Journal of Food and Drug Analysis, Vol. 13, No. 4, 2005, Pages 348-356 藥物食品分析 第十三卷 第四期

Investigation of the Physicochemical Properties of Concentrated Fruit Vinegar

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(Received: January 26, 2005; Accepted: June 8, 2005)

ABSTRACT

Since consuming vinegar on a regular basis can contribute to the maintenance of good health, many fruit vinegar products are sold in Taiwan. Using 66 fruit vinegars purchased in local markets as samples, this study investigated the labeling, pricing and physicochemical properties of commercial concentrated fruit vinegar in order to understand their production methods and quality. Two out of the 66 samples had no label, while only 29 samples listed nutrient content. According to the labels, 26 of the fruit vinegar samples were made from juice mixed with grain vinegar (JG), while 28 samples were produced from juice via alcoholic and vinegar fermentation (F). The remaining samples were produced by fermentation and mixed with grain vinegar, alcoholic vinegar and juice. Most of the domestic products, such as mei (also called as Japanese apricot), cider, orange, lemon and blended vinegar, were produced by mixing juice with grain vinegar, whereas most imported cider and wine vinegar were produced by fermentation. Wine vinegar had the highest unit price of all fruit vinegar samples.

Appearance of these vinegar samples differed significantly. The variations in pH and acidity were less than other physicochemical properties. Total sugar content of vinegar without sugar was less than 3%, while those with sugar added ranged from 8% to 64%. Most imported cider and wine vinegar samples had no sugar added, with the acidity being about 5~7%. Most domestic products with sugar added have the average acidity of less than 3%. Variations in soluble solids content and density of the fruit vinegar were similar to the variation in total sugar content. Besides acetic acid, the major organic acids found in fruit vinegar are malic, lactic and citric acids. Mulberry vinegar was found to be higher in lactic and succinic acids than other fruit vinegar. Red wine vinegar was rich in tartaric, malic and lactic acids.

The Chinese National Standards (CNS14834, N5239), which regulates edible vinegar focuses on "seasoning vinegar" but not "vinegar beverages". Since people are paying much more attention to health, the number of concentrated vinegar products in Taiwan is expected to increase in the future. Thus, appropriate rules are required to regulate vinegar products.

Key words: fruit vinegar, physicochemical properties

INTRODUCTION

Humans have used vinegar as condiment and food preservative for thousands of years. Apart from the antibacterial activity(1), consumption of vinegar is associated with health benefits, including lowering blood pressure, reducing risk of cardiovascular disease(2,3), antioxidant activity(4) and promoting nutrient metabolism(5). Since consumption of vinegar can help in the maintenance of health, many fruit vinegar products have been available in addition to the traditional vinegar, such as rice vinegar and Gao-liang vinegar. Based on the concentration of acetic acid in fruit vinegar found in the market in Taiwan, these products can be categorized into two types: fruit vinegar beverage (FVB), which has low acetic acid and can be drunk neat; and concentrated fruit vinegar (CFV), which has a high content of acetic acid and need to be diluted 4~8 times with water before drinking. This study focused on CFV which includes major fruit vinegar products.

Edible vinegar is classified into brewing vinegar and artificial vinegar according to the Chinese National Standard definitions (CNS14834, N5239)(6). The difference between these two types is whether glacial acetic acid (or acetic acid) has been added. According to the CNS brewing vinegar standards, the definition of fruit vinegar, such as cider, wine or orange vinegar, is that it must have been fermented from at least one kind of fruit, and that each liter of raw material must contain more than 300 g of fruit juice. The acidity levels of brewing vinegar and artificial vinegar must also be higher than 4.2% and 4.5% for grain vinegar and fruit vinegar, respectively. On the other hand, non-salt soluble solids must be higher than 1.3% and 1.2%, respectively. Besides acidity and non-salt soluble solids, there is no other quality standard for consumers to judge quality. The study of Koizumi *et al.*(7) found that, for amino acids and organic acids, some high price special vinegar in Japan did not offer the good quality.

In order to understand the production methods and the quality of concentrated fruit vinegar, 66 concentrated fruit vinegar acquired from local commercial markets were inspected for label content, price, color, pH, acidity, density, soluble solids, sugar content and organic acids. Our goal was to provide a guideline for both consumers and manufacturers in the consumption and production of fruit vinegar.

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MATERIALS AND METHODS

I. *Sample Materials*

Sixty-six concentrated fruit vinegar samples were acquired from supermarkets, department stores and organic food stores in Taiwan.

II. *Methods*

(I) *Density*

Density of the fruit vinegar was calculated directly by the weight and volume of each sample.

(II) *Color*

Hunter L, a and b values were measured with a colormeter (DR. LANGE Micro Color, Germany). A standard white tile with reflectance values of X = 76.3, Y = 81.1 and Z = 84.8 was used as a reference.

(III) *pH*

A pH meter (MP220 pH Meter, Mettler-Toledo, Switzerland) was used to measure the pH of the fruit vinegars.

(IV) *Acidity (CNS14834, N5239)*

After adding 2 drops of phenolphthalein as an indicator, 10 mL of sample was titrated with 0.5 N NaOH, until the solution appeared pink in color. Results were expressed as percentage of acetic acid (g acetic acid/100 g sample).

(V) *Soluble Solids*

For most concentrated fruit vinegar samples with high sugar content, the samples formed a sticky film making them difficult to weigh to a constant weight during drying at 105°C. Therefore, the soluble solids method of CNS14384 N5239 was not used in this study. Soluble solids were measured with refractometers (HAND REFRACTOMETER, N-1E and N2, ATAGO, Japan), with the results reported as Degrees Brix.

(VI) *Total Sugar Content*

For the concentrated fruit vinegar samples having various types of sugar, such as sucrose, fructose, glucose, honey, oligosaccharide and low calorie sweetener, it was difficult to analyze the individual sugar by HPLC. We modified the method of Wen (2001)[8] to measure the total sugar content. Vinegar samples were first hydrolyzed with HCl at 100°C for 30 min, and then neutralized with NaOH. After appropriate dilution with water, 3 mL of DNSA (3,5-dinitrosalicylic acid) was added to 1 mL of hydrolyzed samples or standard glucose solution (0~2.0 mg/mL), respectively, and heated in a 100°C water bath for 5 min. After cooling, 10 mL of water was added to the reaction solution and the optical density was measured at 540 nm (U-2000 Spectrophotometer, HITACHI, Japan). Total sugar content was quantified by comparison with the standard glucose curve.

(VII) *Organic Acids*[8]

Organic acids analyzed in this study were tartaric, malic, lactic, acetic, citric and succinic acids. They were determined with a high performance liquid chromatograph (L-6200 Intelligent Pump & L-4200 UV-VIS Detector, HITACHI, Japan) with a Lichrospher 100RP-18 (250 × 4.6 mm) column. Twenty microliter of sample was injected and the elution phase used was 1% phosphate buffer (pH 2.4) at a flow rate of 0.8 mL/min. Detection was set at 220 nm.

(VIII) All the above mentioned data were the average of triplicates.

RESULTS AND DISCUSSION

Sixty-six CFVs, including 12 mei, 17 cider, 3 mulberry, 4 lemon, 8 blended, 15 wine, 2 orange and 5 others (starfruit, blueberry, pineapple, grapefruit and psssion fruit) vinegar are listed in Table 1. In addition to 8 ciders, 14 wines and 1 blended vinegar samples were imported; while all others were domestic. Apart from the wine vinegar which are consumed as a condiment, all other products were diluted with 4~8 parts of water as a beverage. Most were either mei or cider vinegar.

I. *Labeling and Pricing of CFV*

Two samples acquired from organic food stores had no label except for the product name (1 starfruit vinegar and 1 mei vinegar). Of the 64 samples with labels, 29 had nutrients listed on the label, while 35 did not. Production methods were classified into 5 categories, according to information on the labels. They were brewed from juice by alcoholic and vinegar fermentation (F); brewed from juice and alcohol (FA); F mixed with grain vinegar (FG); juice mixed with grain vinegar (JG); and F mixed with juice (FJ). From Table 1, it can be seen that 28 samples were F and 26 were JG. Those categorized as FG, FA and FJ had 6, 3 and 1 samples, respectively. Domestic products, such as mei, cider, mulberry, lemon and blended vinegar, were mostly made of juice mixed with rice vinegar or Gao-liang vinegar, whereas most imported products were produced by alcoholic and vinegar fermentation. Total sugar contents in 16 samples were more than 20% exceeding the amount shown on the labels. This implied that CFV quality was not

Table 1. Label analysis and classification of concentrated fruit vinegar in the marketplace

Samples	Total	Mei	Cider		Mulberry	Orange	Lemon	Wine	Blended	Others
			Domestic	Imported						
No. of sample	66	12	9	8	3	2	4	15	8	5
Classification[a]										
F	28	2	3	6	2			13	2	
JG	26	5	4		1	2	4	1	6	3
FG	6	3	2							1
FA	3			2				1		
FJ	1	1								
Unknown	2	1								1
Unlabeled	2	1								1
Labeled										
Without NL[b]	35	6	1	5	3	0	0	15	4	1
With NL	29	5	8	3	0	2	4	0	4	3
Incorrectly labeled[c]	16	2	5	2		2	2		2	1

[a]F: vinegar produced from juice by alcoholic and vinegar fermentation; FA: vinegar fermentation made from juice and alcohol; FG: F mixed with grain vinegar; JG: juice mixed with grain vinegar; FJ: F mixed with juice.
[b]NL: nutrient label.
[c]Total sugar contents more than 20% exceeding the amount stated on the label.

Table 2. Unit price and volume of concentrated fruit vinegar in the marketplace

	Mei	Cider		Mulberry	Lemon	Winec	Blended	Starfruit
		Domestic	Imported					
Sample no.	12	9	8	3	4	15	8	1
Volume (mL)								
Min	500	300	200	600	500	150	300	600
Max	750	750	750	600	750	1000	630	
Price (NT)								
Min	89	65	68	200	89	68	38	350
Max	500	450	565	250	342	400	300	
Price (NT/100 mL)								
Min	14.8	13.2	13.6	33.3	17.5	24.5	12.7	
Max	70.0	75.0	94.2	41.7	68.4	80.0	50.0	
Mean	37.3	27.1	36.4	38.9	32.0	49.5	30.5	58.3
> NT50	70.0	75.0[a]	94.2[b]		68.4[b]	80.0		58.3[a]
	66.7[a]					79.2		
	50					74.2		
						68.4		

[a]Samples purchased from organic food stores.
[b]Samples with labels stressing health.
[c]14 imported and 1 domestic samples were included.

under adequate control.

The prices and volume per unit of CFV sold in the marketplace are listed in Table 2. The minimum and maximum volumes of domestic samples were 300 mL and 750 mL, respectively, while the volumes for imported samples ranged from 150 mL to 1000 mL. Prices differed significantly due to volume, fruit content and whether it was touted as being organic or not. Thus, the unit volume price (UVP, NT/100 mL) of samples was used for comparison. Four wine vinegar samples had UVP higher than NT 50. Wine vinegar had the highest average UVP (NT 49.5 /100 mL) among all CFV, possibly due to the juice brewing process and long shelf life.

The average UVP of mulberry vinegar was the next highest, with UVP between NT 33 and NT 42. Except mulberry vinegar, the maximum UVP was more than three times that of the minimum. The minimum and the maximum UVP of imported cider vinegar had the largest spread, from NT 13.6 to NT 94.2.

Three mei vinegar samples had UVP higher than NT 50, and these samples were all emphasized for long soaking time with grain vinegar. The UVP of one domestic cider vinegar, purchased from an organic food store, was NT 75.0, while the UVP of other domestic cider vinegar samples ranged between NT 13.2 and 23.8 (data not shown). The UVP of most imported cider vinegars ranged between NT 13.6 and 37.5 (data not shown), which were slightly higher than those of domestic samples. One imported cider vinegar with the highest UVP of NT 94.2 had lactic acid and other healthy constituents added. The UVP of most lemon vinegar ranged from NT 17.5 to 22.8, but one sample with traditional Chinese medicine added had a high UVP of NT 68.4. The UVP (NT 58.3) of starfruit vinegar purchased from an organic food store was also above the average UVP of other fruit vinegar samples.

II. *Physicochemical Analysis of CFV*

(I) *Concentrated Mei Vinegar*

Table 3 shows that the brightness (Hunter L) and yellow color (Hunter b) of the 12 mei vinegar samples did not vary significantly; and they were in the range of 30.4~45.1 and 9.3~15.4, respectively. Red color (Hunter a), however, had a large variance (CV = 88.2%). The pH and acidity were in the range of 2.30~3.70 and 0.76~3.63 %. The acidity of samples A7 and A9 was surprisingly only 1.65 and 0.76 %, but their pH was as low as 2.49 and 2.30, respectively. It was absurd that the pH of other 10 samples with higher acidity was higher than these two samples. The pH is a measure of the concentration for hydrogen ion in solution. Since the total concentrations of organic acids in these two samples were almost equal to the acidity; they must have strong non-organic acid(s) added to have such low pH.

Soluble solids (SS) for 12 mei vinegar samples were in the range of 15.4 to 52.2 °Brix and total sugar (TS) ranged between 12.0 and 63.9%. SS and TS of samples A1 and A6 were significantly lower than the others. Difference in density ranged from 1.05 to 1.26 g/mL, which had the lowest CV of 5.7%.

Citric and malic acids are the main organic acids in mei juice[9]. Higher UVP samples, such as A8, A10 and A11, the concentration of acetic acid in A10 was only 1.01 mg/g, which was lower than the concentration of malic (2.59 mg/g) and citric acids (27.36 mg/g). Similarly, the acetic acid in A11 was only 9.39 mg/g, which was also lower than its citric acid content (16.90 mg/g). Additionally, the content of citric acid in A8 (11.50 mg/g) reached about half of the considerably high acetic acid content (23.90 mg/g). A large amount of mei juice or citric acid was possibly added to A8, A10 and A11 samples to reduce the pungent characteristics of mei vinegar.

(II) *Concentrated Cider Vinegar*

Nine domestic and 8 imported cider vinegar samples were analyzed in this study. Table 4 shows that domestic samples with higher TS, such as B1, B3, B5 and B9, were less bright than samples with lower TS. This might be due to Maillard reactions or the polymerization of polyphenols. Except for C8, all imported cider vinegar samples were low in TS, with the range from 0.3 to 3.3%. For imported samples with lower TS, those having a bright appearance were higher in Hunter L and lower in both Hunter a and b values than the domestic ones. Except C8 (2.78%), the acidity of most imported samples was about 5%, and the pH of all imported samples was in the range of 2.34 to 3.17. Differences in the acidity of domestic samples were larger than those for imported ones, with the pH slightly higher in the range of 2.82 to 3.50. The acidity of the low sugar domestic cider vinegar, B6, B7 and B8, was 5.13, 5.19 and 3.49%, respectively, with the last one below the Chinese National Standards. Similar to the mei samples A7 and A9, C8 had pH and acidity much lower than that of other samples, implying that this sample must have some strong non-organic acid(s) added.

Among the domestic samples, B6 and B7 had acetic acid content compatible to imported samples. However, the acetic acid contents of one imported (C8) and four domestic (B3, B4, B5 and B9) samples were as low as 13.4~18.8 mg/g, which might be the results of adding a large volume of sugar.

Next to acetic acid, lactic acid was the most abundant

Table 3. Analysis of physicochemical properties of concentrated mei vinegar in the marketplace

Samples	L	a	b	pH	ACI[a] (%)	SS (°Brix)	DEN (g/mL)	TS (%)	TA	MA	LA	AA	CA	SA
									(mg/g)					
A1	30.4	7.6	12.1	2.77	3.40	21.9	1.08	14.9	—[c]	4.60	—	31.80	3.70	0.50
A2	43.1	1.0	12.5	3.04	1.58	45.6	1.24	50.0	—	0.70	1.30	18.10	2.10	—
A3	43.1	0.5	15.2	2.94	1.52	49.0	1.24	53.1	—	—	1.40	22.30	1.40	—
A4	31.9	7.8	13.9	2.71	2.33	40.4	1.20	36.0	—	1.00	1.80	26.90	1.50	—
A5	43.2	1.0	12.5	3.41	1.42	41.0	1.21	38.3	—	0.10	0.45	14.54	0.42	—
A6	45.1	-0.3	9.3	3.70	1.35	15.4	1.05	12.0	—	0.90	1.10	20.90	0.30	0.30
A7	34.3	6.2	15.3	2.49	1.65	49.6	1.23	48.9	—	1.20	3.00	14.80	—	—
A8[b]	36.2	5.9	14.2	2.66	2.85	41.8	1.21	39.6	—	3.10	3.50	23.90	11.50	0.40
A9	39.3	2.7	12.5	2.30	0.76	52.2	1.26	52.8	0.13	0.18	0.11	5.98	1.15	—
A10[b]	38.1	3.3	14.4	2.94	3.38	30.4	1.15	35.7	—	2.59	0.20	1.01	27.36	0.45
A11[b]	33.1	7.6	14.4	2.82	3.63	30.6	1.15	41.4	—	2.01	1.64	9.39	16.90	—
A12	43.2	0.2	15.4	3.12	1.54	49.5	1.25	63.9	0.30	0.43	0.61	12.61	2.07	0.47
Mean	38.4	3.6	13.5	2.91	2.12	39.0	1.19	40.6	0.04	1.40	1.26	16.85	5.70	0.18
CV	13.4	88.2	13.2	13.2	45.5	30.5	5.7	37.4	254	100	88.4	52.9	150	126

[a]ACI: acidity; SS: soluble solids; DEN: density; TS: total sugar; TA: tartaric acid; MA: malic acid; LA: lactic acid; AA: acetic acid; CA: citric acid; SA: succinic acid.
[b]Price per 100 mL vinegar was higher than NT 50.
[c]Not detected.

Table 4. Analysis of physicochemical properties of concentrated cider vinegar in the marketplace

Samples	L	a	b	pH	ACI[a] (%)	SS (°Brix)	DEN (g/mL)	TS (%)	TA	MA	LA	AA	CA	SA
									(mg/g)					
Domestic														
B1	37.5	5.0	15.6	3.13	1.61	46.8	1.23	51.6	—[c]	2.40	1.70	23.8	—	—
B2	44.6	-0.2	11.7	3.33	2.40	15.0	1.04	8.2	—	1.80	1.70	24.4	5.90	—
B3	29.6	8.7	12.4	2.87	1.68	49.0	1.24	49.7	—	3.60	0.90	18.3	0.20	—
B4	44.6	-0.1	10.0	3.50	1.17	32.5	1.16	21.8	—	0.70	1.00	17.9	—	—
B5	38.4	4.0	16.3	3.06	1.68	46.0	1.23	44.2	—	3.00	1.60	18.8	—	—
B6	45.8	-0.4	8.4	2.82	5.13	6.0	0.97	1.7	—	2.80	2.00	60.4	—	—
B7	42.3	1.8	11.5	2.91	5.19	4.2	1.00	0.9	—	0.70	4.20	62.6	—	—
B8[b]	47.5	-0.3	3.4	2.97	3.49	2.6	0.99	0.3	—	—	6.95	23.8	—	0.52
B9	32.5	7.3	14.1	3.28	1.75	48.4	1.25	64.3	—	3.33	0.32	13.4	—	0.55
Mean	40.3	2.9	11.5	3.10	2.68	27.8	1.12	27.0		2.04	2.26	29.3	0.68	0.12
CV	15.4	123	34.4	7.5	58.0	74.3	10.5	94.9		63.9	91.2	63.6	289	199
Imported														
C1	39.7	3.3	11.6	3.01	5.28	4.3	1.00	0.5	—	—	3.80	62.4	—	0.90
C2	48.1	-0.7	4.1	2.61	5.03	5.5	1.01	2.8	—	1.50	—	59.9	—	0.70
C3	47.9	-1.0	5.7	2.64	5.09	5.5	1.01	2.7	—	1.60	—	59.5	—	—
C4	47.3	-0.6	5.2	2.77	5.07	6.5	1.01	3.3	2.80	1.60	1.50	60.5	—	—
C5	38.3	3.8	11.9	2.95	4.78	3.8	0.99	1.2	—	0.28	1.76	51.8	—	—
C6	42.6	2.1	10.9	2.74	4.99	3.8	0.99	0.3	1.36	0.29	0.49	51.0	0.14	—
C7	40.1	4.1	11.2	3.17	4.53	3.8	1.00	1.9	—	0.21	1.13	53.2	—	—
C8[b]	44.1	-2.0	20.9	2.34	2.78	31.9	1.16	33.8	—	0.54	0.70	15.4	9.36	—
Mean	43.5	1.1	10.2	2.78	4.62	8.1	1.02	5.81	0.52	0.73	1.08	51.5	1.13	0.20
CV	9.08	218	52.9	9.4	22.0	119	5.6	196	199	95.6	120	30.7	278	187

[a]Same as Table 3.
[b]Price per 100 mL vinegar was higher than NT 50.
[c]Not detected.

Table 5. Analysis of physicochemical properties of concentrated mulberry and lemon vinegar in the marketplace

Samples	L	a	b	pH	ACI[a] (%)	SS (°Brix)	DEN (g/mL)	TS (%)	TA	MA	LA	AA	CA	SA
									(mg/g)					
Mulberry vinegar														
D1	19.2	10.1	1.8	2.92	2.16	30.0	1.14	32.5	—[c]	3.30	2.30	21.70	2.10	0.40
D2	22.0	15.8	5.5	2.88	2.86	53.8	1.27	41.5	—	0.50	7.90	29.50	3.40	4.70
D3	17.1	2.1	-0.3	3.00	2.87	34.6	1.17	32.2	—	0.80	2.70	24.70	—	—
Mean	19.4	9.3	2.3	2.93	2.63	39.5	1.19	35.4		1.53	4.30	25.30	1.83	1.70
CV	12.7	73.7	126	2.1	15.5	32.0	5.6	14.9		100	75.7	15.6	93.6	153
Lemon vinegar														
E1	41.9	1.1	12.8	3.44	2.47	14.2	1.04	8.0	3.00	1.00	—	22.70	9.70	0.40
E2	44.0	1.1	13.8	2.55	2.48	58.0	1.29	56.5	—	—	—	15.70	12.70	—
E3[b]	33.0	9.7	12.2	2.55	2.77	38.0	1.19	33.8	—	0.50	0.84	24.64	2.52	—
E4	46.4	-0.3	9.0	2.52	2.38	32.0	1.16	24.3	—	1.12	1.80	3.49	18.39	—
Mean	41.3	2.9	12.0	2.77	2.53	35.6	1.17	30.7	0.75	0.65	0.66	16.63	10.83	0.10
CV	14.2	158	17.4	16.3	6.7	50.8	8.8	66.2	200	78.4	130	57.5	61.0	200

[a]Same as Table 3.
[b]Price per 100 mL vinegar was higher than NT 50.
[c]Not detected.

organic acid reported by Natera *et al.*[(10)] for 11 cider vinegar samples with an average content of 2.02 mg/g. The average contents of malic and citric acids for those 11 cider vinegar samples were 0.086 and 0.157 mg/g, respectively. On the other hand, lactic, malic and citric acids in the analysis of 13 cider vinegar samples by Gerbi *et al.*[(11)] were 0.02, 0.72 and 0.26 mg/g, respectively. In this study, the average contents of lactic, malic and citric acids for the 9 domestic samples were 2.26, 2.04 and 0.68 mg/g, and those for the 8 imported samples were 1.08, 0.73 and 1.13 mg/g, respectively. The content of lactic acid was in between the results of Natera *et al.* and Gerbi *et al.*, while the malic acid content was similar to that of Gerbi *et al.* but much higher than that of Natera *et al.* For citric acid, its content in the imported sample C8 and the domestic sample B2 was 9.36 and 5.90 mg/g, respectively, which were strangely higher than other samples and those in the two previous studies.

(III) *Concentrated Mulberry and Lemon Vinegars*

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Three mulberry vinegar samples, as expected from the color of the fruit itself, were the least bright and deepest red in color (Table 5). The pH was about 2.93, acidity was in the range of 2.16~2.87% and average TS was 35.4%. Regardless of clarity, there were large differences in SS among the three mulberry vinegar samples ranging from 30.0 to 53.8 °Brix. Besides acetic acid, the main organic acids in the mulberry vinegar were malic, lactic and citric acids. Due to the abnormally high lactic acid content of one sample, the average lactic acid content of 4.30 mg/g was the highest of all the vinegar samples.

As the result of the addition of wheat greens, mulberry and spices, one lemon vinegar sample (E3) had high UVP of NT 68.4/100 mL and was darker in appearance than the other three samples (Table 5). The pH of the 4 samples ranged from 2.52 to 3.44, and the acidity ranged from 2.38 to 2.77%. Variation in TS was large, i.e. in the range of 8.0~56.5%. Differences in SS and density were the same as TS. Organic acid analysis showed that the acetic acid content of sample E4 was only 3.49 mg/g, which was much lower than citric acid content (18.39 mg/g). For the 4 lemon vinegar samples, the average citric acid content was considerably high as compared with other types of vinegar, probably because of lemon being the raw material.

(IV) *Concentrated Wine Vinegar*

Imported wine vinegar samples are generally used for seasoning. However, people in Taiwan have different dietary habits from Americans or Europeans, such as rare use of wine vinegar for seasoning. Fourteen imported and 1 domestic wine vinegar (F0) samples were investigated in this study. F0 was brewed from grape and glutinous rice and was sold as a seasoning. In Table 6, it can be seen that large variations exist in the physicochemical properties. Therefore, comparison was carried out mainly according to the TS and raw material.

Samples F0~F8 with TS below 3.5% were classified as low sugar wine vinegar (LSWV) while the samples with TS higher than 12.8% were classified as wine vinegar with sugar added (SWV). The 15 wine vinegar samples were further classified into 2 categories according to their raw material; white wine vinegar (WWV) for samples F1, F5, F6, F7 and F8, and red wine vinegar (RWV) for the remaining 10 samples. Table 6 shows that WWV and LSWV were high in Hunter L, while RWV was high in Hunter a. This might be due to the high sugar content, polymerization of phenols, or the addition of caramel in the RWV samples. WWV with a slightly yellowish color

Table 6. Analysis of physicochemical properties of concentrated wine vinegar in the marketplace

Samples	L	a	b	pH	ACI[a] (%)	SS (°Brix)	DEN (g/mL)	TS (%)	TA	MA	LA	AA	CA	SA
									(mg/g)					
F0	23.1	12.5	5.3	2.79	4.97	6.0	0.99	3.5	0.20	0.66	—[d]	42.34	—	—
F1	47.8	- 0.6	3.8	2.53	5.17	4.6	0.97	0.6	0.02	—	0.78	50.18	—	—
F2	29.4	9.4	12.3	2.64	7.11	4.9	1.00	2.6	1.09	0.33	0.29	55.39	8.62	—
F3	36.3	11.0	7.5	2.96	6.56	4.2	1.01	2.5	0.61	—	0.42	62.01	0.20	—
F4	36.8	7.1	10.5	2.90	5.84	4.3	1.00	2.3	1.49	—	0.17	62.28	0.01	0.17
F5[b]	45.5	0.7	6.7	2.78	5.58	4.8	1.00	0.7	0.60	2.19	0.69	58.14	—	—
F6[b,c]	48.9	-0.2	0.4	2.89	4.95	3.0	1.00	0.7	1.26	0.49	0.21	47.35	—	—
F7	41.4	2.8	11.6	3.20	7.14	4.4	1.00	2.2	1.57	0.29	0.76	59.22	—	—
F8	41.3	2.7	11.4	3.17	6.39	4.3	1.00	2.4	1.56	—	0.88	66.52	—	—
F9	17.6	1.9	0.1	3.12	5.99	23.3	1.09	29.7	3.49	6.84	3.92	70.56	—	0.99
F10[b]	17.3	1.9	-0.3	3.13	7.06	24.2	1.08	20.5	10.40	10.60	3.00	71.09	2.50	—
F11	17.5	1.8	0.1	3.06	7.18	24.0	1.07	30.7	3.39	5.44	2.92	74.16	—	0.52
F12[b]	16.5	2.1	-0.1	3.03	6.05	22.7	1.07	12.8	3.80	9.41	3.68	57.19	0.38	2.05
F13	16.8	1.8	0.1	3.32	5.90	33.0	1.17	30.6	5.12	16.68	11.71	74.59	1.80	—
F14	17.1	1.8	0.0	3.23	5.96	23.1	1.09	18.3	5.16	5.37	2.86	57.95	0.30	0.96
Low sugar wine vinegar (LSWV): F0~F8														
Mean	38.9	5.0	7.7	2.87	5.97	4.5	1.00	1.94	0.93	0.44	0.47	55.94	0.98	0.02
CV	22.0	99.9	52.8	7.7	14.6	17.5	1.1	54.1	63.7	159	68.5	14.1	292	300
Sugar- added wine vinegar (SWV): F9~F14														
Mean	17.1	1.9	-0.02	3.15	6.36	25.1	1.09	23.8	5.23	9.06	4.68	67.59	0.83	0.75
CV	2.5	6.2	9.6	3.5	9.4	15.7	3.3	32.1	50.8	47.4	74.1	11.7	127	102
White wine vinegar (WWV): F1 and F5~F8														
Mean	45.0	1.1	6.8	2.91	5.85	4.22	0.99	1.32	1.00	0.60	0.67	56.28	0.00	0.00
CV	7.9	148	71.6	9.6	15.5	16.8	1.4	68.1	67.4	154	39.6	13.6		
Red wine vinegar (RWV): F0, F2~F4, and F9~F14														
Mean	22.8	5.1	3.6	3.02	6.26	17.0	1.06	15.4	3.48	5.53	2.90	62.76	1.38	0.47
CV	33.7	109	134	6.6	11.3	63.9	5.4	79.9	87.0	101	120	16.2	195	146

[a]Same as Table 3.
[b]Price per 100 mL vinegar was higher than NT 50.
[c]Distilled wine vinegar.
[d]Not detected.

was higher in Hunter b. For F6, the only one distilled wine vinegar among all samples had Hunter a and b values significantly lower than those of other WWV.

The 15 wine vinegar samples had pH of 2.53~3.32 and acidity above 4.95%. Due to the low TS of LSWV, in the range of 0.6~3.5%, their density was near 1.00 and SS was between 3.0 and 6.0 °Brix. The TS of SWV ranged from 12.8 to 30.7%, and SS ranged from 22.7 to 33.0 °Brix.

Table 6 also shows that apart from acetic acid, the major organic acids in the wine vinegar were tartaric, malic and lactic acids. During malolactic fermenting stage of wine fermentation, malic acid would change to lactic acid[12] and the lactic acid would then decrease in vinegar fermentation[13,14]. Thus, the analysis of organic acids in this study has confirmed the study of Natera *et al.*[10]. Tartaric and malic acids levels in SWV or RWV were the highest in all CFV, while the content of lactic acid was the closest to that of mulberry vinegar. The levels of tartaric, malic and lactic acids in LSWV or WWV were significantly lower than those in SWV or RWV.

(V) *Concentrated Blended Fruit Vinegar and Other Fruit Vinegar*

Because of the difference in fruit species, juice content, sweetener types and grain vinegar used, there were many differences in the appearance of concentrated blended fruit vinegar (Table 7). The Hunter L, a and b values of the 8 blended fruit vinegar samples varied significantly. Differences in pH and acidity were apparently small, being in the range of 2.32~3.32 and 0.64~2.10%, respectively. It was suspicious that the acidity of both H2 and H7 was 2.10%, and the pH was 3.17 and 3.02, respectively. Samples H1, H3, H4, H5 and H8 not only had low acidity (0.87~1.32%), but also had an unreasonably low pH (2.32~2.93) as compared to either blended vinegar or other kinds of fruit vinegar.

There was a great deal of variation in TS and SS for these samples. Sample H7 used an artificial sweetener shown on the label to claim its low calorie. However, its TS was as high as 41.1%, which was not less than the other samples.

Blended fruit vinegar samples were mixtures of different juices or juice vinegar, which created complex organic acid composition. The organic acids in blended fruit vinegar were mainly malic, lactic and citric acids. However, except acetic acid, there was no other organic acid detectable for sample H4. One reason for that is that except acetic acid, the amount of other organic acids in sample H4 after being diluted with 100 parts of water was beyond the detectable limit of HPLC used in this study. Another possibility might be that the fruit vinegar was made by simply mixing fruit juice with acetic acid or glacial acetic acid and water, resulting in the concentrations of other organic acids too low to be detected.

Other concentrated fruit vinegar were passion fruit (*Pedulis*), pineapple, blueberry, grapefruit, starfruit and orange vinegar. Orange O1 with less sugar added had a bright appearance. Apparently the amount of juice used for orange O2 was high, resulting in higher citric acid content than orange O1. Differences in color, fruit juice, sugar content for the other 5 fruit vinegar were large and the variation in physicochemical properties examined was high. The tartaric acid contents of these samples were too low to

Table 7. Analysis of physicochemical properties of concentrated blended and other vinegar in the marketplace

Samples	L	a	b	pH	ACI[a] (%)	SS (°Brix)	DEN (g/mL)	TS (%)	TA	MA	LA	AA	CA	SA
									(mg/g)					
Blended vinegar														
H1	47.8	-0.5	5.4	2.57	0.87	43.2	1.21	48.2	—[d]	0.10	1.90	9.10	0.20	0.30
H2	36.6	4.1	15.3	3.17	2.10	18.2	1.06	12.5	3.10	1.90	2.40	23.00	6.10	—
H3	42.5	1.1	14.1	2.32	1.05	29.6	1.14	29.2	2.50	0.90	0.90	15.00	—	—
H4	48.5	-0.8	3.9	2.66	0.98	29.2	1.14	32.8	—	—	14.50	—	—	
H5	36.6	4.6	14.6	2.78	1.32	33.0	1.16	35.7	—	5.40	1.80	15.00	2.60	—
H6	38.5	2.3	12.5	3.32	0.64	13.6	1.02	9.6	—	0.53	2.30	4.24	1.48	—
H7[c]	25.1	14.4	9.4	3.02	2.10	44.0	1.21	41.1	1.50	0.80	5.36	17.83	0.33	—
H8	48.5	-0.7	2.6	2.93	1.23	28.4	1.15	38.8	0.16	0.49	0.84	10.43	0.17	—
Mean	40.5	3.1	9.7	2.85	1.29	29.9	1.14	31.0	0.91	1.26	1.94	13.64	1.36	0.04
CV	19.9	165	52.9	11.6	42.3	35.6	5.9	43.8	142	140	83.0	41.9	156	283
Other vinegar														
Passion fruit	37.4	4.8	16.5	2.95	1.84	45.4	1.24	52.6		0.40	—	21.30	4.60	—
Pineapple	38.7	4.4	18.5	3.79	1.27	40.0	1.15	38.6	—	0.40	0.80	17.70	—	—
Blueberry	19.9	7.1	-2.2	3.40	1.13	35.0	1.19	36.3	—	1.47	—	18.48	—	0.84
Grapefruit	36.5	4.8	16.4	3.36	1.64	46.4	1.23	57.0	—	0.65	0.95	12.73	6.39	—
Starfruit[b]	42.5	1.3	10.8	2.59	2.77	29.0	1.13	35.2	—	0.36	2.32	24.40	0.22	—
Orange (O 1)	47.8	-0.7	5.5	3.78	1.09	40.8	1.18	22.7	—	—	0.80	16.50	—	0.10
Orange (O 2)	37.1	2.7	16.7	3.32	1.62	45.8	1.22	42.6	—	1.80	—	11.50	7.10	—

[a]Same as Table 3.
[b]Price per 100 mL vinegar was higher than NT 50.
[c]The sample had a low calorie sweetener added.
[d]Not detected.

be detected. Apart from acetic acid, citric acid was the most abundant in passion fruit vinegar, while the next important organic acids were malic and succinic acids in blueberry vinegar and lactic acid in starfruit vinegar.

CONCLUSIONS

According to regulations of the Governing Food Sanitation Act[15], prepackaged foods or food additives must indicate the product name, ingredients, food additives, manufacturer's name and expiry date on the container or packaging in Chinese and common symbols. Five out of 66 samples collected in this study, were acquired from organic food stores. For 2 of these samples, apart from the product name, there was no information label on the container or packaging. Samples acquired from organic food stores were always higher in price than those purchased from the market, and labeling was either non-existent or incomplete.

Because of the lack of fermentation technology, or for lowering manufacturing costs and small- scale production facilities, most domestic fruit vinegar samples were made from juice mixed with grain vinegar. Normally consumers hardly distinguish these from the products made by vinegar fermentation even they read product labels carefully. In fact, based on CNS regulations for edible vinegar, the name of the vinegar is determined by the main raw material it was fermented from; thus, most fruit vinegar samples in the marketplace should be categorized as "rice vinegar" or "Gao-liang vinegar".

There seems to be no standard manufacturing procedures or quality standards established as a reference for total acidity, total sugar content, or clarity methods of fruit vinegars. Therefore, the variations found in the physicochemical properties of the samples in this study were very large. According to the CNS, the acidity of grain vinegar and fruit vinegar must be higher than 4.2% and 4.5%, respectively. In this study, the acidity of imported samples ranged from 5% to 7% but only three domestic vinegar samples, 2 cider and 1 wine vinegar, their acidity was found higher than 4.5%, and that of the remaining samples was less than 3.6%. It is surely due to adding juice or sugar and resulted in the decrease of the vinegar acidity.

The acetic acid content of 7 samples (A9, A10, A11, E4, H1, H6 and H8) was less than (or equal to) 10 mg/g, and three of them (A10, A11 and E4) had acetic acid content less than citric acid content. The major acid component of vinegar is acetic acid. If its content is less than other organic acids, it surely cannot be called vinegar. Furthermore, from the results of analyzing both pH and acidity of these CFV samples, it showed the possibility of adding non-organic acid(s) in some samples.

The CNS for grain, fruit and culinary vinegar do not regulate the amount of sugar content. In order to obtain an appropriate sugar/acid ratio after dilution for drinking, most fruit vinegars had a great deal of sugar, fructose or honey added. This can cause the evaluation of non-salt soluble solids to be misleading in the analysis of concentrated fruit vinegar. The TS content of 62 samples analyzed were more than 20% above the amount listed on the label. This implies that the quality of CFV in Taiwan is not under adequate control.

In order to safeguard consumers, appropriate regulations must be enforced so that product names and labeling, as well as quality standards, can be used to differentiate the fruit vinegar between straight fermented vinegars and juice mixed with grain vinegar.

ACKNOWLEDGEMENTS

Authors thank Tajen Institute of Technology for the financial support (TS 92086-1 and 92086-3).

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