b}
Kaew	117.20 ± 0.48	94.30 ± 0.19^{a}	65.72 ± 2.58^{d}
Chok Anan	108.22 ± 28.48	78.92 ± 1.15^{d}	117.81 ± 2.48^{a}
Maha Chanok	77.27 ± 0.76	80.99 ± 0.10^{c}	83.08 ± 0.57^{b}

Sensory evaluation

The levels of consumers' acceptability based on the 9-point hedonic scale. The original 9-point scale, developed by the U.S. army for menu planning for their canteens, consisted of a series of nine verbal categories representing degrees of liking from 'dislike extremely' to 'like extremely'. For subsequent quantitative and statistical analysis, the verbal categories are generally converted to numerical values: 'like extremely' as '9', 'dislike extremely' as '1'. The levels of consumers' acceptability based on the 9-point hedonic scale of the drinking vinegars, a blend of the vinegars made from different mango cultivars and honey, are depicted in Fig. 3. The results showed that significant ($p < 0.05$) differences in color and clearance were observed among the drinking vinegars produced from different mango cultivars. The drinking vinegar produced from 'Kaew' cultivar displayed the highest level of consumers' preference, with the mean overall acceptability score of 6.23 ± 1.86.

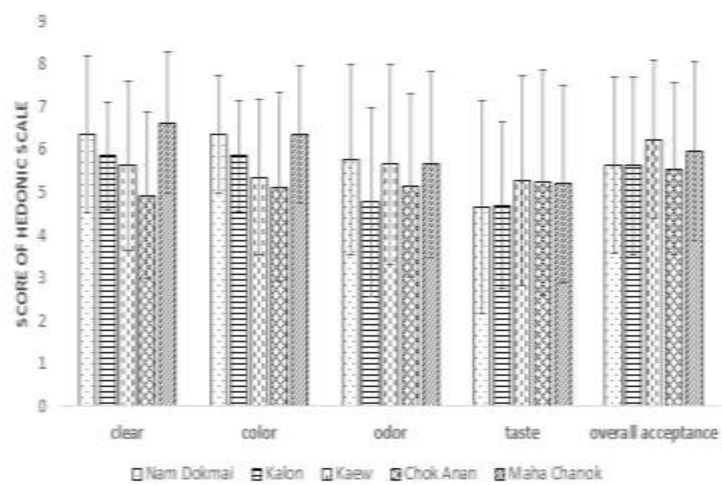

Figure 3. Sensory scores of the drinking vinegars blended from the five fermented mango vinegars

Discussion

Chemical properties of the mango juice, wines and vinegars

The mango wine produced from 'Nam Dokmai' cultivar contained the highest alcohol content of 14.82%, with the lowest alcohol content of 9.14%

observed for that produced from ‘Kalon’ cultivar, which was much greater than that (6.8%) detected in the mango wines produced in an earlier study (Reddy and Reddy, 2011). The difference in alcohol content in mango wines between Nam Dokmai’ cultivars and ‘Kalon’ cultivars may be due to different of in its cultivars nutrients. Therefore, the efficiency of sugar consumption of yeast was differently. The mango wine produced from ‘Chok Anan’ cultivar contained the highest level of acetic acid of 1.32 ± 0.47% while that from ‘Maha Chanok’ cultivar had the lowest acetic acid content of 0.30 ± 0.15%, which was higher than that detected in lychee wine containing the acetic acid content of 0.04 g/100 mL (Chen and Liu, 2016). As given in Fig. 1B and 1C the most rapidly utilized fructose was observed in the mango wine produced from ‘Kalon’ cultivar which was completely depleted after 2 days of the fermentation. Meanwhile, fructose was completely depleted in all wine samples after 8 days of the fermentation. The rapid utilization of glucose and fructose and the consequent increase in the levels of alcohol confirmed that the yeast dominated the fermentation, which was supported by an earlier study (Taniasuri *et al*., 2016) which elucidated the rapid utilization of glucose and fructose in the production of wine durian, in which at the end of the fermentation fructose was completely depleted while glucose remained at 0.046 g/100 mL. In Fig. 2B., the alcohols were not completely depleted, in which at the end of acetous fermentation the vinegar produced from ‘Kaew’ cultivar contained the highest alcohol content of 1.44 ± 0.10% while that produced from ‘Kalon’ cultivar had the lowest alcohol content of 0.21 ± 0.19%, which was in disagreement with an earlier study (Li *et al*., 2014) which elucidated that the alcohol content in the *Hericium erinaceus* vinegar was 0% after 9 days of acetic fermentation. The highest acetic acid value of 6.96 ± 0.08% observed in the mango vinegar produced from ‘Kalon’ cultivar and the lowest 4.88 ± 0.00% in that produced from ‘Nam Dokmai’ cultivar (Fig. 2B), which was much lower than that obtained in a previous study (Li *et al*., 2014), in which an acetic acid content of 21.56 mg/mL was detected in the *H. erinaceus* vinegar after 9 days of acetous fermentation.

Total phenolic contents and antioxidant activities

The levels of antioxidant activities of the mango vinegars are presented in Table 1. the wine produced from ‘Nam Dokmai’ cultivar had the highest antioxidant activity of 84.16 ± 6.72%, which was greater than that produced from jack fruit (69.44 ± 0.34%) (Jagtap *et al.*, 2011). Interestingly, the antioxidant activity of the mango wine obtained from ‘Kaew’ cultivar was higher than that of white wine imported from Czech Republic since 2006 (90 mg/L) (Stratil *et al.*, 2008). On the other hand, the vinegar produced from 'Maha Chanok' cultivar was observed to exhibit the highest antioxidant activity of 91.00 ± 2.37%, which was much greater than that detected in the purple sweet potato makgeolli vinegar (67.63 ± 0.17%) (Chun *et al.*, 2014). Mango juice is naturally rich in polyphenols include ellagic acid, gallic acid, quercetin, catechin, epicatechin, chlorogenic acid, mangiferin and kaempferol which are powerfull antioxidants. (Santhiraseggaram *et al.,* 2015), and the polyphenol compound occur in wine and vinegar have antioxidant activity and free-radical scavenging capacity

On table 2 the vinegar produced from 'Chok Anan' cultivar was found to contain the highest total phenolic content of 117.81 ± 2.48 mg/L, which was much greater than that detected in the purple sweet potato makgeolli vinegar (24.73 ± 0.04 mg/L) (Chun *et al.,* 2014).

Sensory evaluation

In Fig. 3. The results showed that significant (p < 0.05) differences in color and clearance were observed among the drinking vinegars produced from different mango cultivars. The drinking vinegar produced from 'Kaew' cultivar displayed the highest level of consumers' preference, with the mean overall acceptability score of 6.23 ± 1.86, which was equivalent to the hedonic scale of 9. The 9-point hedonic scale has been the primary method of hedonic scaling in food science, which has been widely used for assessment of consumers' acceptability of foods and drinks (Cardello, 2017). For instance, (Varakumar *et al.*, 2012) employed the 9-point hedonic scale to evaluate the consumers' acceptability of mango wine produced using a novel yeast-mango-peel immobilized biocatalyst system, and the average values were recorded for the four evaluated attributes of which the aroma is the one with a slightly higher value, followed by the taste, appearance, and overall acceptance, with respective notes of 7.9, 7.7, 7.6, and 7.5.

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