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Chemical compositional characterization of eight pear cultivars grown in China

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Abstract

The sugar, organic acid, amino acid and fatty acid compounds of eight commercial pear cultivars were identified and quantified using high-performance liquid chromatography (HPLC) equipped with RI and UV detectors and gas-chromatography (GC) equipped with FID detector. The mineral composition was determined by inductively coupled plasma-mass spectrometry (ICP-MS). The results showed great quantitative differences in the composition of the pear cultivars. Fructose was the dominant sugar in the eight pear varieties, followed by glucose and sucrose, while malic acid was the principal organic acid. The C16:0, C18:0, C18:1, C18:2 and C18:3 fatty acids were clearly the most abundant fatty acids, and the C18 family comprised more than 70% of the total fatty acids content. Asparagine and serine were the principal amino acids. Potassium is the most abundant mineral, followed by magnesium and calcium. The results provide important information on how to make the best use of pear cultivars investigated for different uses, which is of significance for both technological research and processing practice.

Keywords: Pear cultivars; Chemical composition; Gas chromatography (GC); High performance liquid chromatography (HPLC); Inductively coupled plasma-mass spectrometry (ICP-MS)

1. Introduction

China is an important pear-producing nation. The annual production of pear fruit is very large, and reached 1100 thousand tons in 2005. Pear fruits are popular among consumers due to their sweetness, crispness, characteristic fragrance and slight aroma. Most pear fruit is consumed directly as a source of monosaccharides, minerals when fully mature, according to commercial practice. A proportion of them is also used for the preparation of fresh juice, canned beverages, alcoholic beverages, jellies and jams.

The edible part of the fruit contains considerable amounts of sugars, vitamins, organic acids, polyphenols and minerals and other nutrients. Free sugars, organic acids, free amino acids and fatty acids, mineral and aroma compounds are natural components of many fruit and vegetables, and play important roles in maintaining fruit quality and determining nutritive value (Ashoor & Kanox, 1982). The nature and concentration of these constituents in fruit are of interest because of their influence on the fruit's organoleptic properties. There have been several studies focusing on the certain chemical composition of pear fruit, which have quantified parameters such as total sugars, titratable acidity (TA) and soluble solids content (SSC) (Chen & Yan, 2004; Teng & Liu, 1999). Changes in the individual sugar, organic acid and phenol acid and volatile compositions of stored Yali and Kuerle fragrant

Abbreviations: GC, Gas chromatography; HPLC, High performance liquid chromatography; ICP-MS, Inductively couple plasma-mass spectrometry; TA, Titratable acidity; FID, Flame ionization detector; TSS, Total soluble solids; RI detector, Refractive index detector; UV detector, Ultraviolet detector.

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pear (Chen & Yan, 2004), and the amino acid composition of Yali pear have also been studied (Wang, Xu, Chen, Zhang, & Li, 2002).

However, there is lack of comprehensive compositional data regarding the chemical content of different pear cultivars cultivated and processed in China. Therefore, this research focused on analysis and comparison of the chemical compositions such as individual sugar, individual organic acid, amino acid, fatty acid, and mineral compositions of different pear cultivars. A more detailed knowledge of the variability of these composition contents of the cultivars will be of benefit in the future selection of pear genotypes with improved nutritional quality and processing characteristics of pear juice.

2. Materials and methods

2.1. Standards and reagents

All chemicals used in the experiment were HPLC or GC or analytical grade, they are fructose, glucose, and sucrose, tartaric acid, quinic, malic acid, shikimic acid, citric acid and succinic acid, α-aminobutyric acid, asparagine, serine, glutamine, glycine, histidine, arginine, threonine, alanine, proline, cysteine, tyrosine, valine, methionine, lysine, isoleucine, leucine and phenylalanine and *N*-hydroxsuccinimide-activated heterocydic carbama (HPLC grade, purity > 98%), purchased from Sigma. The standards of fatty acid (lauric acid, myristic acid, palmitic acid, palmitoleic acid, margaric, stearic acid, oleic acid, linoleic acid, α-linolenic acid, arachidic acid, eicosenoic acid, arachidonic acid, and docosapentaenoic acid) were GC grade (purity > 98%) and supplied by T. Hasegawa Co. Ltd., Japan. Other chemical reagents (K_2HPO_4, CH_3CN, NaCl, KOH, chloroform, methanol, petroleum ether, HCl, acetonitrile, and nitric acid) were of analytical grade (purity > 90%) and purchased from Beijing Kanglin Co. (Beijing, China).

Sugar and organic acid standards were used to obtain a linear curve. Five standard concentrations were prepared in distilled water, K_2HPO_4 solution and CH_3CN solution, and the linearity of the response to RI (K-2301, KNAUER, Berlin, Germany) and UV detectors (K-2501, KNAUER, Berlin, Germany) tested for each sugar and organic acid compound. All correlation coefficients were in the required range (Chen & Yan, 2004; Gao, Liao, & Hu, 2004). The linear curves derived from the standards were used to qualitatively and quantitatively measure the sugar and organic acid contents of samples. A calibration mixture of fatty acid standards was used for identification and quantification of the fatty acids (Pablo, Domingo, & Francisco, 2000). All analyses were performed three times and the results are mean ± SD of independent pear fruit samples. The fatty acid composition was expressed as a percentage of total content of fatty acids. An internal standard (α-aminobutyric acid) method was used to determine the amino acid contents. ICP-MS (Hewlett Packard 4500) was used for mineral composition analysis.

2.2. Sample preparation

Eight pear cultivars (Yali pear, Kuerle Fragrant pear, Dangshan pear, Nanguo pear, Jingbai pear, Ninomiyahaku pear, Niitaka pear, and Wujiuxiang pear) grown in Beijing city of China were used for this study. The pear fruits were harvested at their commercial maturity. Fruits were loosely packed inside conventional modular bulk containers with a polyliner and stored in a cool room at 0 °C, 80–90% relative humidity. The humidity inside the polyliner was approximately 95%. The air was exchanged with fans four times daily to remove ethylene. Before analysis, samples were prepared by extracting juice from cored fruit flesh using a commercial blender (HR-101 C, Beijing, China). Five to eight pears from each variety were pooled into juice, and then filtered through filter paper.

2.3. Sugar analysis

Composition of sugars was determined using the method of Dolenc and Stampar (Dolenc & Stampar, 1997), with modifications. Samples were prepared from seven to ten fresh fruit of eight pear cultivars. The pear fruit juice (10 g) was milled and diluted to 100 ml with redistilled water, and then filtered through a 0.45 μm Millipore filter. An aliquot of 20 μl was injected into the HPLC system (KNAUER, Berlin, Germany), equipped with a model K-1001 pump, thermostated column compartment model A-150, K-2301 RI detector, connected to with BF-2000 chemstation software, a PRONTOSIL 120-10-amino (250 × 4.6 mm I.D., 10 μm), and 120-10-C18 H (250 × 4.6 mm I.D., 10 μm) column (KNAUER, Berlin, Germany). The mobile phase consisted acetonitrile-water (85:15, v/v), at a flow rate of 1.5 ml/min at 30 °C.

2.4. Organic acids analysis

Samples were prepared from seven to ten fresh fruit of eight pear cultivars. The juice was pooled, and then filtered through filter paper. The pear fruit juice (10 g) was milled and diluted to 50 ml with $K_2HPO_4 \cdot 3H_2O$ (0.01 M, pH = 2.6), and then filtered through a 0.45 μm Millipore Organic filter. An aliquot of 20 μl was injected into the HPLC system (KNAUER, Berlin, Germany), equipped with model K-1001 pump, thermostated column compartment model A-150, K-2501 UV detector (KNAUER, Berlin, Germany) with wavelength set to 210 nm (Chen & Yan, 2004) connected to with BF-2000 chemstation software, a reversed phase PRONTOSIL 120-10-C18H (250 × 4.6 mm I.D., 10.0 μm) column, (KNAUER, Berlin, Germany), the mobile phase consisted of an aqueous solution of $K_2HPO_4 \cdot 3H_2O$ 0.01 M (pH = 2.6) at a flow rate of 0.5 ml/min at 30 °C.

2.5. Fatty acid analysis

The fatty acid profile was obtained by gas chromatography coupled with FID after esterification of the polar lipid

(Pablo et al., 2000). The pear fruit juice (10 g) of each specimen were placed in tared test tubes, heated at 100 °C for 5 min in order to inactive the lipase, and then 30 ml chloroform/methanol (1:2, v/v) was added. Samples were extracted for 20 min and filtered with 20 ml chloroform, and the resultant extracts combined and shaken in a vibrator (WZS-200A, Shanghai, China) for 15 min with 20 ml of an aqueous solution of NaCl 0.76% (w/v). The aqueous layer was removed and the residual vaporized using a vacuum machine (RE-3000, Beijing, China), and was redissolved in 6 ml petroleum ether (90–120 boiling point range) with saturated methanol and 6 ml methanol with saturated petroleum ether. The substrates were re-extracted with 6 ml of the same solvent and concentrated, and then dissolved in 1 ml methanol (GC grade) for storage at −20 °C for esterification.

The polar lipid was redissolved in 2 ml of KOH 0.4 M in methanol and 2 ml benzene-petroleum ether (1:1, v/v) (30–60 boiling point range), vibrated, and then allowed to rest for 15 min. Distilled water (16 ml) was added to the vials, the upper layer of the extracts withdrawn and vaporized under pure nitrogen stream, and then redissolved in 1 ml hexane for analysis by gas chromatography.

Fatty acid analysis was performed using a Hewlett–Packard Gas Chromatography (5890) machine with FID detector, connected to with BF-2000 chemstation software. Single aliquots of lipid extract (approximately 0.5 μl) were injected in splitless mode onto the DB-23 (60 m × 0.25 mm I.D., 0.25 μm) column, (Agilent, USA). The injector and detector temperatures were set at 250 °C and 270 °C, respectively. For the temperature gradient, the oven was set at an initial temperature of 130 °C for 1 min, which was increased to 215 °C at a rate of 6 °C/min, maintained for 2 min, then raised again to 230 °C at a rate of 40 °C/min, and held at 230 °C for 40 min. The flow rate was 32 cm/s, nitrogen used as carrier gas, and the electronic pressure control set in the constant flow mode.

2.6. Amino acid analysis

The AccQ.Tag system (Waters) was used for quantitative determination of the amino acid composition. The eight pear fruit pulp samples from each pear specimen (5 g) were homogenised and placed in 10 ml glass ampoules containing 1 ml of internal standard (α-aminobutyric acid) and 9 ml of 6 N HCL. The ampoules were frozen in liquid nitrogen, evacuated, sealed and then placed in the oven for 20 h at 110 °C. After hydrolysis, the acid was removed under vacuum. Samples were redissolved in 50 ml of an aqueous solution of 6 N HCL, and 10 mL aliquots were used for derivatization.

Aliquots were dried in a centrifuge, and then derived with reagent (*N*-Hydroxsuccinimide-activated heterocydic carbama) at 56 °C for 15 min. An aliquot of 5 μl was injected into AccQ-Tag system (Waters Company) equipped with a Waters 2475 fluorescence detector and Waters ACCQTAG column (4.6 × 150 mm) (Waters Company). The mobile phase consisted of special mobile phase (Waters Company)/acetonitrile (93:7, v/v), at a flow rate of 1.0 ml/min.

2.7. Mineral analysis

To determine the minerals, a wet oxidation procedure was applied. Five grams from pear fruit juice were placed in a 250 ml preweighed Erlenmayer flask. Concentrated nitric acid (analytical grade, purity > 98% 30 ml) was added to each flask; the flask was covered and contents allowed to digest for 24 h. The flask was then placed on the Thermolyne Type hot plate at 130 °C to concentrate until the residue was 15 ± 1 g, cooled and transferred into a 100 ml volumetric flask and completed to final volume with distilled deionized water. The blank sample was prepared for corrections applying throughout the entire digestion steps. Standard solutions of each mineral were prepared for the calibration curves under the same condition. Inductively coupled plasma-mass spectrometry (ICP-MS) (Hewlett Packard 4500) and inductively coupled plasma-flame emission spectrometry (ICP-FES) (Shimadzu AA6701 equipped with Shimadzu HVG-1 hydride vapor generator) were used to determine each element (K, Ca, Na, Mg, Zn, Fe, Cu, Mn and B) in three pears. The instrument settings and other experimental conditions were in accordance with the manufacturer's specifications (Anon, 1989a, 1989b). All glassware was washed with detergent, soaked 24 h in 15% (v/v) nitric acid, rinsed with deionized distilled water and dried before use for mineral analysis.

2.8. Statistical analysis

All analyses were performed three times and the results are mean ± SD of eight independent pear fruit samples. Where appropriate, the results were expressed on a fresh weight basis. Analysis of variance (ANOVA) was performed to compare the sample analysis at 5% confidence level.

3. Results and discussion

Basic information on the composition of the pear cultivars investigated is presented in Table 1. The level of maturity time, soluble solids, titrated acid, the ratio of sugar to acid, and Vitamin C content differed considerably. Kuerle fragrant pear and Jingbai pear showed relatively high levels of soluble solids, and Kuerle fragrant pear and Nanguo pear had higher Vitamin C content (4.10 mg/100 ml and 4.55 mg/100 ml). It was noteworthy that Kuerle fragrant pear had the highest soluble solids but the lowest acid content, the sugar/acid ratio of Kuerle fragrant pear is 125.0, and it is an appropriate cultivar for eating fresh. For the production and quality of pear juice concentrates, Dangshan pear, Nanguo pear and Wujiuxiang pear are the most appropriate cultivars for their appropriate sugar/acid ratio.

Table 1
The titrated acid and sugar/acid ratio in pear fruits of different cultivars mean values ± standard deviations ($n = 3$)

cv	Maturity time	TSS (%)	Titrated acid (%)	Sugar/acid	Vitamin C (mg/100 mL)
Yali	September	8.09	0.180	44.9	3.40
Kuerle Fragrant	September	12.5	0.100	125	4.10
Dangshan	September	8.60	0.140	61.4	2.21
Nanguo	September	8.90	0.160	55.6	4.55
Jingbai	July	10.8	0.460	23.5	2.39
Ninomiyahaku	October	9.00	0.150	60.0	3.85
Niitaka	October	9.56	0.250	38.2	1.30
Wujiuxiang	September	8.28	0.150	55.2	3.43

In the present study, we investigated the composition of soluble sugars in eight pear varieties. Identification was confirmed using known standards. Fructose and glucose were identified as the principal monosaccharides in the each pear fruit (Table 2). The results indicated that fructose was the major sugar and fructose levels were almost always higher than glucose levels in eight pear fruits varieties. This accorded with the Code of practice for evaluation of pear juices (Table 2) (AIJN, 2004). There have been numerous studies examining fruit sugar and the increasing levels of fructose, glucose and sucrose at advanced stages of fruit maturity (Ackerman, Fischer, & Amado, 1992; Chen & Yan, 2004; Gao et al., 2004). As shown in Table 2, the fructose content of Nanguo pear (77.1 g/kg of fresh pears) is higher than of Kuerle fragrant pear (60.1 g/kg of fresh pears), Jingbai pear (58.1 g/kg of fresh pears) and Dangshan pear (55.6 g/kg of fresh pears). The quantification of glucose and fructose contents in the present work agree with the previously reported ranges for pear (Chen & Yan, 2004; Gao et al., 2004). The sucrose content of Kuerle Fragrant pear (21.4 g/kg of fresh pears) is the highest of all. The sugar profile of fruit pulp is an important component of chemical composition tables and provides valuable information regarding the authenticity of fruit juices, and individual sugar and total sugar contents correlated well with the sweetness characteristics of the fruit juice, based on sensory evaluation. However, in order to evaluate the quality of pear fruit, other aspects of chemical composition should be determined.

Malic, citric, quinic and shkimic acids were the major organic acids and the predominant organic acid, in the tested pears was malic acid. A review article (Gao et al., 2004) reported that pears from different places contained mainly malic acid, such as, Yali and Xuehua (Tianjin city, China), Cili, Aidang, Xiangshui pear varieties (Shandong, China). In Table 3, the total organic acid content of Dangshan pear was the highest (3607 mg/kg of fresh pears), followed by that of Nanguo pear (2564 mg/kg of fresh pears) and Kuerle fragrant pear (2171 mg/kg of fresh pears). In this study, Kuerle Fragrant pear had a higher sugar: acid ratio than other pears and it is commonly used to determine the sensory and flavor quality of fruit. This is consistent with preference of consumers for Kuerle Fragrant pear fresh fruit, according to the sensory testing.

Linoleic acids and Palmitic were the dominant fatty acids, constituting 70–80% of the total fatty acids in the pear fruit. As far as the essential fatty acids are concerned, all eight pear varieties were rich in linoleic acid (Table 4). The α-linolenic acid content of Dangshan pear was relatively low, but that of Kuerle Fragrant pear was high. This is of nutritional interest since diets based on meat, starch sources, fruits and vegetables are generally low in ω-3 fatty acids. The amounts of linoleic and α-linolenic acid in the plants are therefore noteworthy, as both are essential fatty acids for humans and must be obtained through the diet. The ratio of saturated to unsaturated fatty acids indicates an excess of saturated fatty acids in each pear variety, the optimal value being 30/70 or less (Hervé, Raphaële, & Eric, 2004). The role of fatty acids on fruit aroma has been reported in previous research (Russell, Quamme, & Gray, 1981). For example, it has been reported that Bartlett pear flavor compounds were synthesized when pear puree was

Table 2
Sugar composition of different pear cultivars (g/kg of fresh pears) mean values ± standard deviations ($n = 3$)

cv	Fructose	Glucose	Sucrose	Total sugar
Yali	35.0 ± 0.9	33.9 ± 0.4	8.4 ± 0.7	77 ± 2
Kuerle Fragrant	60.1 ± 0.7	38.8 ± 0.3	21.4 ± 0.8	120 ± 2
Dangshan	55.6 ± 0.8	25.7 ± 0.3	4.7 ± 0.7	86 ± 2
Nanguo	77.1 ± 0.8	16.3 ± 0.4	3.3 ± 0.3	97 ± 2
Jingbai	58.1 ± 0.3	18.2 ± 0.5	5.3 ± 0.6	82 ± 1
Ninomiyahaku	41.9 ± 0.4	19.1 ± 0.6	4.4 ± 0.6	65 ± 2
Niitaka	41.9 ± 0.3	19.3 ± 0.4	10.3 ± 0.7	71 ± 1
Wujiuxiang	40.8 ± 0.4	25.9 ± 0.3	6.8 ± 0.4	74 ± 1
A.I.J.N* (Ref.)	50–90	10–35	Traces-15	

Total sugar content: as the sum of individual sugars.
* AIJN (2004).

Table 3
Organic acid composition of different pear cultivars (mg/kg of fresh pears) mean values ± standard deviations ($n = 3$)

cv	Yali	Kuerle Fragrant	Dangshan	Nanguo	Jingbai	Ninomiyahaku	Niitaka	Wujiu xiang
Tartaric acid	71 ± 1	58.0 ± 0.8	57.4 ± 0.6	10.8 ± 0.4	tr	tr	tr	34.3 ± 0.4
Quinic	216.0 ± 0.1	240.0 ± 0.1	384.0 ± 0.2	326.0 ± 0.7	294.0 ± 0.6	419.1 ± 0.3	220.0 ± 0.2	241.0 ± 0.4
Malic acid	1073.0 ± 0.2	1599.0 ± 0.3	2654 ± 3	1715 ± 3	1379 ± 2	1189 ± 3	1246 ± 2	1133 ± 1
Shikimic acid	106.0 ± 0.2	150.0 ± 0.3	117.0 ± 0.3	119.0 ± 0.6	52.7 ± 0.1	95.7 ± 0.5	78.9 ± 0.5	102.0 ± 0.5
Citric acid	104.0 ± 0.2	50.9 ± 0.2	349.0 ± 0.3	309 ± 1	143 ± 1	123 ± 2.0	91 ± 1	196 ± 2
Succinic acid	48.5 ± 0.1	72.7 ± 0.3	45.2 ± 0.3	83.8 ± 0.6	11.9 ± 0.4	14.6 ± 0.3	16.6 ± 0.7	14.9 ± 0.4
Total organic acid	1619 ± 2	2171 ± 2	3607 ± 5	2564 ± 6	1881 ± 4	1841 ± 6	1652 ± 5	1721 ± 5

Total organic acid content: as the sum of individual organic acid; tr: trace.

Table 4
Fatty acid compositions of different pear cultivars (% of fresh pears) mean values ± standard deviations ($n = 3$)

cv	Yali	Kuerle Fragrant	Dangshan	Nanguo	Jingbai	Ninomiyahaku	Niitaka	Wujiuxiang
Lauric acid (C12:0)	0.40 ± 0.01	0.42 ± 0.02	1.08 ± 0.02	0.31 ± 0.01	1.02 ± 0.02	0.56 ± 0.03	0.57 ± 0.05	0.69 ± 0.02
Myristic acid (C14:0)	0.28 ± 0.03	0.11 ± 0.04	1.45 ± 0.03	0.11 ± 0.02	0.61 ± 0.03	0.15 ± 0.02	0.14 ± 0.02	0.25 ± 0.02
Palmitic acid (C16:0)	22.9 ± 0.5	23.3 ± 0.5	25.0 ± 0.6	20 ± 1	29 ± 1	23 ± 1	23 ± 1	22 ± 1
Palmitoleic acid (C16:1)	0.57 ± 0.07	0.45 ± 0.03	0.29 ± 0.05	0.38 ± 0.03	1.2 ± 0.1	0.66 ± 0.02	0.66 ± 0.02	0.94 ± 0.04
Margaric (C17:0)	0.60 ± 0.01	0.47 ± 0.02	0.44 ± 0.01	0.43 ± 0.03	0.27 ± 0.03	0.60 ± 0.04	0.63 ± 0.03	0.43 ± 0.01
Stearic acid (C18:0)	3.22 ± 0.03	1.52 ± 0.05	1.23 ± 0.02	1.61 ± 0.02	0.82 ± 0.02	2.04 ± 0.02	2.05 ± 0.02	2.16 ± 0.02
Oleic acid (C18:1)	13 ± 1	4.06 ± 1.34	7 ± 1	3.81 ± 0.03	3.5 ± 0.1	2.15 ± 0.09	2.16 ± 0.09	5.2 ± 0.1
Linoleic acid (C18:2)	54.1 ± 0.7	61.8 ± 0.5	61.5 ± 0.8	69 ± 1	59 ± 2	67 ± 2	67 ± 2	61 ± 2
α-Linolenic acid (C18:3)	3.56 ± 0.02	6.86 ± 0.03	1.13 ± 0.04	3.77 ± 0.04	4.99 ± 0.09	2.95 ± 0.04	2.45 ± 0.04	6.16 ± 0.02
Arachidic acid (C20:0)	1.12 ± 0.01	0.95 ± 0.02	0.61 ± 0.03	0.65 ± 0.01	0.25 ± 0.01	0.85 ± 0.01	0.87 ± 0.03	0.68 ± 0.02
Eicosenoic acid (C20:1)	0.14 ± 0.02	0.02 ± 0.02	0.03 ± 0.03	0.03 ± 0.01	0.022 ± 0.001	0.067 ± 0.002	nd	0.03 ± 0.01
Arachidonic acid (C20:4)	0.25 ± 0.01	0.06 ± 0.02	nd	0.10 ± 0.04	nd	0.089 ± 0.001	0.09 ± 0.01	0.095 ± 0.001
Docosapentaenoic acid (C22:5)	0.133 ± 0.002	nd	nd	0.063 ± 0.002	nd	nd	nd	0.19 ± 0.01
SFA/UFA	28/71	27/73	30/70	23/77	31/69	27/73	27/73	26/74

nd: not detected; SFA: saturated fatty acid; MUFA: mono (poly) unsaturated fatty acids.

Table 5
Comparison of amino acid compositions in different pear cultivars (mg/100 g of fresh pears) mean values ± standard deviations ($n = 3$)

cv	Yali pear	Kuerle Fragrant	Dangshan	Nanguo	Jingbai	Ninomiyahaku	Niitaka	Wujiuxiang	A.I.J.N* (Ref.)
Asparagine	11.9 ± 0.1	25.40 ± 0.06	54.5 ± 0.1	13.20 ± 0.03	2.97 ± 0.01	57.90 ± 0.05	49.30 ± 0.04	6.17 ± 0.05	12–220
Serine	67.1 ± 0.2	109.0 ± 0.2	203.0 ± 0.3	107.00 ± 0.05	53.4 ± 0.02	79.90 ± 0.06	69.00 ± 0.03	129.00 ± 0.02	1.5–4
Glutamine	nd	0.020 ± 0.002	nd	nd	nd	nd	nd	0.83 ± 0.01	Max 2
Glycine	0.32 ± 0.02	0.58 ± 0.02	0.44 ± 0.02	0.68 ± 0.03	0.23 ± 0.02	0.34 ± 0.02	0.20 ± 0.01	0.57 ± 0.02	0.1- 0.5
Histidine	1.0 ± 0.1	1.72 ± 0.06	1.17 ± 0.08	1.04 ± 0.02	6.49 ± 0.01	1.32 ± 0.04	0.99 ± 0.02	2.91 ± 0.03	Trace-0.5
Arginine	nd	0.78 ± 0.02	1.20 ± 0.03	nd	nd	0.60 ± 0.05	0.46 ± 0.02	1.48 ± 0.04	Trace-0.5
Threonine	1.86 ± 0.03	2.33 ± 0.02	1.92 ± 0.03	2.06 ± 0.04	1.47 ± 0.02	1.65 ± 0.05	1.47 ± 0.02	3.06 ± 0.03	0.2–1.0
Alanine	2.60 ± 0.03	2.85 ± 0.02	3.27 ± 0.02	3.29 ± 0.03	3.93 ± 0.04	3.60 ± 0.04	2.64 ± 0.04	3.06 ± 0.04	1.0–3.0
Proline	4.6 ± 0.1	4.44 ± 0.03	3.96 ± 0.05	21.90 ± 0.03	33.5 ± 0.03	1.57 ± 0.03	1.25 ± 0.03	15.70 ± 0.03	3.0–5.00
Cysteine	0.71 ± 0.01	0.370 ± 0.004	2.160 ± 0.005	0.72 ± 0.02	0.49 ± 0.03	1.22 ± 0.01	0.75 ± 0.01	1.47 ± 0.04	
Tyrosine	0.45 ± 0.02	0.47 ± 0.04	0.88 ± 0.03	0.70 ± 0.03	0.48 ± 0.02	0.64 ± 0.01	0.50 ± 0.05	1.38 ± 0.02	Trace-0.5
Valine	1.8 ± 0.2	3.8 ± 0.2	1.4 ± 0.2	1.05 ± 0.03	0.40 ± 0.04	2.65 ± 0.06	2.20 ± 0.03	1.92 ± 0.03	0.5–2
Methionine	0.42 ± 0.02	1.05 ± 0.04	0.83 ± 0.02	0.41 ± 0.03	0.27 ± 0.03	1.19 ± 0.03	1.37 ± 0.04	0.67 ± 0.04	Trace
Lysine	nd	0.067 ± 0.001	0.660 ± 0.002	nd	0.20 ± 0.02	0.28 ± 0.03	nd	0.05 ± 0.01	
Isoleucine	0.80 ± 0.03	1.96 ± 0.02	0.74 ± 0.05	1.06 ± 0.04	0.57 ± 0.03	1.55 ± 0.06	1.25 ± 0.05	1.22 ± 0.04	
Leucine	0.11 ± 0.04	0.85 ± 0.02	0.59 ± 0.05	0.38 ± 0.03	0.17 ± 0.02	0.55 ± 0.02	0.39 ± 0.01	0.47 ± 0.02	
Phenylalanine	0.47 ± 0.03	1.18 ± 0.02	0.90 ± 0.02	1.10 ± 0.04	0.81 ± 0.02	0.54 ± 0.06	0.46 ± 0.03	1.03 ± 0.06	
Total amino acid	94 ± 1	156.8 ± 0.8	278 ± 1	154.6 ± 0.5	105.4 ± 0.33	155.5 ± 0.6	181.7 ± 0.4	171.0 ± 0.5	

Total amino acid content: as the sum of individual amino acid. nd: not detected.

Table 6
Mineral composition of different pear cultivars (mg/100 g of fresh pears) mean values ± standard deviations ($n = 3$)

cv	Yali pear	Kuerle Fragrant	Dangshan	Nanguo	Jingbai	Ninomiyahaku	Niitaka	Wujiuxiang	A.I.J.N*(Ref.)
Sodium	2.5 ± 0.5	19.5 ± 0.6	12.0 ± 0.3	12.5 ± 0.1	3.50 ± 0.02	4.45 ± 0.01	4.50 ± 0.01	8.50 ± 0.03	30
Potassium	897 ± 1	1085.0 ± 0.9	1688 ± 2	1068 ± 5.0	1050 ± 3.0	1336 ± 4.0	990 ± 5	1098 ± 6	100–200
Calcium	20.5 ± 0.3	22.5 ± 0.6	11.5 ± 0.6	31.00 ± 0.07	44.50 ± 0.05	46.50 ± 0.04	32.00 ± 0.04	16.00 ± 0.07	3.5–13
Magnesium	35.5 ± 0.3	94.5 ± 0.2	117.0 ± 0.7	68 ± 1	92 ± 2	83 ± 1	76 ± 1	67 ± 1	4.5–9.5
Zinc	0.15 ± 0.01	0.11 ± 0.02	0.21 ± 0.03	0.46 ± 0.05	0.28 ± 0.01	0.81 ± 0.03	0.35 ± 0.01	0.24 ± 0.03	max.0.5
Copper	0.31 ± 0.02	0.41 ± 0.03	0.40 ± 0.04	0.39 ± 0.03	0.28 ± 0.03	0.92 ± 0.04	0.46 ± 0.06	0.30 ± 0.07	max.0.5
Iron	0.48 ± 0.07	0.79 ± 0.03	0.61 ± 0.03	0.51 ± 0.04	0.98 ± 0.06	0.92 ± 0.01	0.73 ± 0.06	0.56 ± 0.08	max. 0.5
Manganese	0.11 ± 0.02	0.18 ± 0.02	0.30 ± 0.03	0.32 ± 0.04	0.47 ± 0.05	0.40 ± 0.06	0.23 ± 0.07	0.17 ± 0.03	
Boron	2.43 ± 0.02	3.75 ± 0.02	7.17 ± 0.02	3.53 ± 0.05	1.76 ± 0.03	1.02 ± 0.02	2.88 ± 0.03	2.97 ± 0.04	

* AIJN (2004).

incubated with C_{18}-unsaturated oleic, linoleic, and linolenic fatty acids. However, in Chinese pears, there was no relevant report.

The major amino acids in the eight pear varieties were asparagine and serine. There was some difference in each pear variety, but the results determined accorded with the Code of practice for evaluation of pear juices. (Table 5) (AIJN, 2004). Dangshan pear pulps had the highest total amino acids content (278 mg/100 g of fresh pears). Lysine and sulphur-containing amino acids are usually limiting in proteins of vegetal origin. While sulphur-containing amino acids were found in all eight pear varieties, and lysine was detected in Kuerle Fragrant, Dangshan pear, Jingbai pear, Ninomiyahaku and Wujiuxiang pear in our experiment. The role of amino acids (mostly amino acids of aroma family) on fruit aroma has been reported in previous research. It has been reported that Tyr and Phe were the formation substrates for volatility components (Wang et al., 2002).

It is noteworthy that trace minerals are important not only for human nutrition, but for plant nutrition as well (Anon, 1989a,b). Potassium, a mineral essential for controlling the salt balance in human tissues, can be detected. Zinc, a trace mineral that is especially important for normal functioning of the immune system, is present in good levels in eight pear fruits. Calcium, a mineral which is essential to bone structure and function, is relatively high in eight pears. The mineral composition from eight pears varieties is listed in Table 6. Potassium is the most abundant mineral, Dangshan pear (1688 mg/kg of fresh pears), Ninomiyahaku (1336 mg/kg of fresh pears), and Kuerle Fragrant pear (1085 mg/kg of fresh pears), followed by magnesium and calcium. The potassium and magnesium content is much higher than the reference. Some origins can show slightly higher calcium values than the indicated maximum value except Dangshan pear. Sodium values below 30 mg/100 g (Table 6) have been observed in eight pears, perhaps for the different pear varieties and the individual method. Meanwhile composition of the microminerals shows levels of iron, copper, zinc, and manganese and relatively high values of boron.

4. Conclusion

The results showed that different pear cultivars have different chemical compositions. Sugars and organic acids are characteristic indexes for pear fruits, important for quality evaluation of fruits. Additionally, amino acid, fatty acid and mineral compositions are also important factors for appraising the characterization of pear cultivars with respect to their nutritional value and potential use for different products.

Pear has been widely commercialized throughout the world. The interest in this Chinese indigenous fruit has increased in recent years, on the one hand in response to the incessant search for new products, and on the other due to its favorable crisp taste. Production and commercialization of local pear varieties are also considered a good way to increase the incomes of local producers.

The accurate analysis of those components enables us to observe the differences in eight pear cultivars. Amongst the eight pear cultivars investigated, the best for direct consumption is Kueler fragrant pear for their high levels of biologically active chemical compounds, however there is a lack of organic acids and other active compounds, just the opposite than in Nanguo pear and Dangshan pear. Thus, regarding the total quality, using different pear cultivars to produce mixed pear juice may be a good choice.

The pear flavor and quality is affected by many factors, such as, fruit variety, region specialty, climate factors, soil condition, orchard managing mode, etc. So we cannot make an arbitrary decision about which kind of pear fruit is of the best quality, but our research can provide eight pear chemical composition characteristics and further research on the chemical composition of other pear fruit should be conducted to enable food technologists to select excellent pear varieties with improved nutritional quality, and to develop more processed pear products.

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