CHARACTERIZATION OF ORGANIC ACIDS AND PHENOLIC COMPOUNDS OF CEREAL VINEGARS AND FRUIT VINEGARS IN CHINA

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ABSTRACT

The presence of phenolic compounds and organic acids in vinegars can make great contribution to sensory quality and functional activity. Results indicated that cereal vinegars exhibited higher total phenolic content, flavanols and DPPH radical-scavenging activity index than fruit vinegars. Gallic acid, catechin hydrate and vanillic acid were detected to be the major phenolic compounds in cereal vinegars. In apple vinegar chlorogenic acid was the characteristic while the most abundant mono-phenol in persimmon and kiwifruit was gallic acid. The most plentiful organic acids were acetic acid and lactic acid, which aggregated account for more than 70% of the total acids among all simples. Furthermore, it was observed that fruit vinegars and cereal vinegars could be clearly discriminated by principle component analysis and cluster analysis.

PRACTICAL APPLICATIONS

Organic acids and polyphenols are vital compounds of vinegars because they greatly contribute to sensory quality and functional activity. In vinegars, the content of organic acids and polyphenols is variable and depends on several factors, mainly raw materials, techniques of processing and microbiological growth. Previous researchers have extensively investigated traditional cereal vinegars and emerging fruit vinegars, respectively. We performed a comparative analysis of cereal vinegars and fruit vinegars and found the characteristic compounds of these two kinds of vinegars. Consequently, this research could give some help to vinegar making and the distinction between the cereal and fruit vinegar.

INTRODUCTION

Vinegar, as a worldwide food condiment and preservative, is produced by fermentation process from cereal or fruit including ethanol fermentation and acetic acid fermentation in many countries such as China, Spain and Japan (Qi et al. 2013).

A large number of reports have indicated that vinegars have anti-microbial (foodborne pathogens) and antioxidant effects. They can also lower lipids (Chou et al. 2015), prevent hypertension and lessen the glycemic index of carbohydrate food (Chen et al. 2014), etc. Due to potential health benefits, there are various vinegar products exploited in the world. Vinegars are traditionally produced by cereal, primarily sorghum and rice. As Shanxi aged vinegar (SAV) gains overwhelming popularity in northern part of China, so is Zhenjiang aromatic vinegar (ZAV) in southern areas. In today’s market, there is a growing demand for fruit vinegar sold as a health food product (Ubeda et al. 2011a). Fruit vinegars such as persimmon vinegar, apple vinegar and jujube vinegar are mainly made of different kinds of fruits and their residuals by modern food processing techniques and traditional fermentation (Liu et al. 2008).

Vinegars are rich in organic acids, amino acids, mineral substances, and also contain phenolic compounds. Phenolics, which containing at least one aromatic ring with one or more hydroxyl groups attached, play a critical role in keeping health-promoting due to their ability to neutralize free radicals that might be generated in the body and lead to
Characterization of cereal vinegars and fruit vinegars

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Table 1. The main raw materials and code of seven vinegar samples

<table>
<thead>
<tr>
<th>Type of samples</th>
<th>Main raw material</th>
<th>Sample code</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAV</td>
<td>Sorghum, barley, pea, wheat bran</td>
<td>SAV1</td>
</tr>
<tr>
<td>SAV</td>
<td>Sorghum, barley, pea, wheat bran, millet shell</td>
<td>SAV2</td>
</tr>
<tr>
<td>SAV</td>
<td>Sorghum, barley, pea, wheat bran, hull, rice husk</td>
<td>SAV3</td>
</tr>
<tr>
<td>ZAV</td>
<td>Glutinous rice, wheat bran</td>
<td>ZAV</td>
</tr>
<tr>
<td>Persimmon vinegar</td>
<td>Persimmon</td>
<td>PV</td>
</tr>
<tr>
<td>Apple vinegar</td>
<td>Apple</td>
<td>AV</td>
</tr>
<tr>
<td>Kiwifruit vinegar</td>
<td>Kiwifruit</td>
<td>KV</td>
</tr>
</tbody>
</table>

Materials and methods

Materials

Three Shanxi aged vinegars and one Zhenjiang aromatic vinegar were purchased in a local supermarket to use as our testing samples. In addition, three fruit vinegars including apple vinegar, persimmon vinegar and kiwifruit vinegar which were fermented in the laboratory in September, 2011 and met standard GB18187—2000 were employed in this experiment. The code and main raw materials of these samples are shown in Table 1.

- p-Dimethylaminocinnamaldehyde (DMACA), 6-hydroxy-2,5,7,8-tetrahydroxylchroman-2-carboxylic acid (trolox), 1,1-diphenyl-2-picrylhydrazyl radical (DPPH), the standards of mono-phenols (Gallic acid, 2,5-Dihydroxybenzoic acid, (+/-)-Catechin hydrate, Vanillic acid, Chlorogenic acid, Caffeic acid, l-Epicatechin, (-)-Epigallocatechin gallate, p-Coumaric acid, trans-Ferulic acid, Salicylic acid, (-)-Epicatechin gallate, Rutin hydrate, Resveratrol, Quercetin and Phloridzin) and organic acids (Quinic acid, Malic acid, Tartaric acid, Vitamin C, Propanedioic acid, Lactic acid, Citric acid, Acetic acid, Fumaric acid, Succinic acid) were all purchased from Sigma Chemical Co. (St. Louis, MI).

Methanol, acetonitrile, Folins–Ciocalteus phenol reagent and glacial acetic acid (HPLC grade) were obtained from Spectrum Chemical Co. (California).

Ethyl acetate, potassium dihydrogen phosphate and phosphoric acid were purchased from Tianjin Tianli Chemical Reagents, Ltd. (Tianjin, China). All other reagents used were of analytical grade unless specially noted.

Determination of Total Phenols, Total Flavanols and DPPH Radical-Scavenging Activity

Total phenolic (TP) content in the whole vinegars was determined by the Folins–Ciocalteus method (Qader et al. 2011). The calibration curve was performed with gallic acid (concentrations ranging between 0 and 1,000 mg/L) and the results were expressed as gallic acid equivalents (GAE). A volume of 0.1 mL of an appropriately diluted vinegar sample and 7 mL of distilled water were added to a test tube, followed by an addition of 0.5 mL of Folins–Ciocalteus reagent. They were mixed thoroughly before 1.5 mL of a 20% sodium carbonate solution was added. Then the mixture was brought to 0.9 mL with distilled water. After allowing the mixture to stand in the dark for 60 min, the absorbance was determined at 765 nm.

Total flavanols (TFA) was determined using the method of Meng et al. (2012) with slight modification. The concentrations of standard solutions chosen to create the calibration curve were 0, 12.5, 25, 50, 100 and 150 mg/L of catechin. And the results were expressed as catechin equivalents (CE). Briefly, 0.1 mL of vinegar sample was added to 3 mL of 0.1% DMACA solution (1 mol/L hydrochloric acid methanol) with sufficient mixing. After the reaction at room temperature for 10 min, the absorbance was measured against a blank at 640 nm in comparison with catechin standard curve.

The DPPH method employed to determine the radical-scavenging capacity of vinegars was based on Li (Li et al. 2009).
Different concentrations of Trolox ranging from 100 to 2,000 mmol were used in the same sample conditions to construct a calibration curve. And the results were expressed as mmol Trolox equivalents (TE)/kg of vinegar. 0.1 mL of appropriately diluted sample was added to 3.9 mL of DPPH solution (25 mg/L in methanol). After standing for 20 min in the dark, the absorbance of the mixture was measured at 515 nm.

All the determinations were accomplished at least in triplicate.

The HPLC Analyses of Mono-Phenols of the Vinegars

Standard stock solutions of each standard compound were prepared and stored in methanol at −30C. The working standard solutions and mixed working standard solutions were prepared for the calibration by diluting the stock solution with methanol according to the assay.

The vinegar samples (SAV1, SAV2, SAV3 and ZAV 15 mL, fruit vinegars 100 mL) were extracted thrice with two times volume of ethyl acetate. The combined ethyl acetate phase was removed by a rotary evaporation at 35C and the remainder was resolved in methanol (chromatography grade) up to a final volume of 5 mL and stored in −30C avoids light preservation. Then the final samples were filtered by Millipore filters of 0.22 µm organic membranes prior to analysis by HPLC. Each sample repeated two times.

Chromatographic conditions: the separations were performed and detected on a Waters XBridgeTM Shield RP18 (4.6 × 250 mm, 3.5 µm) column with a mobile phase of solvent A (acetonitrile-acetic acid, 98:2, V/V)/solvent B (water-acetic acid, 98:2, V/V) mix using a linear gradient under 280 nm. The gradient elution conditions were as follows: 0 ~ 60 min, 5 ~ 15%A; 60 ~ 65 min, 15%A; 65 ~ 66 min, 15 ~ 20%A; 66 ~ 73 min, 20%A; 73 ~ 74 min, 20 ~ 30%A; 74 ~ 80 min, 30%A; 80 ~ 81 min, 30 ~ 40%A; 81 ~ 93 min, 40%A; 93 ~ 95 min, 40 ~ 5%A; 95 ~ 105 min, 5%A. The flow rate was 0.8 mL/min and the injection volume was 20 µL. The column temperature was set at 30C.

The HPLC Analyses of Organic Acid of the Vinegars

Ten organic acids, including quinic, malic, tartaric, vitamin C, propanedioic, lactic, citric, acetic, fumaric and succinic acids, were determined by HPLC.

Standard stock solutions were prepared by accurately weighing 24.0 mg and dissolving in distilled water in a 10 mL brown volumetric flask each of 10 kinds of standard substances, stored in 4C.

Chromatographic separation was carried out at 30C on Diamonsil C18 column. The mobile phase was an aqueous

7% CH$_3$OH-0.01 mol/L NaH$_2$PO$_4$ solution adjusted to pH 2.2. The flow rate was set 0.6 mL/min with 20 µL as the injection volume. The optimum wavelength for the determination of the organic acids was 210 nm.

Statistical Analysis

Results are expressed as means ± standard deviations of three replicates. One-way analysis of variance (ANOVA) was applied to all samples to verify significant difference at 5% level by SPSS version 18.0 software package. Principal component analysis (PCA) and cluster analysis was applied to analysis the mono-phenols and organic acids.
RESULTS

TP, TFA and DPPH Radical-Scavenging Activity of the Vinegars

As shown in Fig. 1A, cereal vinegars exhibited higher TP contents than fruit vinegar. The TP contents decreased in the order: SAV > ZAV > KV > PV > AV with the amount (mg/L) of average 2170.83 for SAV, 1459.72 for ZAV, 754.5 for KV, 343.67 for PV and 274.08 for AV.

The TFA value of the tested vinegars was found to vary from 3.36 mg/L (AV) to 21.03 mg/L (SAV1), averaging 8.77 mg/L. Furthermore, the difference of TFA between various samples is consistent with the TP content.

DPPH radical-scavenging activity is an important index which has been widely used to test the antioxidant ability of samples (Benvenuti et al. 2004). The DPPH radical-scavenging activity of cereal vinegars is generally higher than fruit vinegars. In the cereal vinegars, SAV showed higher scavenging activity than ZAV. In addition, the kiwifruit vinegar exhibited the highest scavenging activity among fruit vinegars.

Analysis of Mono-Phenols in Vinegars by HPLC

The mono-phenols of vinegar samples were determined by HPLC as the same method of 16 authentic standards (Fig. 2). Table 2

![HPLC Chromatogram of 16 Mono-Phenols](Figure 2)

**Table 2.** The Analysis of Mono-Phenols Content in Vinegar Samples (mg/L)

<table>
<thead>
<tr>
<th>Mono-phenols</th>
<th>SAV1</th>
<th>SAV2</th>
<th>SAV3</th>
<th>ZAV</th>
<th>PV</th>
<th>AV</th>
<th>KV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallic acid</td>
<td>89.79 ± 1.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>252.4 ± 2.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>132.7 ± 1.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>555.3 ± 2.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.91 ± 1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.35 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.67 ± 0.59&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>2,5-Dihydroxybenzoic acid</td>
<td>110.79 ± 1.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>139.5 ± 1.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>112.7 ± 0.88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34.00 ± 0.44&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.16 ± 0.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–</td>
<td>1.47 ± 0.34&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>(+/-)-Catechin hydrate</td>
<td>20.80 ± 0.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.73 ± 0.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.35 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.06 ± 0.12&lt;sup&gt;f&lt;/sup&gt;</td>
<td>6.56 ± 0.43&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.12 ± 0.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>–</td>
</tr>
<tr>
<td>Vanillic acid</td>
<td>17.49 ± 0.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.04 ± 0.06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.03 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.04 ± 0.05&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Caffeic acid</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>(+/-)-Epicatechin</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>13.27 ± 0.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>(-/-)-Epigallocatechin gallate</td>
<td>37.93 ± 0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>(+/-)-Epicatechin</td>
<td>–</td>
<td>9.31 ± 0.78&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.27 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.59 ± 0.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.03 ± 0.21&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.33 ± 0.28&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.34 ± 0.01&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Salicylic acid</td>
<td>9.18 ± 0.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.11 ± 0.32&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.52 ± 0.01&lt;sup&gt;f&lt;/sup&gt;</td>
<td>5.54 ± 0.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.02 ± 0.11&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.24 ± 0.07&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.01 ± 0.03&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>(+/-)-Epicatechin</td>
<td>7.19 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Rutin hydrate</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.13 ± 0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.77 ± 0.34&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phloridzin</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.38 ± 0.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.76 ± 0.34&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Resveratrol</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Quercetin</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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<td>–</td>
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</tbody>
</table>

Different letters indicate the statistically significant differences (Duncan’s multiple range test, p < 0.05).
showed that 6 ~ 7 kinds of mono-phenols could be quantified in the cereal vinegars while 6 ~ 9 kinds in fruit vinegars, respectively. The total content of the quantified mono-phenols was decreased successively in the order: ZAV > SAV > PV > KV > AV with the amount (mg/L) of average 333.19 for SAV, 631.31 for ZAV, 23.73 for PV, 16.91 for KV and 13.10 for AV. Gallic acid, catechinhydrate and vanillic acid were detected to be the major phenolic compounds in SAV and ZAV, contributing about 86.94% and 95.45% to the total amount, respectively. In apple vinegar the chlorogenic acid is characteristic compound, which comprises 50.08% of the total quantified mono-phenols.

The HPLC Analysis of Organic Acids of the Vinegars

The organic acids content of samples were determined by HPLC as the same method of 10 authentic standards (Fig. 3). The statistical values for organic acids are shown in Table 3. In vinegars, the most abundant organic acids were acetic acid and lactic acid, which aggregated accounted for more than 70% of the total acids. Additionally, quinic acid, tartaric acid and propanedioic acid were major organic acids in cereal vinegars, comprising 17–24% of the total quantified acids. While in fruit vinegars, the main organic acids were propanedioic acid, malic acid and tartaric acid. What’s more, fumaric acid and vitamin C were found in lower concentrations in both types of vinegars.

The PCA and Cluster Analysis

Furthermore, in order to better understand the similarities and differences in the profiles of the phenolic compounds and organic acids among these vinegars, cluster analysis and PCA was performed using mono-phenols and organic acids as variables.

The graphical representation of the PCA scores showed the differences or similarities among the samples, wherein similar samples tend to form clusters and dissimilar samples are observed at larger distances. The scatter plots of data using the top two principal components (PCs) issued from PCA were obtained as showed in Fig. 4. With regard to the mono-phenols, the two PCs expressed 73.35% of the total variance (PC1 and PC2 accounted for 58.71% and 14.64% of the variance, respectively) (Fig. 4A). Analyzing the next plot, it was observed that the first principal component (PC1) describes 66.97% of total variance, while the second component (PC2) describes 16.79%; the two PCs together accounted for 83.76% of the total variation across the samples. Furthermore, in fruit vinegars, PV and KV had the similar mono-phenols composition. And in cereal vinegars, SAV2 and SAV3 exhibited the similar organic acids content.

As shown in Fig. 4C,D, of the vinegars, SAV2 and SAV3 could be clustered within a short hierarchical distance, indicating they had similar profiles of phenolic compounds and organic acids. A similar fingerprint of phenolic compounds was also observed in PV and KV.

On the whole, the samples can be distinctly divided into two groups according to their raw material, fruit vinegars (PV, KV, AV) and cereal vinegars (SAV1, SAV2, SAV3, ZAV) in terms of phenolic profiles and organic acids.

DISCUSSION

China has a long history of brewing vinegar, which is an indispensible part of ancient civilization. The mature vinegars and

The DISCUSSION portion of the text is not fully visible in the provided content.
the aromatic vinegars are the most popular vinegars in China. Zhenjiang aromatic vinegar, as one of the most famous vinegars in the south of China, is produced from stick rice by solid-state delaminating fermentation. Shanxi aged vinegar, which gains overwhelming popularity in the northern part of China, is generated from several kinds of cereal including sorghum and a large dosage of starter Daqu (take approximately 60% of the raw ingredient, made from pea and barley) as major raw material, millet chaff and wheat bran as filling materials with solid-state fermentation techniques (Wu et al. 2012). Fruit vinegars, mainly made of different kinds of fruits by traditional fermentation and modern processing techniques, have becoming more and more popular throughout the world. In China, especially in northwest region, apple, persimmon and kiwifruit vinegars are the most popular vinegars due to health benefits and good flavor.

The composition of vinegar is variable and depends on several factors, mainly raw materials, techniques of processing and microbiological growth. Organic acids and polyphenols are vital compounds in vinegars because they greatly contribute to sensory quality and functional activity.

Polyphenols constitute one of the most significant quality parameters of vinegar because they greatly affect the sensory quality, especially color, flavor, astringency and bitterness. In addition, the chemical structure of polyphenols enables them to have multiple biological effects, including antioxidant activity, coronary heart disease prevention, antitumor and anti-inflammatory activity (Bataglion et al. 2015). Our results showed that the TP content and flavanols of cereal vinegar are generally higher than fruit vinegar. The plausible explanation may be related to raw materials and brewing process. Sorghum, as one of the most important materials of cereal vinegars, is an abundant source of various phytochemicals including tannins and phenolic acids (Kobue-Lekalake et al. 2007). Wheat brans, barely pea and millet shells are also important parts of the material of cereal vinegars. With regard to brewing process, after acetic acid fermentation ZAV possess less than three months of the aging process and need not to be baked, while SAV have six days of

FIG. 4. THE PCA OF MONO-PHENOLS (A) AND ORGANIC ACIDS (B); THE HIERARCHICAL CLUSTER OF VINEGARS USING MONO-PHENOLS (C) AND ORGANIC ACIDS (D) AS VARIABLES
baking stage and at least 18 months of aging process, and the chemical reaction and enzymatic reaction in this process might contribute to the TP content increase. Based on the above reasons, SAV had the highest TP and the ZAV followed. Previous studies have demonstrated that the kiwi-fruit had higher level of phenolic contents than persimmon and apple (Du 2009). These studies could explain the higher concentrations of phenolic compounds in kiwifruit vinegar. As apple vinegar used in this experiment was made from apple juice, the fact that total polyphenolic content of this vinegar was lower than those of other vinegars may be due to the raw material. Also fruit vinegars exhibited lower radical-scavenging activity than cereal vinegars and it was observed that DPPH radical-scavenging activity index was highly correlated with TP content and flavanols, which is consistent with the finding of Verzelloni (Verzelloni et al. 2007). With respect to mono-phenols, gallic acid, which seems to have anti-fungal and anti-viral properties, has been circumstantiated abound in cereals. It is maybe a vital reason resulted in that gallic acid is the highest mono-phenols in the SAV and ZAV of analyzed samples.

Organic acids occur in fermented products as a result of hydrolysis, biochemical metabolism and microbial activity. During fermentation, carbohydrates and proteins are degraded by bacteria producing sugars, small peptides and amino acids that contribute to the taste and flavor of the samples. What’s more, amino acids and sugars are further metabolized during brewing, forming pyruvic acid as a significant intermediate in several organic acid-forming pathways. Organic acids are then produced by the Embden Meyerhof Parnas pathway and hexose monophosphate pathway (Shukla et al. 2010). The amount and type of organic acids present in vinegars not only influence flavor but also nutrition and bioavailability (Shui and Leong 2002). A number of factors, including microbial composition, fermentation environment and the state of original materials can affect the level of organic acids (Choi et al. 2007). In this study, we found that cereal vinegars considerably vary from fruit vinegars. As expected, levels of acetic acid are higher in cereal vinegars than fruit vinegars. This may be due to the presence of ageing period in cereal vinegars. That is, the contents of acetic acid can increase during ageing period. Cereal vinegars, primary served as condiment, possess single composition and acetic acid was the prominent ingredient with high content. In the contrast, fruit vinegars contain complex composition of organic acids. As one of the most popular beverages consumed worldwide, fruit vinegars possess harmonious savoriness and sweetness, gratifying fruit savoury and soft taste.

Finally, PCA and cluster analysis was carried out to better understand the similarities and differences in the concentration of the phenolic compounds and organic acids among these vinegars. The samples used in our experiment can be perfectly divided into two classes, cereal vinegars and fruit vinegars, according to their raw ingredient. Furthermore, the two fruit vinegar, i.e., persimmon and kiwifruit had the similar mono-phenols level because of the similar composition of raw materials. The use of similar raw ingredients and fermentation methods are the possible reason for the small difference between SAV2 and SAV3.

CONCLUSIONS

Cereal vinegars and fruit vinegars, as worldwide food condiments and health beverages, are becoming more and more popular throughout the world. Our results indicated that cereal vinegars exhibited higher TP content, TFA and DPPH radical-scavenging activity index than fruit vinegars. With regard to the mono-phenol, gallic acid and catechinhydrate were detected to be the major phenolic compounds in cereal vinegars. With reference to organic acids, the most abundant organic acids were acetic acid, lactic acid and quinic acid in cereal vinegars, while in fruit vinegars the main organic acids were acetic acid, lactic acid and propanedioic acid.

ACKNOWLEDGMENTS

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